GEOGRAPHIC INFORMATION SYSTEM EMERGENCY SERVICES RESPONSE CAPABILITIES ANALYSIS

FINAL REPORT

International Association of Fire Fighters
1750 New York Avenue, N.W.
Washington, DC 20006

SPOKANE FIRE DEPARTMENT

Spokane, WA

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Dedication

This Report is Dedicated to the Citizens of Spokane, Washington who Deserve the Most Efficient and Effective Fire, Rescue, and Emergency Medical Services Available.

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Executive Summary

This report summarizes the results of a station location, staffing, and emergency vehicle travel time analysis for the Spokane Fire Department at the request of the Spokane Firefighters Union, International Association of Fire Fighters (IAFF) Local 29. The Spokane Fire Department provides emergency response services to the City of Spokane including fire suppression, emergency medical services (EMS) first response at the basic life support (BLS) and advanced life support (ALS) levels, hazardous materials response, and fire prevention.

A SAFER grant was awarded to the Spokane Fire Department in 2016 that allowed for the hiring of 48 new firefighters. The term of the grant was two years and it is set to expire in 2019. Pursuant to the expiration of the SAFER monies, the city maintains it will no longer have the funds needed to keep these 48 firefighters, and they will be laid off. Local 29 is concerned that without additional funding to maintain these positions, the fire department will not be able to deliver the level of service now provided to the citizens of Spokane.

Currently, the fire department staffs engines with three firefighters and the quints[1] with four firefighters. The National Fire Protection Association's (NFPA®) Standard 1710: *Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments* requires a minimum of four personnel on all fire suppression apparatus. However, with the expected staffing reductions due to the loss of the SAFER funding, staffing on the quints will be reduced to three firefighters each. The department is also expected to lose the Safety Officer position. In addition, the Spokane Fire Department's three alternative response units (ARUs), staffed by two firefighters each, will be taken out of service. These units respond to alpha and bravo EMS calls and provide assistance on other operations as needed. Removing the ARUs from service would place a greater burden on engine companies and would likely result in longer response times for Spokane residents.

It is essential that the Spokane Fire Department provides fire protection and EMS response in an effective and efficient manner. To do so, it must be staffed and positioned appropriately to address emergencies in an equitable manner, as they occur, including the capacity to address surges in demand. The Spokane Fire Department has failed to grow with the community, and as such, has experienced significantly deteriorated response capabilities and has increased risk to the

[1] Quints are combination apparatus, with both engine and ladder truck capabilities. Quints are able to carry a limited amount of water but are restricted in the delivery of it due to a significantly reduced complement of available hose. Quints also carry ladders, but due to limited space, may not be able to carry the number and lengths of ground ladders required by industry standards for aerial apparatus. Furthermore, if a quint is expected to perform as both an engine and a ladder simultaneously, it must be staffed with more than 4 personnel.

firefighters and the citizens of Spokane. This document will discuss the importance of maintaining adequate resources located appropriately to meet demand safely and effectively by examining station locations, current and recommended staffing and deployment configurations, and incident demand data.

Analysis and Methods

Using Geographic Information Systems (GIS), analysis was performed to evaluate how different staffing and deployment configurations impact the department's response capabilities. Using historical traffic patterns,[2] analysis was performed to examine the department's ability to meet industry standard response requirements such as 4-minute initial unit arrival, the establishment of a minimum of four personnel on scene within 4 minutes, and the assembly of the required numbers of personnel for response to low-, medium-, and high-hazard structure fires.[3]

Analysis was also performed to examine the department's past workload and response performance. Spokane Fire Department provided computer-aided dispatch (CAD) data for all emergencies responded to from January 1, 2016 through October 31, 2018. The CAD data contain, but are not limited to, information about the type of the emergency incident, the responding apparatus, time an apparatus was assigned, time en route, and time of arrival on scene.

The CAD data provided did not include call volume for the entire year of 2018; therefore, year-to-year analyses only include 10 months of data from 2018 (January – October). It should be noted that the CAD data for 2017 did not contain information on ARU 3 likely due to mis-coded apparatus names for ARU 3 in the system.

Analysis of the CAD data evaluated the department's historical response capabilities and determined the effects of reducing staffing and removing apparatus from service due to lack of funding and the resultant layoffs. The department's workload was assessed using several parameters including the total number of hours ARUs and engines are engaged in response, the number of hours of ARUs and engines are making runs at the same time, and the frequency of back-to-back responses.[4] These factors were examined to determine how changes in staffing and

[2] Historical traffic data contained in ESRI's StreetMap Premium, version 18.1.

[3] According to NFPA 1710, a typical low-hazard structure is defined as a 2,000 ft^2 single-family home with no exposures and no basement. A typical medium-hazard structure is a 2,000 ft^2 – 196,000 ft^2 building such as a garden apartment, open-air strip shopping center, offices, mercantile, and industrial occupancies. A high-hazard occupancy is one that presents a high life hazard or large fire potential due to its construction, configuration, or the presence of specific materials, processes or contents. Examples include schools, hospitals, nursing homes, explosives plants, refineries, and high-rise buildings.

[4] Back-to-back responses refer to occurrences where units have been dispatched within 10 minutes of becoming available from a previous emergency.

deployment will affect Spokane's response capabilities and how performance will be reduced if funding for the 48 firefighters hired under the SAFER grant is not continued.

Key Findings

The Spokane Fire Department is not currently in compliance with performance and staffing objectives set by NFPA 1710, NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*, and the Occupational Safety and Health Administration's (OSHA) Regulation 29 CFR 1910.134[5]. This increases risk to the citizens of, and visitors to, Spokane. Accordingly, the Spokane Fire department should maintain all current firefighter positions and keep all current apparatus staffed and in service. These findings are based on the following facts:

- When suppression apparatus are staffed with less than four firefighters, crews must wait on personnel arriving later before making entry into environments that are immediately dangerous to life and health (IDLH), such as those occurring in structure fires, in order to meet the objectives of industry standards and OSHA rules and regulations.

- ARUs 1, 3, and 15 are engaged in responses for as many or more hours as engines. If ARUs were taken out of service, many of these responses would become the responsibility of the engines.

- The number of hours that ARUs 1, 3, and 15 and Engines 1, 3, and 15 are engaged at the same time has increased significantly since 2016.

- When ARUs 1, 3, and 5 are unavailable for immediate response, Engines 1, 3, and 15 respond to a significantly higher number of back-to-back incidents[6]. If these ARUs are taken out of service, back-to-back responses would likely increase.

- Travel times of Engines 1, 3, and 15 and ARUs 1, 3, and 15 increase as more apparatus become engaged in responses. If ARUs are taken out of service, it is likely travel times of Engines 1, 3, and 15 would increase.

- NFPA 1710 requires the first arriving company at a structure fire to be on scene within four minutes to 90% of incidents. The standard also requires a minimum of four personnel on suppression apparatus. Currently, the combination of these requirements[7] can only be met on 34.8% of roads within the response jurisdiction. Almost two-thirds of Spokane's

[5] Also known as the "2 In/2 Out" Regulation.
[6] Back-to-back responses refer to occurrences where units have been dispatched within 10 minutes of becoming available from a previous emergency.
[7] A minimum of four firefighters arriving within a four-minute travel time.

roads are outside of the existing four-personnel, four-minute response area. If the proposed staffing and apparatus reductions are implemented, four firefighters could only assemble within four minutes on 22.8% of roads, a 34.3% decrease.

- NFPA 1710 has established the objective of 15 firefighters arriving within eight minutes of travel as the standard for safe, effective, and efficient operations at a typical, low-hazard residential structure fire.[8] Spokane can only provide for the arrival of 15 firefighters within eight minutes to the scene of a fire on 44.7% of roads within the response area. If the proposed staffing and apparatus reductions are implemented, 15 firefighters could only assemble within 8 minutes on 33.6% of roads, a 24.9% decrease.

- NFPA 1710 requires a minimum of 28 firefighters[9] arriving on the scene of a medium-hazard[10] structure fire within eight minutes of travel. As the department does not provide medical transport, it is responsible for sending a minimum of 26 personnel. Currently, this objective can only be met on 15% of response area roads. If the proposed staffing and apparatus reductions are implemented, 26 firefighters could only assemble within 8 minutes on 6.2% of roads, a 58.4% decrease.

- NFPA 1710 requires a minimum of 43 firefighters[11] to arrive on the scene of a high-rise[12] structure fire within 10 minutes and 10 seconds. As the department does not provide medical transport, it is responsible for sending a minimum of 39 personnel. Spokane can only meet this objective on 13% of area roads. If the proposed staffing and apparatus reductions are implemented, 39 firefighters could only assemble on 4.2% of roads, a 67.2% decrease.

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[8] A typical low-hazard structure is defined as a 2,000 ft^2 single-family home with no exposures and no basement.
[9] Spokane Fire Department does not provide medical transport. Therefore, the department would be required to arrive with 24 firefighters, 1 incident commander, and 1 chief's aide to a medium-hazard structure fire. NFPA 1710, §5.2.4.2.1 (9) requires, "The establishment of an initial medical care component consisting of at least two members capable of providing immediate on-scene emergency medical support and transport that provides rapid access to civilians or members potentially needing medical treatment. Where this level of emergency medical care is provided by outside agencies or organizations, these agencies or organizations shall be included in the deployment plana and meet these requirements".
[10] NFPA Standard 1710 defines a typical medium-hazard structure as a 2,000 ft^2 – 196,000 ft^2 building such as a garden apartment, open-air strip shopping center, offices, mercantile, and industrial occupancies.
[11] Spokane Fire Department does not provide medical transport. Therefore, the department would be required to arrive with 32 firefighters, 6 officers, and 1 incident commander for a high-rise/high-hazard fire. NFPA 1710 §5.2.4.4.1 (17) requires, "Provision of a minimum of two crews trained in emergency medical services with on-scene transport capability, each crew with a minimum of two members. At least one of the members shall be trained to the ALS level."
[12] NFPA Standard 1710 defines a high-rise structure as a building with the highest floor greater than 75 feet above the lowest level of fire department vehicle access. §5.2.4.4.1.

- Many of Spokane's roads are currently not serviced within safe and effective time frames. If the proposed cuts are implemented, the city would be less able to provide service safely and effectively.

Recommendations

The Spokane Fire Department needs to maintain current staffing and apparatus levels. Proposed reductions will greatly increase response times and endanger the city of Spokane and its firefighters. These findings are reflected in the following recommendations:

- The fire department should make every effort to maintain the 48 firefighter positions currently funded through the SAFER grant.

- The department should maintain the alternative response units (ARUs) at Stations 1, 3, and 15.

- The department should continue to staff Quint 11 and Quint 13 with four firefighters each in order to meet NFPA 1710 minimum staffing objectives. The Spokane Fire Department should strive to staff every suppression apparatus with a minimum of four firefighters each in order to meet the objectives of NFPA 1710.

- The department should maintain the Safety Officer position.

- Spokane should maintain ongoing assessments of hazards, risks, and demands to determine appropriate apparatus and staffing levels. A risk assessment and critical task analysis should be performed. The risk assessment will identify all risks within response area limits and the critical task analysis will determine what resources are needed to mitigate those risks.

- Response data should be continually captured and analyzed to identify changing trends and determine where resources are needed. This is also important for any future decisions regarding the fire department.

Executive Summary Conclusion

This analysis assessed the existing and proposed staffing and deployment of the Spokane Fire Department. Currently, Spokane's fire suppression resources are not deployed or staffed adequately for the arrival of a first response company of four firefighters within four minutes or the arrival of an effective response force (15 firefighters) within eight minutes to 90% of incidents (NFPA 1710). Current resource deployment also does not enable the department to meet travel time and performance objectives for low-, medium-, and high-hazard[13] fires included in the industry standard NFPA 1710. With the proposed changes implemented, Spokane would be even farther from meeting these objectives.

The recommendations in this analysis to maintain staffing and keep ARUs in service are necessary in order to maintain current levels of performance and safety. Geographic assessment of the Spokane Fire Department response capabilities shows that the fire department is currently understaffed and unable to deploy an adequate number of firefighters to many of the city's roads. Should the proposed staffing and apparatus reductions be implemented, Spokane's response capabilities would be further reduced.

[13] A high-hazard occupancy is one that presents a high life hazard or large fire potential due to its construction, configuration, or the presence of specific materials, processes or contents. Examples include schools, hospitals, nursing homes, explosives plants, refineries, and high-rise buildings. NFPA 1710, §3.3.28 and A.5.2.4.5.1 (1).

Risk Factors

Spokane is located in Spokane County in eastern Washington, approximately 18 miles west of the Idaho border. The U.S. Census American Community Survey estimates the city had 212,982 residents in 2017.[14] A further assessment of the 2017 American Community Survey revealed that 21.1% of the population was in a vulnerable category based on age. This category consists of persons under the age of 5 (6.6%) and persons who are 65 years of age and older (14.5%).[15] Approximately 16.2% of the population has a reported disability, and 39.7% of people 65 and older have a reported disability.[16] A vulnerable population is a group of people that are at higher risk of suffering injury and death because of their inability, or reduced ability, to evacuate in an emergency without assistance. Typically, people within these categories have an increased likelihood of being injured or killed during hazardous emergencies and place a higher demand on emergency medical services.

The city has a total of 88,683 housing units of which 67% were detached single-family homes, 2.5% were attached single-family homes, 28.9% were multifamily structures, and 1.5% were mobile homes.[17] Of these structures, 45.8% were built between 1940 and 1979 and 26.5% were built before 1940.[18] Typically, when there are high numbers of older buildings constructed before modern fire codes were developed, there is an increased demand on emergency services. In addition, approximately 19.4% of people were living below the poverty line. Those living in poverty generally lack the means to properly maintain their residences which can lead to an increased risk for fire.

In addition to the vulnerable groups and housing, the city of Spokane is at risk for natural disasters. Spokane County developed a Hazard Mitigation Plan that identified potential hazards including, but not limited to, landslides, flooding, wildfires, hazardous materials spills, earthquakes, and urban fire.[19]

[14] Spokane, Washington, American FactFinder U.S. Census Bureau, 2013-2017 American Community Survey 5-Year Estimates
[15] Ibid.
[16] Ibid.
[17] Ibid.
[18] Ibid.
[19] https://www.spokanecounty.org/1939/Mitigation-Plan

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Fire Suppression Operations

The business of providing emergency services has always been labor intensive and remains so today. Although new technology has improved firefighting equipment and protective gear and has led to advances in modern medicine, it is the firefighters who still perform the time-critical tasks necessary to contain and extinguish fires, rescue trapped occupants from a burning structure, and provide emergency medical and rescue services.

A small flame can quickly burn out of control and become a major fire in a short period of time. This is because fire grows and expands exponentially as time passes. In the time frame of fire growth, the temperature of a fire rises to above 1,000° Fahrenheit (F). It is generally accepted in the fire service that for a medium growth rate fire,[20] flashover—the very rapid spreading of the fire due to super heating of room contents and other combustibles—can occur. Assuming an immediate discovery of a fire, followed by an un-delayed call to 9-1-1, and dispatch of emergency responders, flashover is likely to occur within 8 minutes of fire ignition. However, studies conducted by the Underwriters Laboratory (UL) and the National Institute of Standards and Technology (NIST) have proved that, due to new building construction materials and room contents that act as fuel, flashover may occur much sooner.

At the point of flashover, the odds of survival for unprotected individuals inside the affected area are virtually non-existent. The rapid response of an appropriate number of firefighters is therefore essential to initiating effective fire suppression and rescue operations that seek to minimize fire spread and maximize the odds of preserving both life and property.

This section will explain fire growth and the importance of fire department response to a low-hazard structure fire. A low-hazard structure fire is defined as a fire that occurs in a typical, 2,000 square foot, single-family residential home with no basement or exposures.[21]

[20] As defined in the *Handbook of the Society of Fire Protection Engineers*, a fast fire grows exponentially to 1.0 MW in 150 seconds. A medium fire grows exponentially to 1 MW in 300 seconds. A slow fire grows exponentially to 1 MW in 600 seconds. A 1 MW fire can be thought-of as a typical upholstered chair burning at its peak. A large sofa might be 2 to 3 MWs.

[21] NFPA 1710, 2016 ed. Pg. 1710-16 A.4.1.2.5.1

Fire Growth

The Incipient Phase

The first stage of any fire is the incipient stage. In this stage a high heat source is applied to a combustible material. The heat source causes chemical changes to the material's surface which converts from a solid and begins to release combustible gases. If enough combustible gases are released the material will begin to burn freely.

This process is exothermic, which means that it produces heat. The heat being generated raises the temperature of surrounding materials, which in turn begin to release more combustible gases into the environment and begins a chemical chain reaction of heat release and burning. At this point the fire may go out if the first object completely burns before another begins or the fire can progress to the next stage, which is called the Free Burning Phase.

The Free Burning Phase

The second stage of fire growth is the "free" or "open burning" stage. When an object in a room starts to burn, (such as the armchair in Figure 1, following page), it burns in much the same way as it would in an open area. In this phase of the fire, oxygen in the air is drawn into the flame and combustible gases rise to the ceiling and spread out laterally. Simultaneously, the materials that are burning continue to release more heat, which heats nearby objects and materials to their ignition temperature, and they begin burning as well. Inside a room, unlike in an open area, after a short period of time confinement begins to influence fire development. The combustible gases that have collected on the ceiling will eventually begin to support fire and will begin to burn. Thermal radiation from this hot layer begins to heat the ceiling, the upper walls, and all the objects in the lower part of the room which will augment both the rate of burning of the original object and the rate of flame spread over its surface.

When this occurs, the structure fire reaches a critical point: either it has sufficient oxygen available to move on to the next stage or the fire has insufficient oxygen available to burn and it progresses back to the incipient stage. However, since structures are not airtight, there is a low likelihood of the fire depleting the available oxygen. During this stage of fire growth, toxic chemicals released by the fire and high heat are enough to burn people in the immediate area and disorient and/or incapacitate people in the structure. Without rapid response and intervention by an adequately staffed fire department, the fire will likely spread to the rest of the structure.

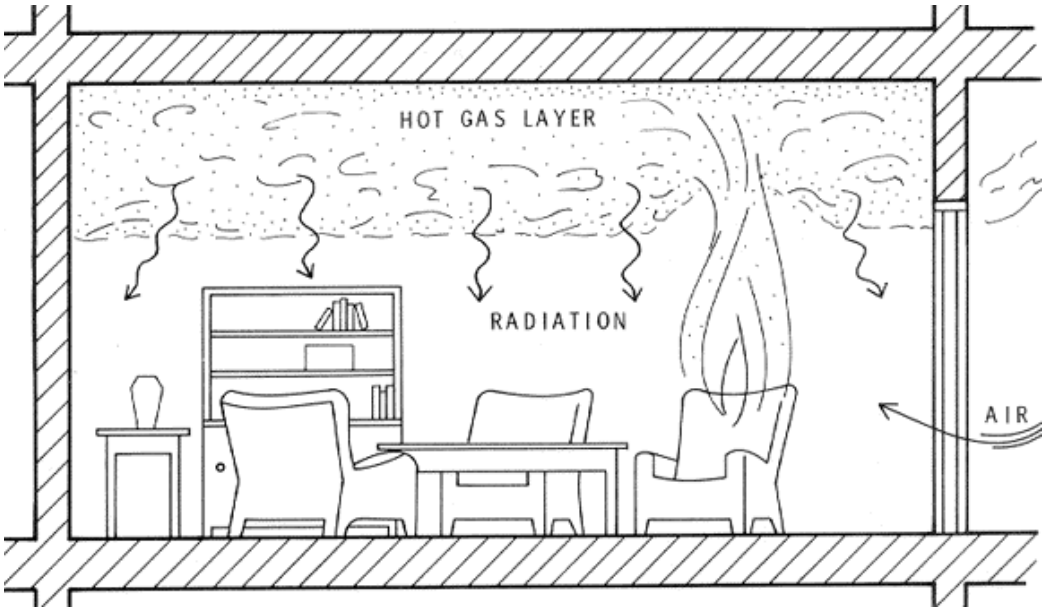


Figure 1: Fire Growth in a Compartment.[22] The above figure depicts the growth of fire in a compartment, which is an enclosed space or room in a building. In a compartment the walls, ceiling, floors, and objects absorb radiant heat produced by the fire. Unabsorbed heat is reflected back to the initial fuel source, which is depicted by the armchair above. This reflected heat continues to increase the temperature of the fuel source and therefore the rate of combustion. Hot smoke, combustible gases, and super-heated air will then rise to the ceiling and spread at first laterally across the ceiling, but later downward towards other fuel sources and the floor of the compartment. As this toxic, super-heated cloud touches cooler materials, the heat is conducted to them, thus increasing their temperature and eventually leading to pyrolysis, which is the process where a fuel source begins to release flammable vapor. This release of flammable vapor leads to further fire growth and eventually flashover. Flashover is the point at which all exposed fuel sources in a compartment ignite.

If there is sufficient oxygen, then the fire will continue to grow and the heating of the other combustibles in the room will continue to the point where they reach their ignition temperatures more or less simultaneously. If this occurs, all combustible materials in the room will spontaneously ignite. This transition from the burning of one or two objects to full room involvement is referred to as flashover. [23]

Flashover

Flashover, when it occurs, is the most significant event during a structure fire. As combustible gases are produced by the two previous stages, they are not entirely consumed and are therefore available fuels. These "available fuels" rise and form a superheated gas layer at the ceiling that continues to increase, until it begins to bank down to the floor, heating all combustible objects regardless of their proximity to the burning object. In a typical structure fire, the gas layer at the ceiling can quickly reach temperatures of 1,200˚ F and higher. With enough existing oxygen at

[22] Image courtesy of University of California at Davis Fire Department
[23] J.R. Mehaffey, Ph.D., Flammability of Building Materials and Fire Growth, Institute for Research in Construction (1987)

the floor level, flashover occurs, which is when everything in the room ignites at once. The instantaneous eruption of flames generates a tremendous amount of heat, smoke, and pressure. The pressure generated from this explosion has enough force to push fire beyond the room of origin and into the rest of the structure, as well as through doors and windows.

As has been noted, at the time of flashover, windows in the room will break. When these windows break, as a result of the increased pressure in the room, a fresh supply of air from the outside of the building is available to help the fire grow and spread. Based on the dynamics of fire behavior in an unprotected structure fire, any decrease in emergency unit response capabilities will correlate directly with an increase in expected life, property, and economic loss.

The Importance of Adequate Staffing: Concentration

NFPA 1500 and 1710 both recommend that a minimum acceptable fire company staffing level should be four members responding on, or arriving with, each engine and ladder company responding to any type of fire.

A prime objective of fire service agencies is to maintain enough strategically located personnel and equipment so that the minimum effective response force can reach a reasonable number of fire scenes before flashover occurs.[24] Of utmost importance in limiting fire spread is the quick arrival of sufficient numbers of personnel and equipment to attack and extinguish the fire, as well as rescue any trapped occupants and care for the injured. Sub-optimal staffing of arriving units may delay such an attack, thus allowing the fire to progress to more dangerous conditions for firefighters and civilians.

Staffing deficiencies on primary fire suppression apparatus negatively affect the ability of the fire department to safely and effectively mitigate emergencies and therefore correlate directly with higher risks and increased losses, both physically and economically. Continued fire growth beyond the time of firefighter on scene arrival is directly linked to the time it takes to initiate fire suppression operations. As indicated in Table 1, responding companies staffed with four firefighters are capable of initiating critical fireground operational tasks more efficiently than those with crew sizes below industry standards.

[24] University of California at Davis Fire Department website; site visited June 7, 2004.
< http://fire.ucdavis.edu/ucdfire/UCDFDoperations.htm >

Engine Company Duties					Ladder Company Duties			
Fireground Tasks	**Advance Attack Line**	**% Change**	**Water on Fire**	**% Change**	**Primary Search**	**% Change**	**Venting Time**	**% Change**
4 Firefighters	0:03:27		0:08:41		0:08:47		0:04:42	
3 Firefighters	0:03:56	12% Less Efficient	0:09:15	6% Less Efficient	0:09:10	4% Less Efficient	0:07:01	32% Less Efficient
2 Firefighters	0:04:53	29% Less Efficient	0:10:16	15% Less Efficient	0:12:16	28% Less Efficient	0:07:36	38% Less Efficient

Table 1: Impact of Crew Size on a Low-Hazard Residential Fire.[25] The above table compares and contrasts the efficiencies of suppression companies in the completion of critical tasks for fire control and extinguishment. The smaller the crew size, the more tasks an individual must complete as a team member, which contributes to the delay in initiating fire attack and contributes to diminished efficiency in stopping fire loss. The Spokane Fire Department currently staffs all engines with fewer than four firefighters. Quints will also be staffed with fewer than 4 firefighters under the proposed reduction plan.

First-arriving companies staffed with four firefighters are more efficient in all aspects of initial fire suppression and search and rescue operations compared to two- or three-person companies. There is a significant increase in time for all the tasks if a company arrives on scene staffed with only three firefighters compared to four firefighters. According to the NIST Report on Residential Fireground Field Experiments, four-person crews are able to complete time critical fireground tasks 5.1 minutes (nearly 25%) faster than three-person crews. The increase in time to task completion corresponds with an increase in risk to both firefighters and trapped occupants.

With four-person crews, the effectiveness of first-arriving engine company interior attack operations *increases* by 12% to 29% efficiency compared to three- and two-person crews respectively. The efficacy of search and rescue operations also *increases* by 4% to 28% with four-person crews compared to three- and two-person crews. Moreover, with a four-person company, because the first-in unit is staffed with a sufficient number of personnel to accomplish its assigned duties, the second-in company does not need to support first-in company operations and is therefore capable of performing other critical fireground tasks that are likely to improve safety and outcomes.

At the scene of a structure fire, the driver/operator of the first engine company on the scene must remain with the apparatus to operate the pump. This leaves one firefighter to assist the operator in securing a water source from a hydrant and two firefighters to deploy a hoseline and stretch it to the fire. After assisting the operator, the third firefighter should begin to assist the other two firefighters with advancing the hoseline into the building and to the location of the fire. Before

[25] Averill, J.D. et al. (2010). Report on Residential Fireground Field Experiments. NIST Technical Note 1661. National Institute of Standards and Technology; Gaithersburg, MD, April 2010.

initiating fire suppression, the supervising officer of the first arriving engine company is also responsible for walking around the building to assess the situation, determine the extent of the emergency, and request any additional resources necessary to mitigate the fire.

Similarly, the driver/operator of the first arriving ladder company must remain with the apparatus to safely position and operate the aerial device while the other three firefighters also perform critical fireground tasks such as ventilation and search and rescue. Due to the demands of fireground activities, a fire attack initiated by companies with only three or fewer firefighters is not capable of effecting a safe and effective fire suppression and/or rescue operation until additional personnel arrive.

Insufficient numbers of emergency response units, or inadequate staffing levels on those units, exposes civilians and firefighters to increased risk. It also further drains already limited fire department resources and stresses the emergency response system by requiring additional apparatus to respond from further distances. Failing to assemble sufficient resources on the scene of a fire in time to stop the spread and extinguish the fire, conduct a search, and rescue any trapped occupants puts responding firefighters and occupants in a dangerous environment with exponential risk escalation such that it is difficult to catch up and mitigate the event to a positive outcome.

The Importance of Crew Size to Overall Scene Time

Studies have shown that the more personnel that arrive on engine and ladder truck companies to the scene of a fire, the less time it takes to complete all tasks associated with fire suppression, search and rescue, and other critical fireground activities. As dispatched units arrive with sufficient numbers of firefighters, the overall time on the scene of the emergency decreases since critical fireground tasks can be completed simultaneously rather than in sequence. This also results in the decrease of on-scene risk levels. In other words, the more firefighters available to respond and arrive early to a structure fire, the less time it takes to extinguish the fire and perform search and rescue activities, thus reducing the risk of injury and death to both firefighters and trapped occupants and reducing the economic loss to the property.

Overall Scene Time Breakdown by Crew Size		
Scenario	**Total Time**	**Efficiency**
4-Person Close Stagger	0:15:44	
3-Person Close Stagger	0:20:30	23% Less Efficient
2-Person Close Stagger	0:22:16	29% Less Efficient
4-Person Far Stagger	0:15:48	
3-Person Far Stagger	0:21:17	26% Less Efficient
2-Person Far Stagger	0:22:52	31% Less Efficient

Table 2: The Relationship between Crew Size and Scene Time.[26] The above table displays how companies staffed with larger crew sizes will be on the scene of an emergency for a shorter time than smaller sized companies. This lag on scene could be translated to mean that emergency resources will be unavailable longer to address other emergencies that may arise.

As Table 2 shows, units that arrive with only two firefighters on an engine or ladder truck are on the scene of a fire almost 7 minutes longer than units that arrive with four firefighters on each crew. Responding units arriving with only three firefighters on an apparatus are on the scene of a fire 5 to 6 minutes longer than units that arrive with four firefighters on each apparatus. In addition to crew size, the time between the arriving crews matters to overall effectiveness and total on scene time.

In the NIST study on the low hazard residential fire, close stagger was defined as a 1-minute time difference in the arrival of each responding company. Far stagger was defined as a 2-minute time difference in the arrival of each responding company.[27] [28] The results show a consistent pattern of units arriving with four firefighters in a close stagger or far stagger will decrease the overall time at the scene of the emergency compared to units that arrive with two or three firefighters, and are more efficient in fire suppression tasks as well.

[26] Ibid.
[27] Ibid.
[28] One-minute and two-minute arrival stagger times were determined from analysis of deployment data from more than 300 U.S. fire departments responding to a survey on fire department operations conducted by the International Association of Fire Chiefs and the International Association of Firefighters.

Physiological Strain on Smaller Crew Sizes

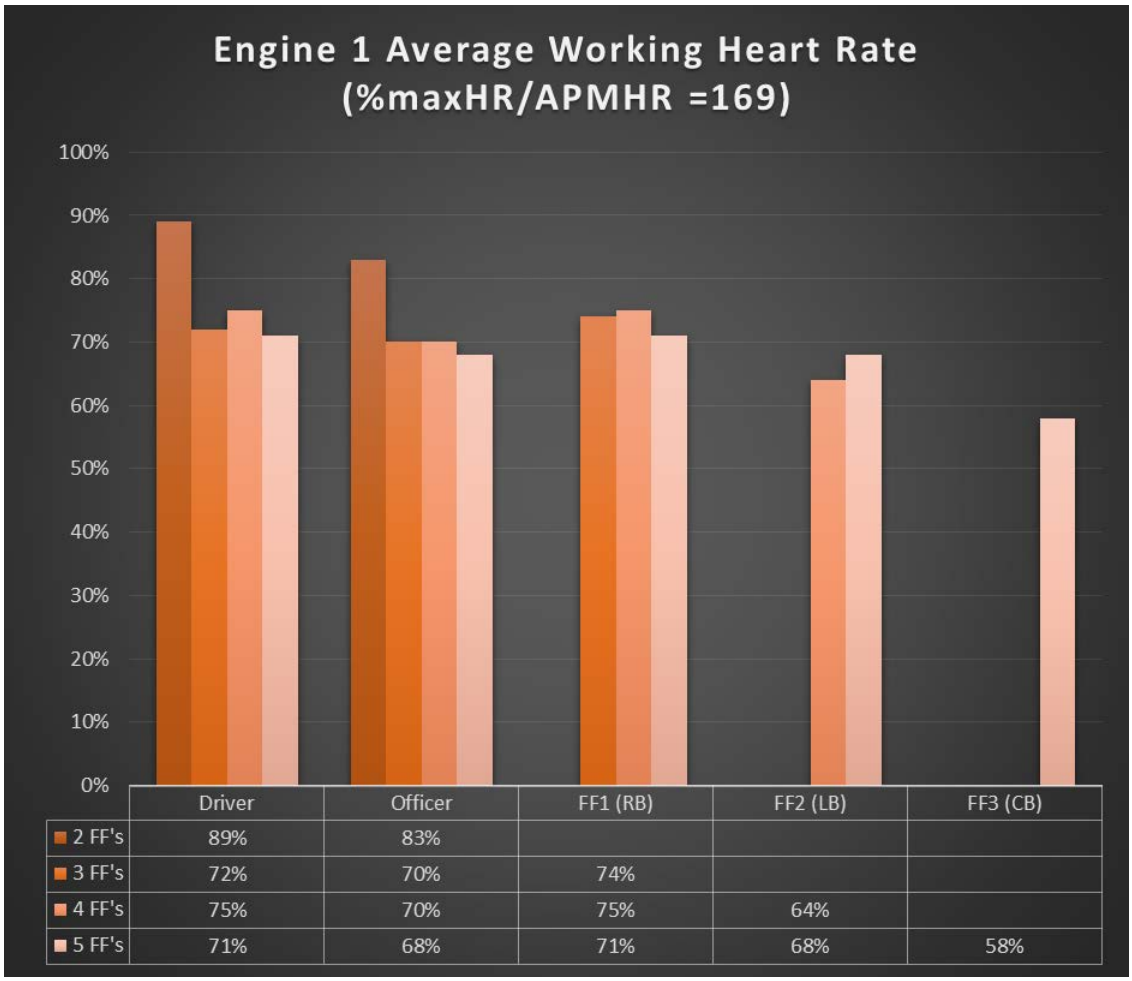
The same NIST study also examined the relationship between crew size and physiological strain. Two important conclusions were drawn from this part of the experiments.

- Average heart rates were higher for members of small crews.
- These higher heart rates were maintained for longer durations.[29]

In 2017 alone, 53% of all firefighter fatalities were related to overexertion.[30] There is strong epidemiological evidence that heavy physical exertion can trigger sudden cardiac events.[31] Smaller crews are responsible for performing a number of tasks that are designed to be performed by multiple people and frequently in teams of two. This means that firefighters on smaller crews are required to work harder than larger crews to accomplish multiple tasks. Additionally, as discussed earlier, firefighters on smaller crews will also be working longer than larger sized crews. Working harder and longer in high heat and dangerous, stressful environments increases the likelihood of firefighters suffering an injury, or worse dying, as a result of overexertion.

Charts 1 and 2, on the following pages, highlight the cardiovascular impact on firefighters based on crew size for the first arriving engine and truck company. The heart rates of firefighters of crew sizes ranging from 2 to 5 firefighters were measured as they participated in the NIST study. The study was able to conclude that not only do smaller crews work harder and longer than larger crews, their heart rates are also more elevated for longer periods of time as well. This increases the risk of firefighters suffering an injury or death from overexertion. A firefighter suffering a medical emergency on the scene of a working fire, EMS, or rescue incident negatively impacts outcomes and increases the risk to the community, the citizen requiring assistance, and the firefighter.

[29] Averill, J.D. et al. (2010). Report on Residential Fireground Field Experiments. NIST Technical Note 1661. National Institute of Standards and Technology; Gaithersburg, MD, April 2010.
[30] Fahy, R.F., LeBlanc, P.R., Molis, J.L. (June 2018) Firefighter Fatalities in the United States-2017. NFPA.
[31] Albert, C.A., Mittleman, M.A., Chae C.U., Lee, I.M., Hennekens, C.H., Manson, J.E. (2000) Triggering Sudden Death from Cardiac Causes by Vigorous Exertion. N Engl J Med 343(19):1355-1361



	Driver	Officer	FF1 (RB)	FF2 (LB)	FF3 (CB)
2 FF's	89%	83%			
3 FF's	72%	70%	74%		
4 FF's	75%	70%	75%	64%	
5 FF's	71%	68%	71%	68%	58%

Chart 1: Average Peak Heart Rate of First Engine (E1) with Different Crew Sizes by Riding Position.[32] *In Chart 1, heart rates are expressed as a percent of maximal age-predicted maximal HR.* The average heart rates for firefighters on the first engine company were above 80% of age-predicted maximum values when only 2 firefighters were working. When staffing was at 2 firefighters, the driver of the apparatus had an average peak heart rate of nearly 90% of the age-predicted maximum. This is largely due to the number of additional tasks the driver must perform to prepare the engine to pump water to the fire and then join the officer to stretch hose to the fire. As can be seen, the larger the crew size, the lower the heart rate.[33] Decision makers could potentially reduce their liability for firefighter injury and death by ensuring staffing is compliant with the minimum recommended industry standards of four firefighters per apparatus.

[32] Riding positions for Chart 1 are as follows: Driver, Officer, Firefighter 1-Right Bucket (RB) seat, Firefighter 2-Left Bucket (LB) seat, Firefighter 3-Center Bucket (CB) seat. A fire company that is staffed with 2 will consist of a Driver and an "Officer."

[33] Smith, D.L., Benedict, R. Effect of Deployment of Resources on Cardiovascular Strain of Firefighters. April, 2010. Pp 5-7

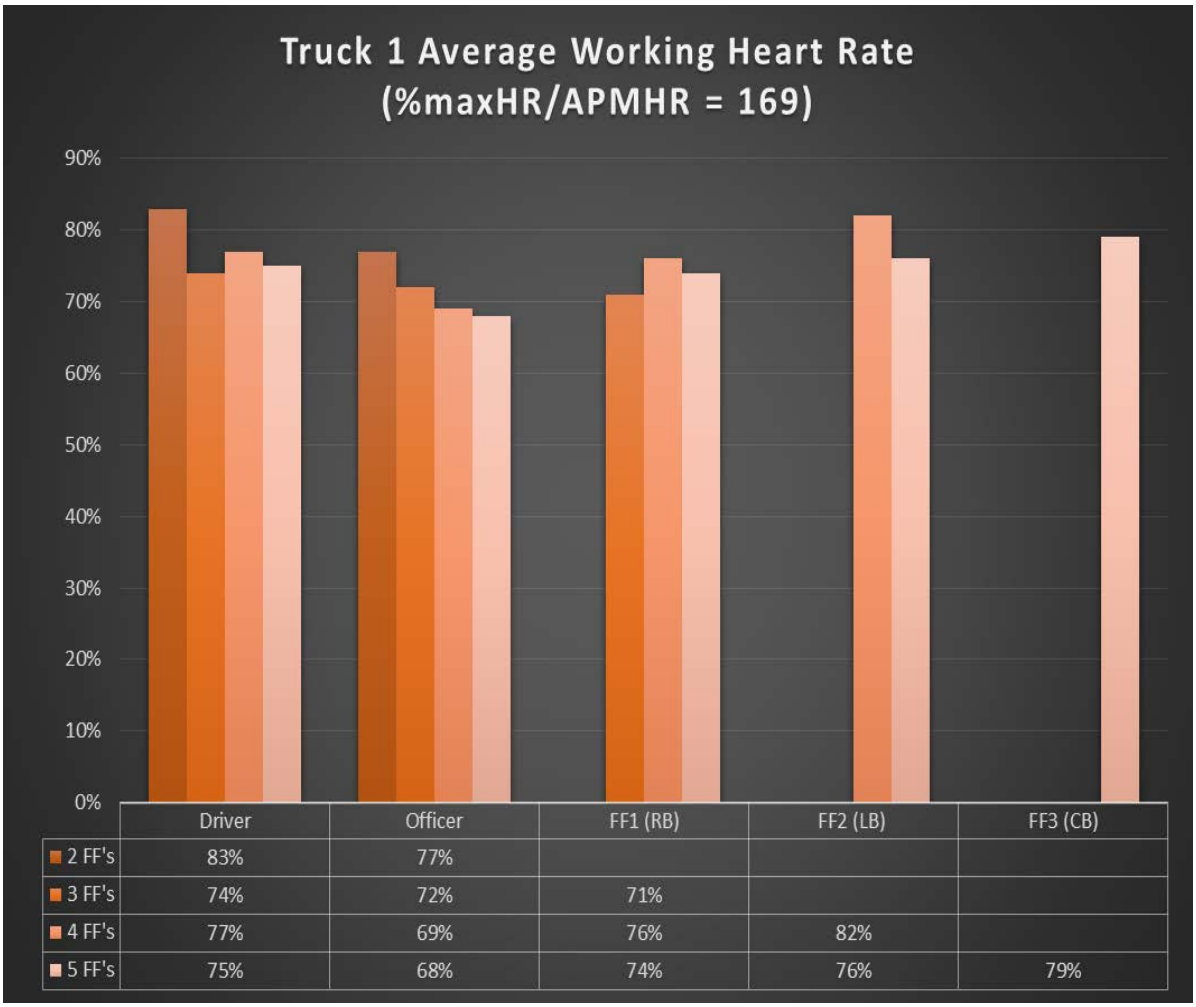


Chart 2: Average Peak Heart Rate of First Truck (T1) with Different Crew Sizes by Riding Position.[34] *In Chart 2, heart rates are expressed as a percent of maximal age-predicted maximal HR.* The average heart rates for firefighters on the first truck company were above 80% of age-predicted maximum values when only 2 firefighters were working.[35] Decision makers could potentially reduce their liability for firefighter injury and death by ensuring staffing is compliant with the minimum recommended industry standards of four firefighters per apparatus.

The Importance of a Rapid Response

Uncontained fire in a structure grows exponentially with every passing minute. Any delay in the initiation of fire suppression and rescue operations, such as the 5- to 7-minute delay that results from smaller sized crews of firefighters, translates directly into a proportional *increase* in

[34] Riding positions for Chart 2 are as follows: Driver, Officer, Firefighter 1-Right Bucket (RB) seat, Firefighter 2-Left Bucket (LB) seat, Firefighter 3-Center Bucket (CB) seat. A fire company that is staffed with 2 will consist of a Driver and an "Officer."

[35] Smith, D.L., Benedict, R. Effect of Deployment of Resources on Cardiovascular Strain of Firefighters. April, 2010. Pp 5-7

expected property, life, and economic losses as is shown in Table 3, following page. It warrants emphasizing that if a structure has no automatic suppression or detection system, a more advanced fire may exist by the time the fire department is notified of the emergency and is able to respond. Fires of an extended duration weaken structural support members, compromising the structural integrity of a building and forcing operations to shift from an offensive to defensive mode.[36] As with inadequate staffing, this type of operation will continue until enough resources can be amassed to mitigate the event.

In the NIST study on the low-hazard residential fire, researchers also used fire modeling to mark the degree of the toxicity of the environment for a range of growth fires (slow, medium, and fast). Occupant exposures were calculated both when firefighters arrive earlier to the scene, and when arriving later. The modeling showed that the longer it takes for firefighters to rescue trapped occupants, the greater the risk posed to both the firefighters and occupants by increasing atmospheric toxicity in the structure.

[36] According to the NFPA, "it's important to realize that every 250 GPM stream applied to the building can add up to one ton per minute to the load the weakened structure is carrying."

Rate Per 1,000 Fires			
Flame Spread:	**Civilian Deaths**	**Civilian Injuries**	**Average Dollar Loss per Fire**
Confined fires (identified by incident type)	0.00	10.29	$212.00
Confined to object of origin	0.65	13.53	$1,565.00
Confined to room of origin, including confined fires by incident type[37]	1.91	25.32	$2,993.00
Beyond the room, but confined to floor of origin	22.73	64.13	$7,445.00
Beyond floor of origin	24.63	60.41	$58,431.00

Table 3: The Relationship between Fire Extension and Fire Loss.[38] The above table displays the rates of civilian injuries and deaths per 1,000 fires, as well as the average property damage. Following the far-left column from top to bottom, each row represents a more advanced level of fire involvement in a residence. Typically, the more advanced the fire, the larger the delay in suppression. Assuming an early discovery of a fire, companies staffed with larger crew sizes help to minimize deaths, injuries, and property loss. This highlights why a 5- to 7- minute delay in suppression activities by smaller sized crews results in higher economic losses to a residence.

OSHA's "2 In/2 Out" Regulation

The "2 In/2 Out" Regulation is part of paragraph (g)(4) of the United States Occupational Safety and Health Administration's revised respiratory protection standard, 29 CFR 1910.134. The focus of this important section is the safety of firefighters engaged in interior structural firefighting. OSHA's requirements for the number of firefighters required to be present when conducting operations in atmospheres that are immediately dangerous to life and health also covers the number of persons who must be on the scene before firefighting personnel may initiate an interior attack on a structural fire. An interior structural fire (*an advanced fire that has spread inside of the building where high temperatures, heat and dense smoke are normally occurring*) would present an IDLH environment and, therefore, require the use of respirators. In those cases, at least two standby persons, in addition to the minimum of two persons inside needed to fight the fire, must be present before firefighters may enter the building.[39] [40] This

[37] NFIRS 5.0 has six categories of confined structure fires, including cooking fires confined to the cooking vessel, confined chimney or flue fire, confined incinerator fire, confined fuel burner or boiler fire or delayed ignition, confined commercial compactor fire, and trash or rubbish fire in a structure with no flame damage to the structure or its contents. Homes include one- and two-family homes (including manufactured housing) and apartments or other multifamily housing. These statistics are national estimates based on fires reported to U.S. municipal fire departments and so exclude fires reported only to federal or state agencies. National estimates are projections. Casualty and loss projections can be heavily influenced by the inclusion or exclusion of one unusually serious fire. Property damage has not been adjusted for inflation.

[38] National Fire Protection Association, NFPA 1710 (2016), Table A.5.2.2.2.1 (b) Fire Extension in Residential Structures, 2006-2010.

[39] According to NFPA standards relating to firefighter safety and health, the incident commander may make exceptions to these rules if necessary to save lives. The Standard does not prohibit firefighters from entering a burning structure to perform rescue operations when there is a "reasonable" belief that victims may be inside.

[40] Paula O. White, letter to Thomas N. Cooper, 1 November 1995 (OSHA)

requirement is mirrored in NFPA 1500, which states that "a rapid intervention team shall consist of at least two members and shall be available for rescue of a member or a team if the need arises. Once a second team is assigned or operating in the hazardous area, the incident shall no longer be considered in the 'initial stage,' and at least one rapid intervention crew shall be required."

NFPA Standard 1710 also supports the OSHA Regulation by requiring a minimum of four personnel on all suppression apparatus. Portions of the 1710 Standard recommend that "fire companies whose primary functions are to pump and deliver water and perform basic firefighting at fires, including search and rescue… shall be staffed with **a minimum of four on-duty members**,"[41] while "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 [also] be staffed with **a minimum of four on-duty members**."[42] For either fire suppression company, NFPA 1710 states that in jurisdictions with tactical hazards, high hazard occupancies, high incident frequencies, geographical restrictions, or other pertinent factors as identified by the authority having jurisdiction, these companies shall be staffed with a minimum of five or six on-duty members.[43]

[41] NFPA 1710, § 5.2.3.1 and §5.2.3.1.1.
[42] NFPA 1710, § 5.2.3.2 and §5.2.3.2.1.
[43] NFPA 1710, § 5.2.3.1.2, §5.2.3.1.2.1, §5.2.3.2.2, and §5.2.3.2.2.1.

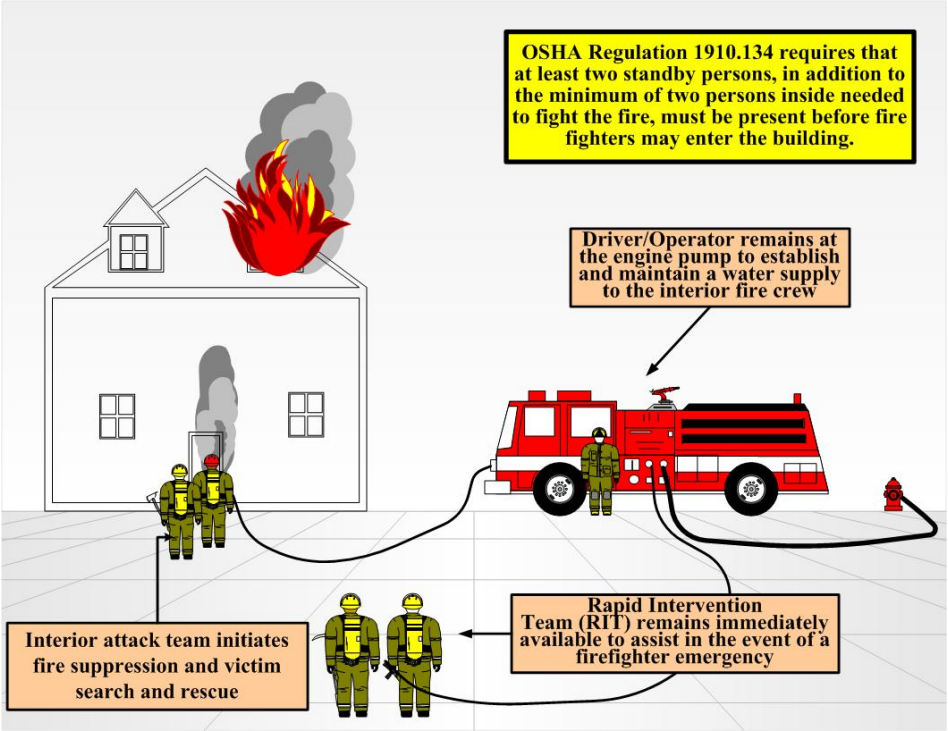


Figure 2: The OSHA "2 In/2 Out" Regulation. The above figure depicts the number of firefighters required to meet OSHA Regulation 1910.134, which demands one firefighter outside for every firefighter inside. The firefighters outside can support a secondary attack line and facilitate the rescue of trapped or disabled firefighters should the need arise. In this scenario the driver/operator of the apparatus is not counted towards the total number of firefighters.

A number of incidents exists in which the failure to follow the "2 In/2 Out" Regulation have contributed to firefighter casualties. For example, in Bridgeport, Connecticut in July 2010, two firefighters died following a fire where the National Institute of Occupational Safety and Health (NIOSH) later found that although a "Mayday" was called by the firefighters, it wasn't responded to promptly as there was no incident safety officer or rapid intervention team (RIT) readily available on scene. In a second case, two firefighters were killed in a fire in San Francisco, California in June 2011. The initial RIT was re-assigned to firefighting duties, and the back-up RIT did not arrive on scene until after the victims were removed.

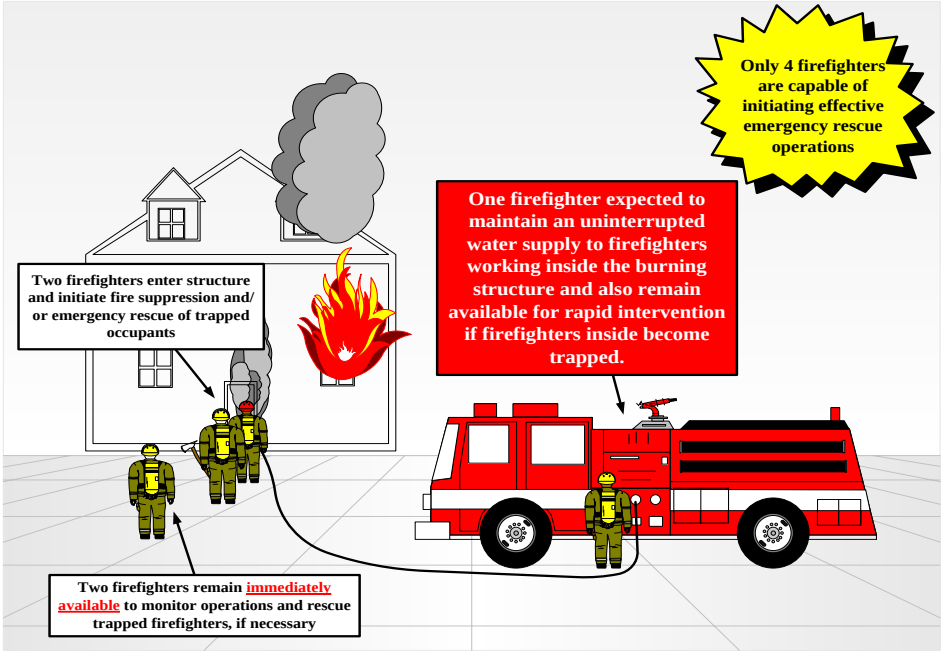


Figure 3: Emergency "2 In/2 Out" Operations. In the emergency model depicted above, the arriving fire apparatus is staffed with a crew of 4 personnel and operates under emergency conditions. In this case the driver/operator of the fire apparatus is also counted as a firefighter, which means that firefighter must be dressed in personal protective equipment (PPE) and be ready to participate in rescue if the need should arise.

When confronted with occupants trapped in a burning structure and a single fire company is on scene, only a company staffed with four firefighters is able to initiate emergency search and rescue operations in compliance with the "2 In/2 Out" Regulation. As indicated in the previous graphic, this requires the complete engagement of every firefighter from the first-in fire company, staffed with four, to participate in the effort, and means that the driver-operator of the apparatus must tend to the pump to ensure the delivery of water to the firefighters performing the initial attack and search and rescue operations and be prepared to make entry with the remaining firefighter should the crew operating inside become trapped.

Regardless, when there exists an immediate threat to life, only a company of four firefighters can initiate fire suppression and rescue operations in compliance with "2 In/2 Out" Regulation, and in a manner that minimizes the threat of personal injury. In crews with fewer than 4 firefighters, the first-in company must wait until the arrival of the second-in unit to initiate safe and effective fire suppression and rescue operations. This condition underlines the importance and desirability of fire companies to be staffed with a minimum of four firefighters and stresses the benefit of four-person companies and their ability to save lives without having to wait for the second-in company to arrive.

Initial Full Alarm Assignment

Initial Full Alarm Assignment Capability, as outlined in NFPA Standard 1710, recommends that the "fire department shall have the capability to deploy an initial full alarm assignment within a 480-second travel time to 90 percent of the incidents… [and that the] initial full alarm shall provide for the following:

Assignment	*Required Personnel*
Incident Command	1 Officer
Uninterrupted Water Supply	1 Pump Operator
Water Flow from Two Handlines	4 Firefighters (2 for each line)
Support for Handlines	2 Firefighters (1 for each line)
Victim Search and Rescue Team	2 Firefighters
Ventilation Team	2 Firefighters
Aerial Operator	1 Firefighter
Initial Rapid Intervention Crew (IRIC)	2 Firefighters
Required Minimum Personnel for Full Alarm	**14 Firefighters & 1 Scene Commander**

Table 4: NFPA 1710, §5.2.4.1.1. This breakdown of the expected capabilities of a full alarm assignment, in compliance with NFPA 1710, requires a minimum contingent of 15 fire suppression personnel. NFPA 1710 also requires that supervisory chief officers shall be assisted by a staff aide[44] which will increase on-scene staffing to 16 personnel required to arrive at the scene of a structure fire within 8 minutes of travel. Although not specifically discussed in the standard, an industry best practice is to have a second uninterrupted water supply which requires a second dedicated engine pump operator. This second, dedicated pump operator brings the total count of firefighters to 17.

[44] NFPA 1710, § 5.2.2.2.4 and § 5.2.2.2.5

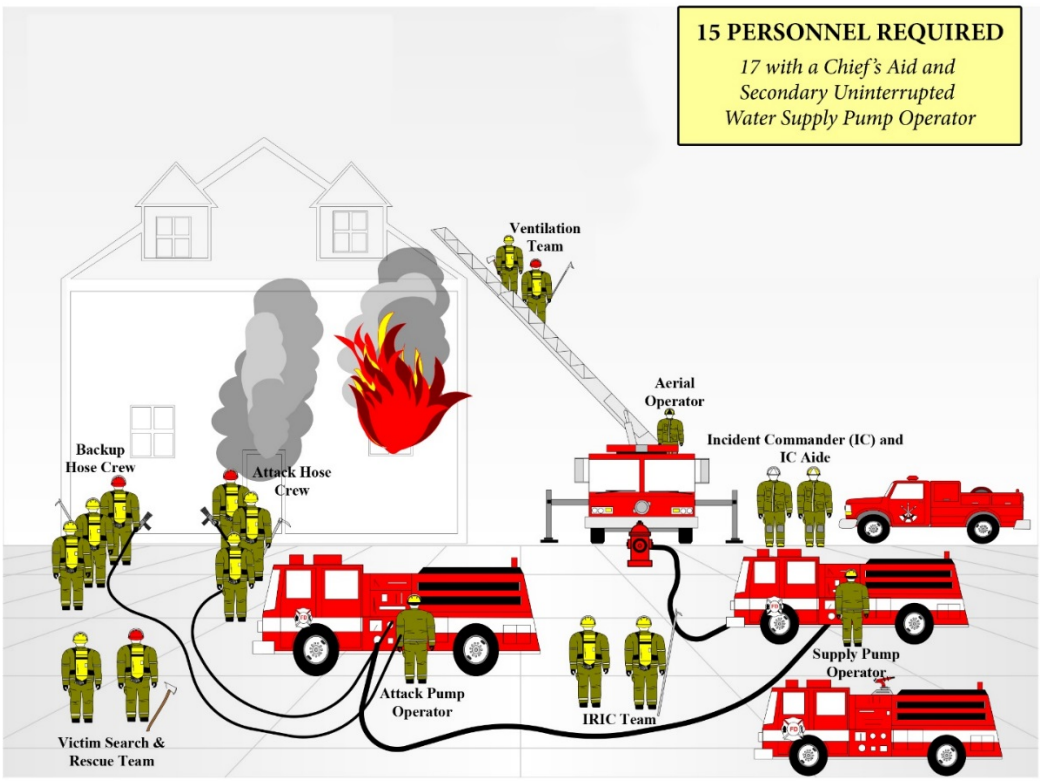


Figure 4: Initial Full Alarm Assignment Deployed Within 8 Minutes. The above figure depicts the full alarm assignment discussed in NFPA 1710, with an additional firefighter to act as the incident commander's aide, and another additional firefighter to act as a pump operator for a supply apparatus.

In addition, NFPA 1710, §5.2.4.5.2 states, "The fire department shall have the capability for additional alarm assignments that can provide for additional command staff, members, and additional services, including the application of water to the fire; engagement in search and rescue, forcible entry, ventilation, and preservation of property; safety and accountability for personnel; and provision of support activities…"

The ability of adequate fire suppression forces to greatly influence the outcome of a structural fire is undeniable and predictable. Each stage of fire extension beyond the room of origin directly increases the rate of civilian deaths, injuries, and property damage.

Fire growth is exponential, growing in a non-linear manner over time. Extending the time for crew assembly by waiting for additional crews to arrive causes on-scene risk to escalate. The higher the risks at the time firefighters engage in fire suppression, the greater the chance of poor outcomes including civilian injury or death, firefighter injury or death, and increased property loss.

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High-Rise Operations

Although this section specifically addresses fire response to high-rise buildings, it is important to note that the discussion can be extrapolated to large area buildings such as manufacturing centers, warehouses, grocery stores, schools, and other structures with a high fire load and populations.

Overview of High-Rises

High-rise buildings were once found exclusively in urban cities. However, today they are commonly found in small and mid-sized suburban communities as well. Many high-rise buildings in suburban areas are newer, shorter, and protected by automatic sprinkler systems, although this is not always a guarantee. NFPA 101, Life Safety Code, 2015 Edition and the International Code Council's International Building Code both define a high-rise structure as a building more than 75 ft. (23 m) in height, measured from the lowest level of fire department vehicle access to the bottom of the highest occupied floor. High-rises, which are described in NFPA 1710 §A.3.3.28 as high-hazard occupancies, represent an extraordinary challenge to fire departments and are some of the most challenging incidents firefighters encounter.

High-rise buildings may hold thousands of people above the reach of fire department aerial devices and the chance of rescuing victims from the exterior is greatly reduced once a fire has reached flashover. The risks to firefighters and occupants increase in proportion to the height of the building and the height of the fire above grade level.[45] This is especially true once firefighters are operating above the reach of aerial ladders on truck companies. In these situations, the only viable means of ingress or egress is the interior stairs. Therefore, a sound fire department deployment strategy, effective operational tactics, and engineered fire protection systems cannot be separated from firefighter safety. As in any structure fire, engine company and truck company operations must be coordinated.

High-rise buildings present a unique threat to the fire service. Multi-floor fires such as the Interstate Building Fire, One Meridian Plaza Fire, World Trade Center collapse, Cook County Administration Building Fire, and Deutsche Bank Building Fire each represented serious challenges to the operational capabilities of a modern fire department. According to the NFPA, between 2009 and 2013, there were an estimated 14,500 reported high-rise structure fires per year that resulted in associated losses of 40 civilian deaths, 520 civilian injuries, and $154

[45] Klaene, B. and Sanders, R. (2007). Structural Firefighting: Strategies and Tactics- High-Rise. Jones and Bartlett 2007.

million in direct property damage. Office buildings, hotels, apartment buildings, dormitories, and health care facilities accounted for almost three-quarters (73%) of these high-rise fires.[46]

Although the frequency of fires in high-rise structures is low, they pose a high consequence of loss with regards to injury, loss of life, and property damage. Even if a department does not respond to high-rise buildings at present, it may in the future as urban sprawl continues and/or jurisdictional border restrictions and population growth require taller buildings to meet residential needs.

High-Rise Firefighting Tactics

As has been stated, in a high-rise fire the risks to firefighters and occupants increases in proportion to the height of the building and the height of the fire above ground level. As the level of the fire floor gets higher, firefighters are required to carry more equipment further and must rely more on the building's standpipe system. A standpipe system is a piping system with discharge outlets at various locations usually located in stairwells on each floor in high-rise buildings that is connected to a water source with pressure supplemented by a fire pump[47] located in the building and/or a fire apparatus with pumping capabilities.

A fire in a high-rise building can threaten occupants and responding firefighters. Because of the amount of time it takes firefighters encumbered with equipment to access the involved floors, the fire may have expanded well past the area of origin. This means that firefighters can encounter a large volume of fire and darkened conditions when they arrive on the involved floors. This can be further complicated if the building is not equipped with a sprinkler system. Additionally, open-layout floor plans such as office buildings with cubicle farms can challenge both the standpipe's flow capacity and fire department resources in regards to search, rescue, and hoseline deployment. The most effective way to extinguish a high-rise fire is by mounting an offensive attack as early as possible, because in the vast majority of historic high-rise fires, the best life safety tactic is extinguishing the fire. Good high-rise firefighting tactics and firefighter/occupant safety cannot be separated. As with a residential structure fire, the first arriving suppression apparatus should be on the scene within four minutes of travel time. However, when responding to any high-hazard buildings or structures, which include high-rises, first responding fire apparatus should be staffed with five to six firefighters per NFPA 1710, upon the determination of the AHJ.

Similar to residential structure fires, there are several critical tasks that must be accomplished. However, unlike residential firefighting in a 2,000 square foot residence, firefighters working at a high-rise fire must travel upwards of more than three stories and carry additional equipment beyond the normal requirements. Additionally, as it takes longer to assemble an effective

[46] Ahrens, Marty. (2016) High-Rise Building Fires. NFPA.
[47] Structural Firefighting Strategy and Tactics 2nd Edition. Klaene B., Sanders R. NFPA 2008

response force and to access the fire floor, firefighters are likely to encounter a large volume of fire and will therefore have an extended fire attack. Because of this, it is necessary to establish an equipment supply chain to transport equipment and resources up and down the building.

Search and Rescue

Search and rescue are critical fireground tasks that comprise a systematic approach to locating possible victims and removing those victims from known danger to a safe area. In a residential structure fire, searches are normally conducted by a crew of two firefighters, supplemented by an attack or ventilation crew. However, high-rise structures pose challenges regarding search and rescue that are not typically encountered in residential housing. For commercial high-rises and wide-area structures, large open areas and cubicle farms require additional search and rescue teams so that thorough searches can occur over a larger area than found in most residences. In addition to these larger areas, search and rescue can be further complicated because conscious victims may retreat to areas in an attempt to find shelter from heat and smoke. These areas may differ from places where they are typically seen by coworkers, making locating them difficult if they are unaccounted for.

In residential high-rises, apartments typically lack two exits and usually share a common hallway for egress. Doors left open by victims fleeing fire can allow fire and smoke to spread into the hallway and impact escape attempts. Firefighters will be slowed in their search since they will be required to force their way into numerous apartments to search for victims. For this reason, regardless of commercial or residential, it is essential for there to be multiple search and rescue teams operating per involved floor to quickly locate victims in large surface areas. It is also necessary for additional search and rescue teams to search the floors above the fire and the highest floor of the building, due to how fire and smoke spread to the rest of the building. Search and rescue teams should also be supplemented with evacuation management teams to assist injured or disabled victims down the stairwells so searching can continue. Because of the larger search area, NFPA 1710 requires a minimum of four firefighters for searching and a minimum of four firefighters for evacuation management teams.

Fire Extinguishment

Fire extinguishment is a critical factor, since the intensity and size of the fire will determine the extent to which combustion gases are heated and how high they will rise inside the building. Building suppression systems, both active and passive, can impact fire growth, occupant safety, and firefighter safety and effectiveness. Such features include active fire detection and automatic sprinkler systems that are designed to either extinguish the fire or contain it until firefighters arrive.

Once firefighters are on scene, they will complete a series of fire confinement and extinguishment tasks. Firefighters access the structure, locate the fire, locate any avenues of

spread, place hoselines, and establish a water supply. Once a water supply is established, water should be placed at the seat of the fire or in the compartment containing the fire to extinguish it. Unlike residential structure fires where hoselines can be stretched from the fire apparatus into the structure, high-rise structures require the use of standpipe systems to combat fire. This requires firefighters to carry multiple sections of hose to the affected floors and connect into the system to fight fire. Minimally, firefighters must deploy two hoselines to the involved floor and one hoseline to the floor above the fire. The third hoseline supports a number of critical tasks in the suppression effort. Principally, it is used to protect search and rescue teams, but also to stop the spread of fire as a result of conduction and convection through exposed pipes, metal framing, and ventilation systems.

Ventilation

Ventilation affects both search and rescue and fire extinguishment. Ventilation may be implemented at any time during the operation, but it should be coordinated with suppression and interior rescue activities. Ventilation is used to channel and remove heated air, smoke, fire gases, and other airborne contaminants. Applying proper ventilation at the right time and place is key to firefighter and occupant safety. Venting at the wrong time or place can draw active fire toward fresh air, which will injure or kill anyone in its path. In instances of high-rise fire suppression, adequate and appropriate ventilation is important to keep stairways free of smoke and noxious gases for victims who are evacuating.

Because of the size of high-rise buildings and high-hazard structures in general, a larger number of firefighters is required for a ventilation team than would be for a residential structure. NFPA 1710 recommends a minimum of four firefighters to be assigned to ventilation.

Support

As has been discussed, fire suppression in a high-rise or high-hazard structure requires the establishment of a supply chain to shuttle equipment to different locations. Additionally, with increased resources and personnel, there is an increased need for additional supervision and accountability.

One critical support variable in high-rise fire operations is the availability of reliable elevators. If firefighters can safely use the elevators to move people and equipment, fireground logistics may be significantly improved. When the fire is located several floors above ground level, there is a strong inclination to use the elevators. However, fire service access elevators[48] may not be available in all buildings. Therefore, adequate stairways are necessary for firefighters to transport equipment and reach the fire floor for suppression.

[48] A fire service elevator is engineered to operate in a building during a fire emergency and complying with prescriptive building code requirements and the American Society of Mechanical Engineers (ASME) A 17.1 safety standard for elevators.

Moving supplies and staff up 10, 20, 30, or more stories is an arduous task. If it is not properly managed, firefighters may be exhausted and unable to fight the fire or rescue trapped occupants. Additionally, joint use of stairways by firefighters moving upward and occupants attempting to evacuate may increase the overall evacuation time of the occupants, as well as delay the firefighters' efforts to begin critical tasks such as fire suppression or search and rescue operations. As such, it is important to have multiple firefighters to help carry equipment upstairs and manage resource distribution.

To accomplish the critical fireground tasks associated with high-rise firefighting and meet the minimum staffing objectives for task completion, NFPA 1710 recommends the following company sizes for the first arriving unit(s) on the scene within four minutes of travel time for response to high-hazard structure:

- In jurisdictions with a high number of incidents or geographical restrictions, as identified by the AHJ, these companies shall be staffed by a minimum of five on-duty members.[49]
- 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.[50]

As indicated by the tasks that must be accomplished on a high-rise fireground, understanding the required resources is critical. The number of firefighters needed to safely and effectively combat a high-rise fire may be large. Although an offensive fire attack is the preferred strategy whenever conditions and resources permit, a defensive attack that limits operations to the outside of a building and generally results in more property damage must be considered when risks to firefighter safety are too great and benefits to building occupants are negligible. The offensive vs. defensive decision is based on a number of factors: fireground staffing available to conduct an interior attack, a sustained water supply, the ability to conduct ventilation, and risk vs. benefit analysis regarding firefighter and occupant safety. Table 5, on the next page, displays the minimum number of firefighters required to arrive as part of the initial full alarm assignment to a high-rise fire.

[49] NFPA 1710. §5.2.3.1.2
[50] NFPA 1710. §5.2.3.1.2.1, §5.2.3.2.2, and §5.2.3.2.2.1.

Assignment	***Required Personnel***
Incident Command	1 Incident Commander 1 Incident Command Aide
Uninterrupted Water Supply	1 Building Fire Pump Observer 1 Fire Engine Operator
Water Flow from Two Handlines on the Involved Floor	4 Firefighters (2 for each line)
Water Flow from One Handline One Floor Above the Involved Floor	2 Firefighters
Rapid Intervention Crew (RIC) Two Floors Below the Involved Floor	4 Firefighters
Victim Search and Rescue Team	4 Firefighters (2 per team)
Point of Entry/Oversight Fire Floor	1 Officer 1 Officer's Aide
Point of Entry/Oversight Floor Above	1 Officer 1 Officer's Aide
Evacuation Management Teams	4 Firefighters (2 per team)
Elevator Management	1 Firefighter
Lobby Operations Officer	1 Officer
Trained Incident Safety Officer	1 Officer
Staging Officer Two Floors Below Involved Floor	1 Officer
Equipment Transport to a Floor Below Involved Floor	2 Firefighters
Firefighter Rehabilitation	2 Firefighters (1 must be ALS)
Vertical Ventilation Crew	1 Officer 3 Firefighters
External Base Operations	1 Officer
2 EMS ALS Transport Units	4 Firefighters
Required Minimum Personnel for Full Alarm	**36 Firefighters** **1 Incident Commander** **6 Officers**

Table 5: Number of Firefighters for an Initial Full Alarm to a High-Rise Fire. Fighting fire in high-rise structures poses many unique obstacles and challenges other than are found in a residential structure fire. Hose cannot be deployed directly from fire apparatus and needs to be carried, with other equipment, to the location of the fire. Search and rescue is impacted by large areas and accessibility concerns. Additionally, because of delays in access, firefighters are likely to encounter a high volume of fire which will necessitate a supply chain to equip ongoing suppression efforts. A single alarm response to a high-rise building minimally requires 43 responders, consisting of 36 firefighters, 1 incident commander, and 6 officers.

Fire Department EMS Operations

In recent years, the provision of emergency medical services has progressed from an amenity to a citizen-required service. More than 90% of career and combination fire departments provide some form of emergency medical care, making fire departments the largest group of prehospital EMS providers in North America. In many fire departments that deliver prehospital care, EMS calls can equate to over 75% of total call volume.

There are six main components of an EMS incident from start to finish.[51] These are (1) detection of the incident, (2) reporting of the incident to a 9-1-1 center, (3) response to the incident by the appropriate emergency resources, (4) on scene care by emergency response personnel, (5) care by emergency personnel while in transit to a medical care facility, and (6) transfer of the patient from emergency response personnel to the medical care facility. Not all EMS events will necessitate all six components, as when a patient refuses treatment, or is treated at the scene and not transported.

In an analysis of data from over 300 fire departments in the United States, first responder units, which are typically fire engines, arrived prior to ambulances approximately 80% of the time.[52] This is likely due to the fact that fire stations housing first responder units, which are equipped and staffed with multi-role firefighter/emergency medical service technicians and supplies, are more centrally located and are able to effect a quicker response and provide life-saving procedures in advance of an ambulance. This reinforces why it is in the best interest of the public good for the fire department to provide EMS transport as well as first response.

The benefit of supporting EMS transport within fire department operations is that fire departments are already geared towards rapid response and rapid intervention. Strategically located stations and personnel are positioned to deliver time critical response and effective fire suppression and are therefore equally situated to provide effective response to time critical requests for EMS service. Both fire suppression and EMS response are required by industry standards to have adequate personnel and resources operating on scene within 4 minutes. In both fire suppression and EMS incidents, time is directly related to the amount of damage, either to the structure or the patient.

When ambulance response is prolonged, a patient will be further delayed in reaching a medical facility to receive definitive care. This is especially dangerous for incidents of chest pain, stroke,

[51] The Star of Life, designated by Leo R. Schwartz, Chief of EMS Branch, National Highway Traffic Safety Administration (NHTSA) in 1997.
[52] Moore-Merrell, L. et al. (2010) Report on Residential EMS Field Experiments, Fire Fighter Safety and Deployment Study; Washington, DC, September 2010.

and survivable cardiac arrest. Many times, patients experiencing symptoms associated with these events may not recognize the onset indicators and immediately call for assistance.[53] [54] [55] [56] Acute Coronary Syndrome (ACS), or heart attack, is the number one leading cause of death in the United States. Experts agree that an ACS event should receive definitive care from a hospital within one hour of onset of symptoms. One study found that definitive care for ACS within one hour of onset improves survivability by 50% and 23% if definitive care was given within 3 hours.[57]

Strokes, which are the number three cause of death in the U.S., as well as a leading cause of disability, also benefit from expedient treatment in definitive care. Ischemic stroke, which is a stroke caused from a blood clot, can be effectively treated if definitive care is received within 3 to 4.5 hours[58] of onset of symptoms. The sooner a patient receives definitive treatment from onset of symptoms, the less likely a patient is to suffer disability from this type of stroke. However, it is important to emphasize that before the time critical treatment can be administered to the patient in the hospital, there is a time intensive assessment that must be performed to ensure the patient is qualified to receive the treatment. The current benchmark for an ischemic stroke patient "door to needle"[59] is less than or equal to 60 minutes. However, Steps Against Recurrent Stroke (STARS) registry shows that the median door to needle time is 96 minutes or 1 hour and 36 minutes.[60]

In two-tiered EMS systems that deploy with sufficient resources, there is an increased likelihood that a patient will receive an ambulance and a first responding fire apparatus in not only a timely manner, but also frequently at the same, or close to the same time. This is extremely beneficial to the patient as most EMS responses, particularly the previously mentioned conditions, are labor intensive. Patients suffering from ACS should not perform any form of exertion as to minimize any damage that is occurring. Patients suffering from strokes are frequently unable to exert due to physical disabilities caused by the incident. An adequately sized crew is able to provide simultaneous interventions while assessment is being performed, thereby reducing the on-scene

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[53] American Heart Association, *Heart Disease and Stroke Statistics-2005 update*, Dallas, TX: AHA 2005

[54] Time from Symptom Onset to treatment and outcomes after thrombolytic therapy. Newby LK, et al. *J Am Coll Cardiol.* 1996:27:1646-1655

[55] An International Perspective on the Time to Treatment of Acute Myocardial Infarction. Dracup, K. et al. *J Nurs Scholarsh* 2003;35:317-323

[56] Prehospital and In-hospital Delays in Acute Stroke Care. Evanson, KR, et al. *Neuroepidemiology* 2001;20:65-76

[57] Association of patient delays with symptoms, cardiac enzymes, and outcomes in acute myocardial infarction. Rawles, JM. Et al. *Eur Heart J.* 1990; 11:643-648.

[58] Thrombolysis with Alteplase 3 to 4.5 Hours after Acute Ischemic Stroke. Hacke, W. et al. *N Engl J Med.* 2008;359:1317-1329

[59] "Door to Needle" is an industry specific term that refers to the time the patient entered the emergency department to the time they received the treatment. A drug named recombinant tissue plasminogen activator (rt-PA) is utilized to dissolve the thrombosis causing the stroke. Current FDA approvals limit this drug's use to 3-4.5 hours from initial symptoms and require a CT scan and labs before administration.

[60] Improving Door-to-Needle Times in Acute Ischemic Stroke: The Design and Rational for the American Heart Association/American Stroke Association's Target: Stroke Initiative. Fonarow, Gregg, et al. *Stroke* 2011;42:00-00

time. Following completion of critical tasks, the crew can then facilitate a safe removal of the patient to the ambulance and minimize the risk of injury to patient and provider.[61]

One of the most labor intensive and time critical requests for EMS response is cardiac arrest, which globally affects 20-140 out of every 100,000 people. Traditionally, the American Heart Association (AHA) taught a method of cardiac resuscitation that involved single rescuer performance of prioritized action.[62] However, there was a gap between instruction and practice which led to confusion and may have potentially reduced survival. In reality, providers respond and function in teams larger than two.

The AHA's guidelines for cardiac resuscitation focus on a team-centric approach. Evidence-based research suggested that the manner in which CPR was being performed was inherently inefficient and only provided 10-30% of the normal blood flow to the heart and 30-40% to the brain.[63] [64] This was linked to provider fatigue from administering chest compressions, and as such, these studies indicate that providers should be rotated to ensure effective depth and rhythm of chest compressions. Consensus documents from the AHA recommend that providers should rotate with every two-minute cycle of CPR. It is also recommended that requests for EMS service for cardiac arrest also have a team leader to organize priorities and direct resources as they arrive or are needed. The team leader would also be responsible for identifying symptoms of fatigue and making appropriate assignment adjustments to ensure maximally efficient CPR.

Although the AHA and other researchers have not identified what an optimally sized crew for effective team-centric CPR should be, some consensus literature from AHA has mentioned that five providers were best suited to perform resuscitation. However, providers may be required to perform multiple tasks. Industry best practices, through the guidance of medical directors, have suggested six providers would be most successful in minimizing confusion and redundancy.

An EMS crew consisting of six personnel would require four personnel arriving with the first responding fire apparatus and two with the ambulance.[65] For an all-ALS system, two of the six should be paramedics, with a minimum of one assigned to each of the responding apparatus. Some ALS systems require two paramedics on the ambulance and a minimum of one on the first responding fire apparatus. However, these deployment options are determined by state directive

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[61] Moore-Merrell, L. et al. (2010) Report on Residential EMS Field Experiments, Fire Fighter Safety and Deployment Study; Washington, DC, September 2010.

[62] Highlights of the 2010 American Heart Association Guidelines for CPR and ECC

[63] Determinants of Blood Flow during Cardiac Resuscitation in Dogs. Halperin, HR et al. *Circulation* 1986;73:539-550

[64] Increased Cortical Cerebral Blood Flow with LUCAS, a New Device for Mechanical Chest Compressions Compared to Standard External Compressions during Experimental Cardiopulmonary Resuscitation. Rubertson S, et al. *Resuscitation*. 2005;65:357-363

[65] NFPA 1917: Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments

or medical director's discretion. Regardless of the make-up of the EMS certification level of the providers on scene, an ALS integrated cardiac arrest response should provide for the following: a lead provider, an airway manager, two providers to interchangeably deliver chest compressions, a provider to establish an intravenous medication line and administer medications, and a provider to operate the monitor.

Fire Department Deployment

Before discussing the staffing and deployment analysis of the Spokane Fire Department resources, it is imperative to understand the intricacies of distribution and concentration. Although adequate staffing is a key element contributing to positive outcomes, fire station location and apparatus are equally important.

The Importance of Adequate Resources: Distribution

Distribution involves locating geographically distributed, ideal first-due resources for all-risk initial intervention. Distribution describes first due arrival. Station locations are needed to assure rapid deployment for optimal response to routine emergencies within the response jurisdiction. Distribution can be evaluated by the percentage of the jurisdiction covered by the first-due units within adopted public policy service level objectives.[66] In this case, distribution is measured by the percentage of roads that are covered from each fire station within 4-minute, 8-minute, and 10-minute, 10-second travel times to adhere to NFPA 1710 standards.

Distribution study requires geographical analysis of first due resources. Distribution measures may include:[67]

- Population per first-due company
- Area served per first-due company (square miles)
- Number of total road miles per first-due company (miles)
- Dwelling unit square footage per first-due company
- Maximum travel time in each first-due company's protection area
- Catchment areas (4-minute road response from all fire stations) to determine gap areas and overlaps of first-due resources
- Areas outside of actual performance
    1. Population not served
    2. Area not served (square miles)
    3. Road miles not served (miles)
    4. Dwelling unit square footage not served
- First-due unit arrival times (Engine, Truck, ALS unit, etc.)

A major item to be considered in the distribution of resources is travel time. It should be a matter of public policy that the distribution of fire stations in the community is based on the

[66] Commission on Fire Accreditation International, 5th Edition. 2008. Page 52.
[67] Commission on Fire Accreditation International, 5th Edition. 2008. Page 52.

element of travel time and the response goal. Travel time should be periodically sampled and analyzed to determine whether or not the fire department is achieving a reasonable response performance to handle emergencies.[68]

Evaluating a small number of incidents for response time performance also does not reflect the true performance of the department. Analyzing tens of thousands of incidents measured over 3-5 years will provide a more accurate assessment of the delivery system performance. Completing the same analysis over a period of time will allow for trend analysis as well.[69]

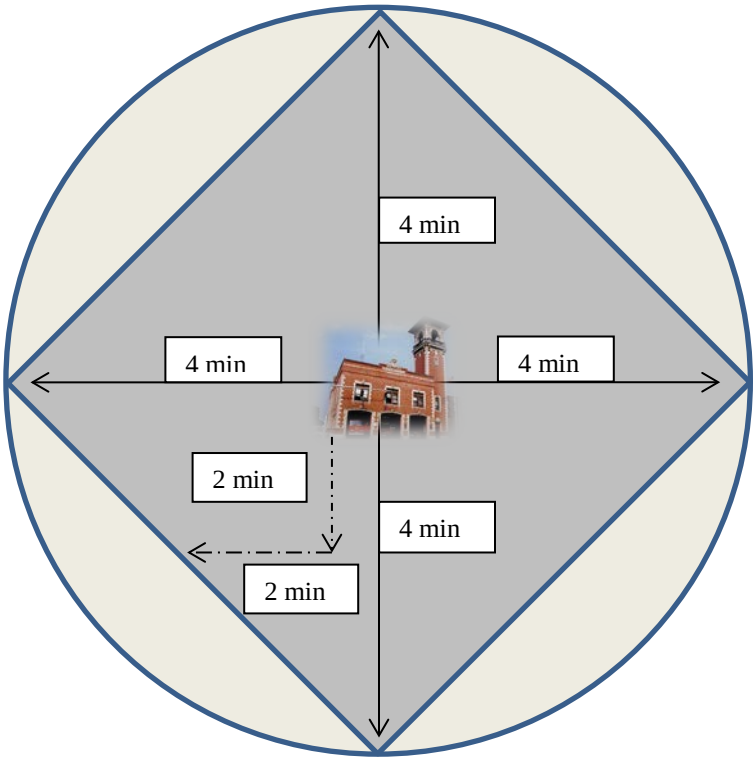

Figure 5: Normal Distribution Model for an Initial 4-Minute Response Area.[70] As depicted in the above figure, fire stations and emergency resources should be distributed throughout a community so that citizens receive equitable coverage and protection. However, there are additional points of concern when modeling a response district such as road network, traffic patterns, and building occupancies.

Distribution strives for an equitable level of outcome: everyone in the community is within the same distance from a fire station. Distribution is based on the probability that all areas experience equal service demands, but not necessarily the same risk or consequences as those demands for service in other areas. For example, suburban communities in a jurisdiction may have the same service demand as an industrial factory area, but the level of risk is very different.

[68] Commission on Fire Accreditation International, 5th Edition. 2008. Page 53
[69] Commission on Fire Accreditation International, 5th Edition. 2008. Page 53
[70] Derived from Commission on Fire Accreditation International, 5th Edition. 2008. Page 53

This can have an impact on fire station locations as placement would probably put the stations near high risk areas to provide shorter travel times. Additionally, EMS response times based on medical emergencies will drive equal distribution in the community and negate distribution based on risk, as the risk is equal.

First unit arrival times are the best measure of distribution. It should be noted that if an area experiences fire unit arrival times outside the adopted performance measure, in this case 4-minute travel time per NFPA 1710, it does not necessarily mean it has a distribution issue.[71] Other issues occur such as reliability, call processing times and turnout times, and traffic which can affect the overall performance of response times.

An effective response force for a fire department is impacted not only by the spacing of fire stations but also by the type and amount of apparatus and personnel staffing the stations. To assemble the necessary apparatus, personnel, and equipment within the prescribed timeframe, all must be close enough to travel to the incident, if available upon dispatch. The placement and spacing of specialty equipment is always challenging.[72] Specialty units tend to be trucks, rescue units, hazmat, or Battalion personnel. Most often there are less of these types of equipment and personnel compared to the first-line response of engines and medic units. Selecting where to put specialty units requires extensive examination of current and future operations within the fire department and a set goal of response time objectives for all-hazards emergencies within a jurisdiction.

Distribution vs. Concentration

Major fires have a significant impact on the resource allocation of any fire department. The dilemma for any fire department is staffing for routine emergencies and also being prepared for the fire or emergency of maximum effort. This balancing of distribution and concentration staffing needs is one that almost all fire agencies face on an ongoing basis.

The art in concentration spacing is to strike a balance with respect as to how much overlap there should be between station areas. Some overlap is necessary to maintain good response times and to provide back-up for distribution when the first-due unit is unavailable for service or deployed on a prior emergency.

Concentration pushes and pulls distribution. Each agency, *after risk assessment and critical task analysis,* must be able to quantify and articulate why its resource allocation methodology meets the governing body's adopted policies for initial effective intervention on both a first-due and multiple-unit basis.[73]

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[71] Commission on Fire Accreditation International, 5th Edition. 2008. Page 55
[72] Commission on Fire Accreditation International, 5th Edition. 2008. Page 62
[73] Commission on Fire Accreditation International, 5th Edition. 2008. Pages 62-63

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CAD Data Analysis

The Spokane Fire Department provided CAD data for January 1, 2016 – October 31, 2018. Information contained in the CAD data included incident number, response date, call type, incident location, apparatus name, time assigned, time en route, time arrived, and time available. There was no data provided for ARU 3 in 2017. The missing data might be attributed to a mis-coding of the apparatus name.

ARU deployment policies have changed to meet the needs of the City of Spokane. ARUs are always in service and deploy from Stations 1, 3, and 15. After receipt of the SAFER grant in 2017, the ARUs were solely tasked with responding to low-acuity incidents with BLS-certified firefighters. At the discretion of the engine officer, they could respond with the engine to a fire or an ALS call if the officer believed the response required additional personnel. However, ARUs have typically responded independently of the engines at their respective stations. This protocol is important to consider when assessing the following graphs.

Spokane engine and ARU responses were examined to determine the potential impacts of removing the ARUs from service. If the ARUs are taken out of service, many of the EMS calls to which they respond would most likely need to be handled by the engine companies deployed from the same stations. ARU responses have increased 2016 – 2018, and ARUs make more responses than some engines. If ARUs are taken out of service, engines will likely make more back-to-back responses. It is also likely that engines will make more responses requiring engines from other stations to cover their first-due district which will increase travel times and leave other areas of the city without coverage. The following graphs show results of analysis of engine and ARU responses, potential for back-to-back engine runs if ARUs are cut, and travel times of apparatus when other apparatus are already engaged.

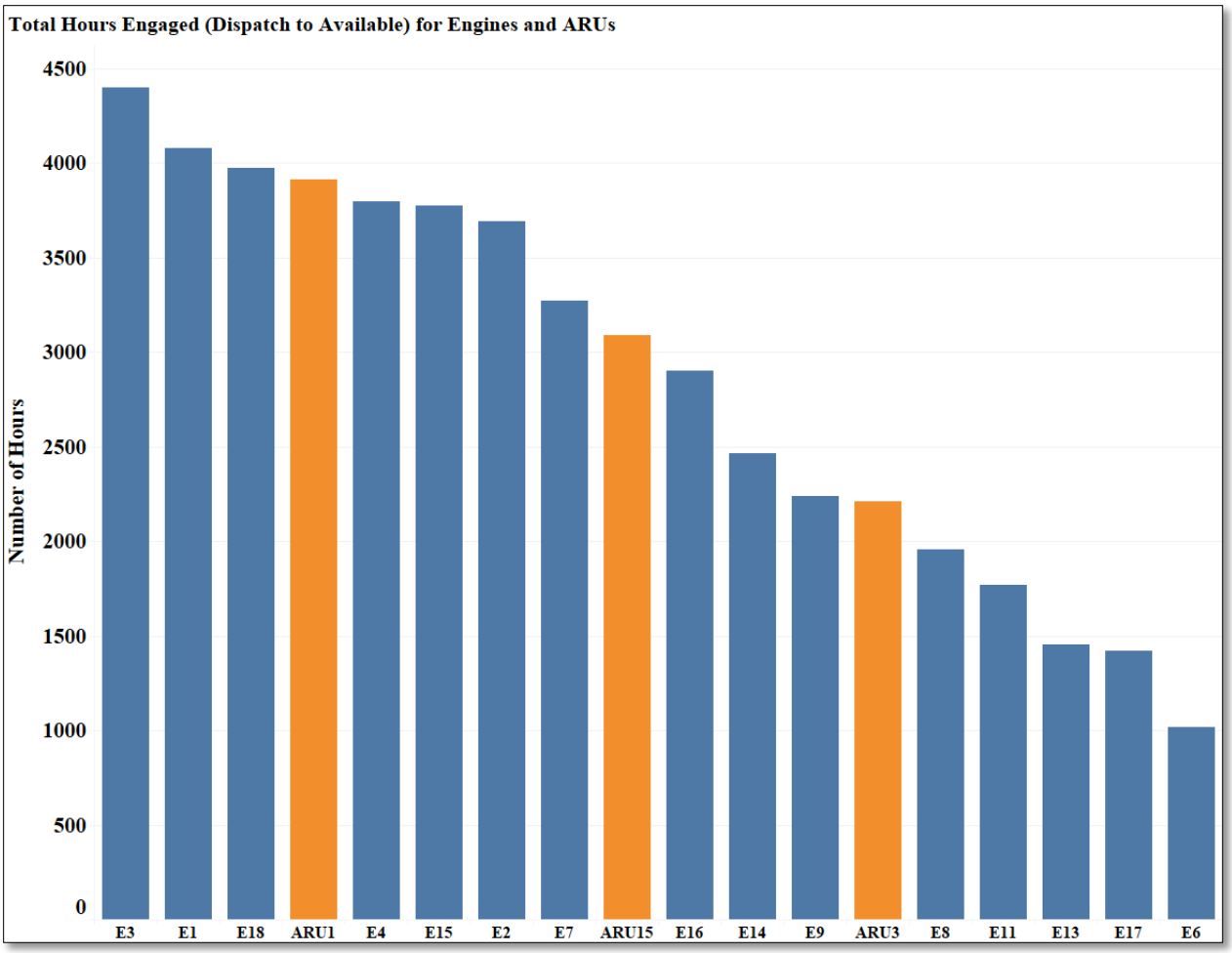


Figure 6: Total Hours Engaged (Dispatch to Available) for Engines and ARUs. Figure 6 shows the total number of hours Spokane's engines and ARUs were engaged January 1, 2016 – October 31, 2018. The hours engaged were calculated as the time from when unit was dispatched until it was marked available. The ARUs were engaged for more hours than some of the engines. If the ARUs are taken out of service as proposed, their responses will most likely be covered by engines which will then likely experience a large increase in usage.

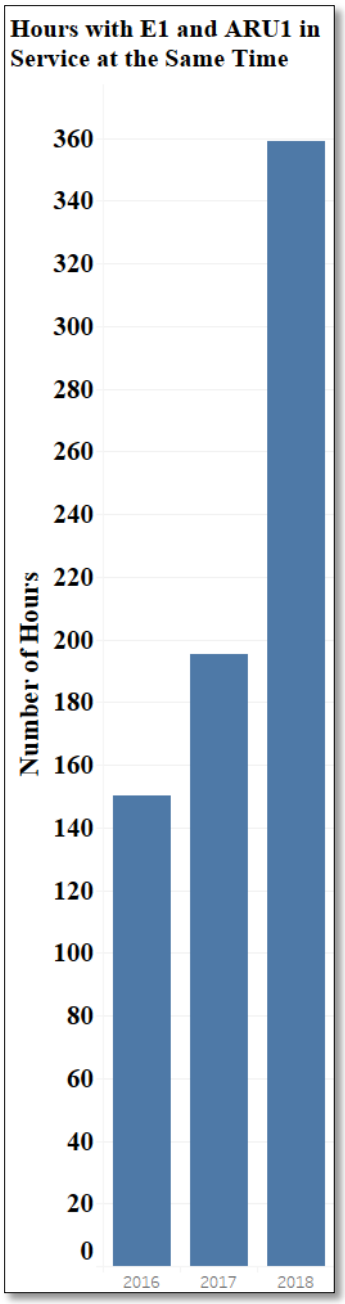


Figure 7: Hours with Engine 1 and ARU 1 in Service at the Same Time. Figure 7 shows the number of hours where both Engine 1 and ARU 1 were in service at the same time January 1, 2016 – October 31, 2018. There is a marked increase in instances in which both units are in service at the same time from 2016 to 2018, particularly accounting for the fact that only 10 months of data are shown for 2018 as compared to the 12 months shown for 2016 and 2017. If ARU 1 is taken out of service, then apparatus from other stations will likely need to respond to incidents when Engine 1 is already engaged. This situation will increase travel time and leave other first-due districts without coverage because their apparatus may be responding to another area.

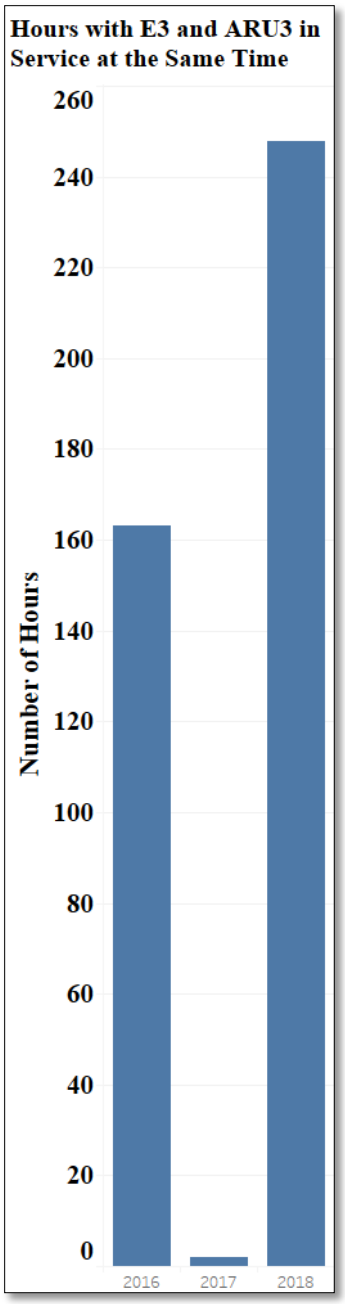


Figure 8: Hours with Engine 3 and ARU 3 in Service at the Same Time. Figure 8 shows the number of hours where both Engine 3 and ARU 3 were in service at the same time January 1, 2016 – October 31, 2018. Due to missing data, 2017 does not show any hours where Engine 3 and ARU 3 are in service at the same time. However, there is a marked increase in instances in which both units are in service at the same time between 2016 and 2018, particularly accounting for the fact that only 10 months of data are shown for 2018 as compared to the 12 months for 2016. If ARU 3 is taken out of service, then apparatus from other stations will likely need to respond to incidents when Engine 3 is already engaged. This situation will increase travel time and leave other first-due districts without coverage because their apparatus may be responding to another area.

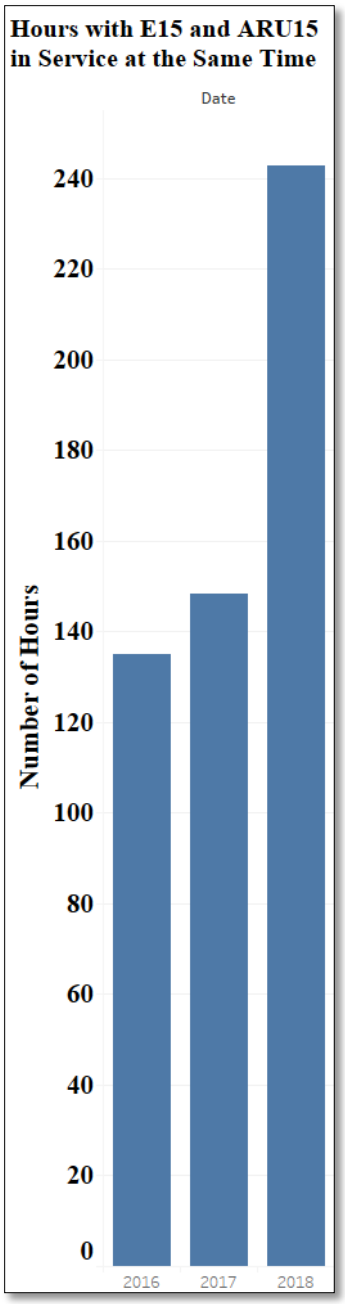


Figure 9: Hours with Engine 15 and ARU 15 in Service at the Same Time. Figure 9 shows the number of hours where both Engine 15 and ARU 15 were in service at the same time January 1, 2016 – October 31, 2018. There is a marked increase in instances in which both units are in service at the same time, particularly accounting for the fact that only 10 months of data are shown for 2018 as compared to the 12 months shown for 2016 and 2017. If ARU 15 is taken out of service, then apparatus from other stations will likely need to respond to incidents when Engine 15 is already engaged. This situation will increase travel time and leave other first-due districts without coverage because their apparatus may be responding to another area.

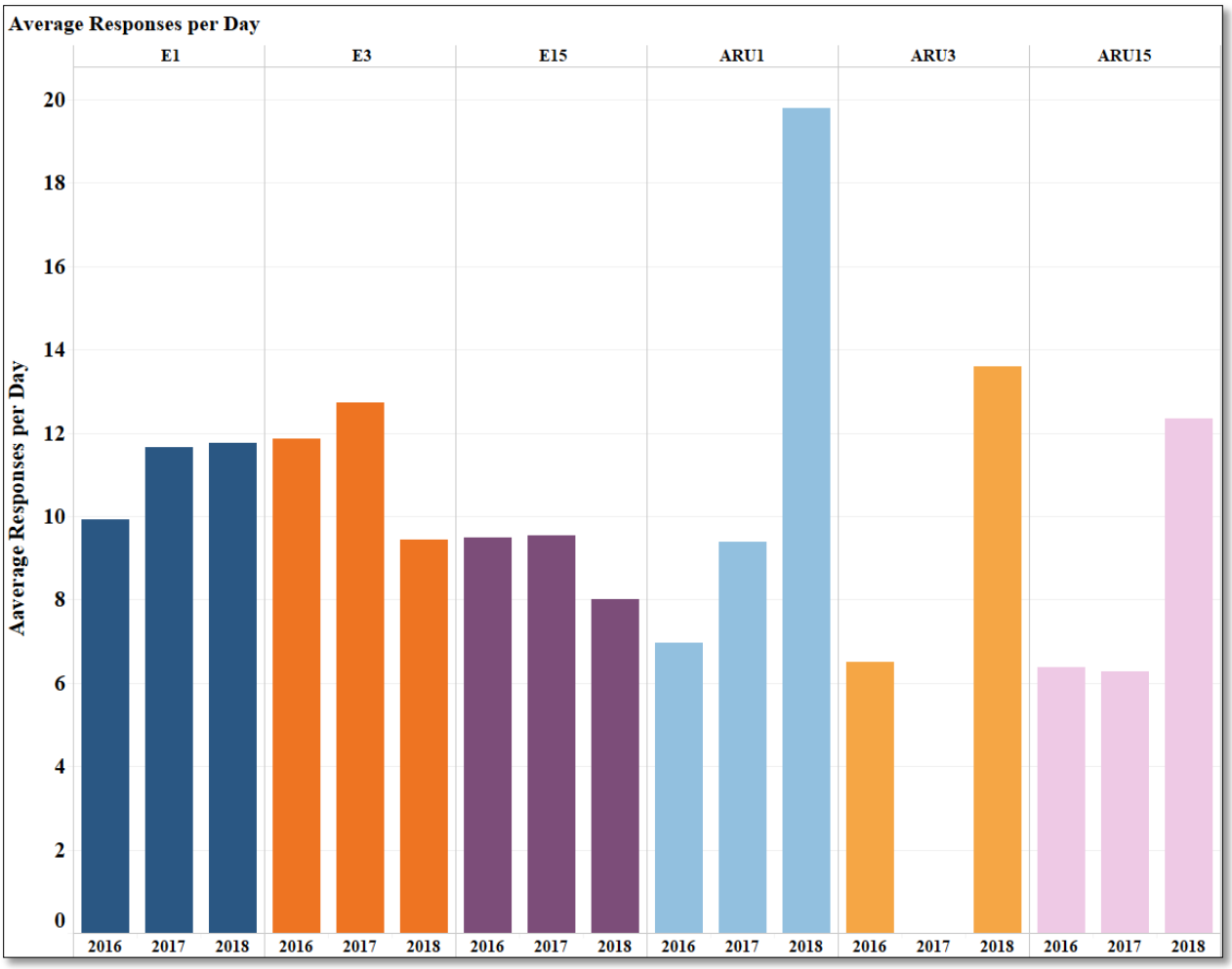


Figure 10: Average Responses per Day. Figure 10 shows the average number of responses Spokane's engines and ARUs made per day January 1, 2016 – October 31, 2018. Data on ARU 3 responses in 2017 was not available. Engines made between 9.44 and 12.73 responses per day. ARUs made between 6.27 and19.8 responses per day. If the ARUs are taken out of service, the engines that are deploying from the same stations will likely see an increase in responses. As the engine responses increase, their back-to-back responses will also likely increase, as seen in the following figures.

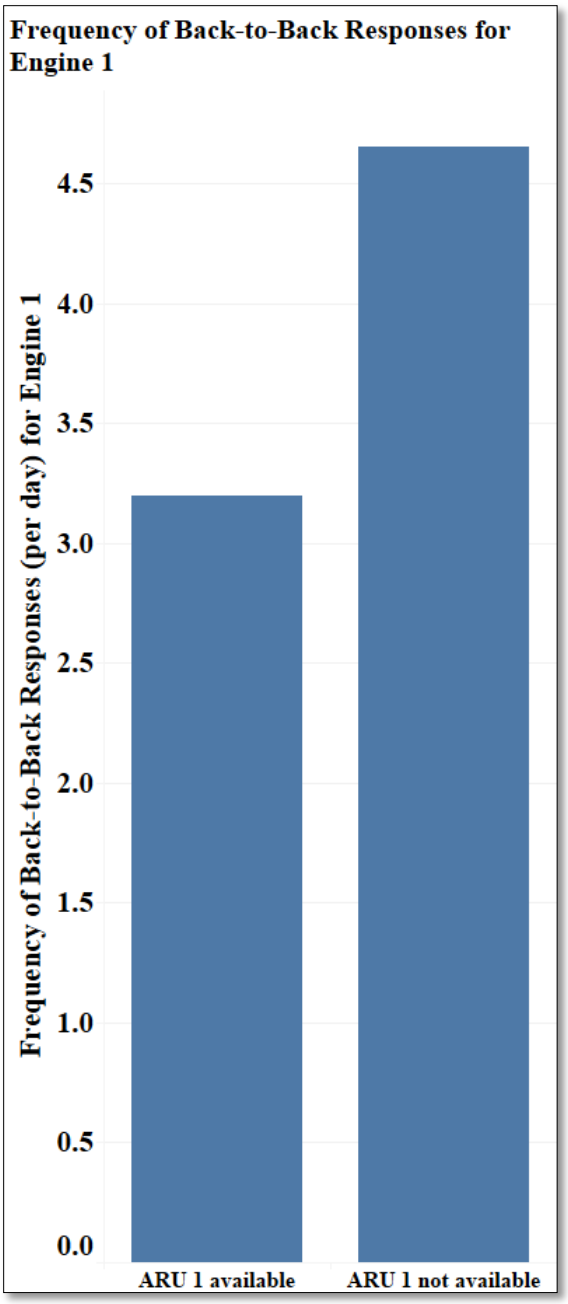


Figure 11: Frequency of Back-to-Back Responses for Engine 1. Figure 11 shows the rate of back-to-back responses for Engine 1 when ARU 1 is available as opposed to when ARU 1 is not available January 1, 2016 – October 31, 2018. When the ARU is available, Engine 1 makes significantly fewer back-to-back responses. This result shows that if ARU 1 is taken out of service Engine 1 will likely make more back-to-back responses. Not only will Engine 1 likely make more back-to-back responses, but it will also likely make more total responses. With increases in responses and back-to-back responses, other apparatus from other stations are also likely to be engaged more often, thus reducing the department's capacity for response.

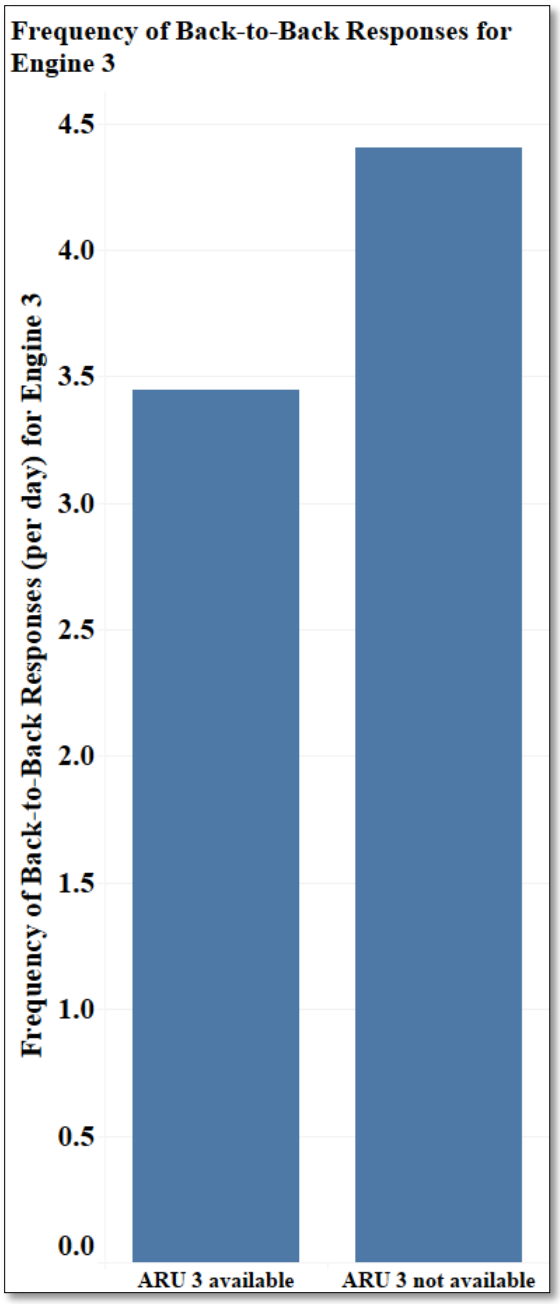


Figure 12: Frequency of Back-to-Back Responses for Engine 3. Figure 12 shows the rate of back-to-back responses for Engine 3 when ARU 3 is available as opposed to when it is not available January 1, 2016 – October 31, 2018. When the ARU is available, Engine 3 makes significantly fewer back-to-back responses. This result shows that if ARU 3 is taken out of service Engine 3 will likely make more back-to-back responses. Not only will Engine 3 likely make more back-to-back responses, but it will also likely make more total responses. With increases in responses and back-to-back responses, other apparatus from other stations are also likely to be engaged more often, thus reducing the department's capacity for response.

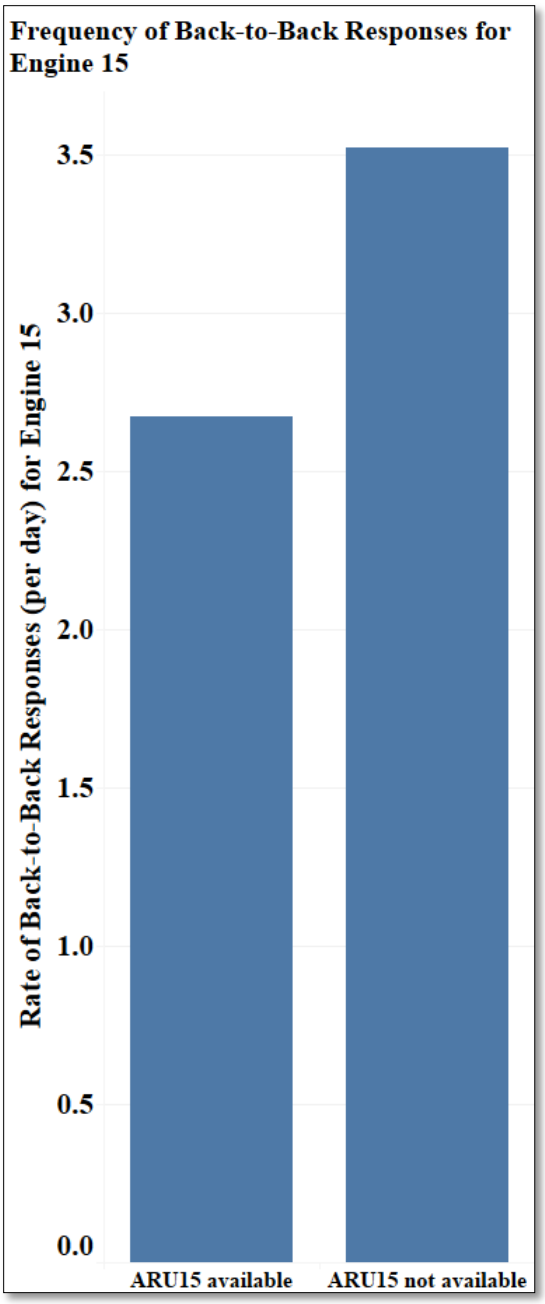


Figure 13: Frequency of Back-to-Back Responses for Engine 15. Figure 13 shows the rate of back-to-back responses for Engine 15 when ARU 15 is available as opposed to when it is not available January 1, 2016 – October 31, 2018. When the ARU is available, Engine 15 makes significantly fewer back-to-back responses. This result shows that if ARU 15 is taken out of service Engine 15 will likely make more back-to-back responses. Not only will Engine 15 likely make more back-to-back responses, but it will also likely make more total responses. With increases in responses and back-to-back responses, other apparatus from other stations are also likely to be engaged more often, thus reducing the department's capacity for response.

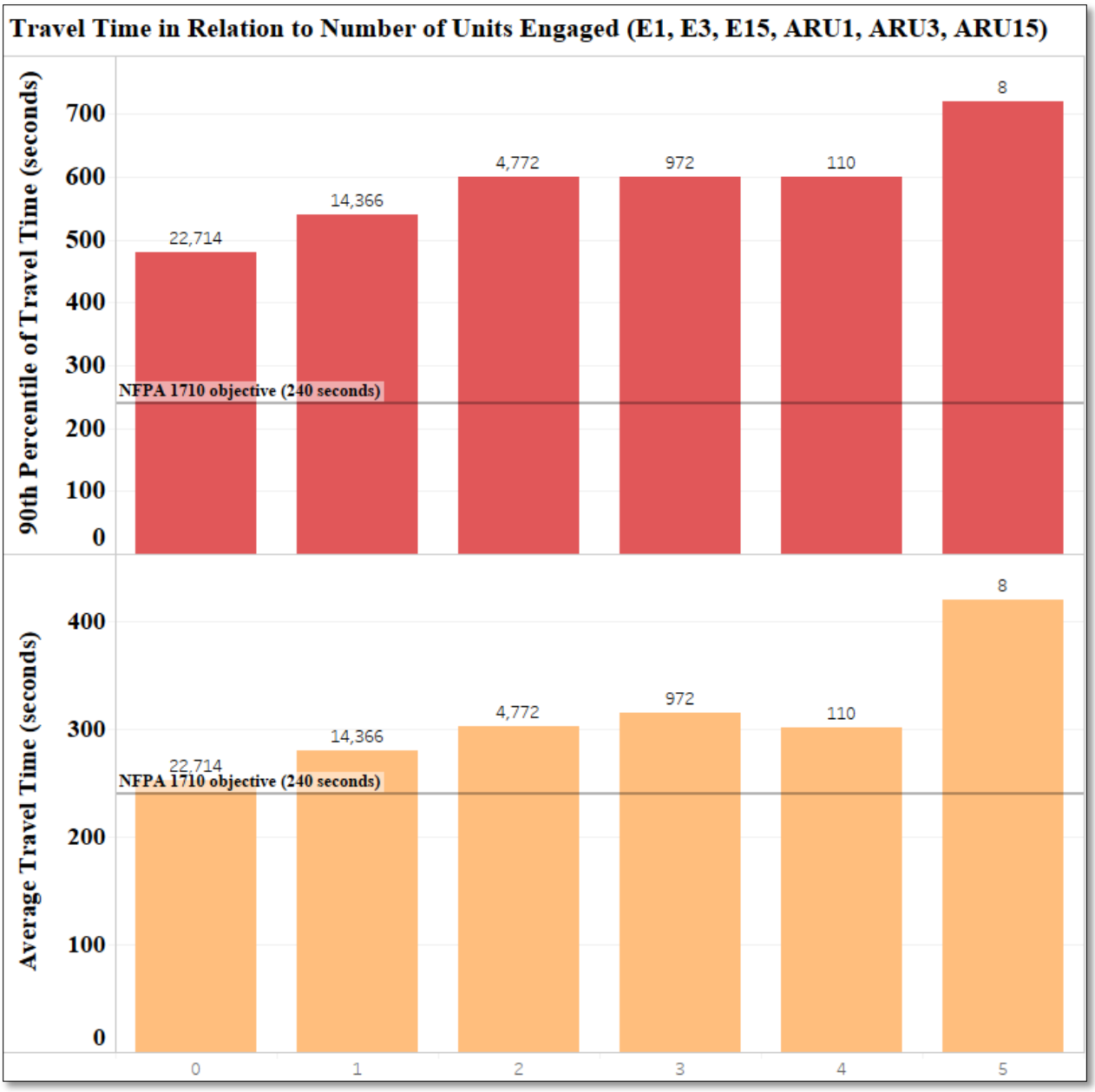


Figure 14: Travel Time in Relation to Number of Units Engaged (Engine 1, Engine 3, Engine 15, ARU 1, ARU 3, ARU 15). Figure 14 shows the 90th percentile and average travel times for apparatus when a varying number of units are deployed. The number on top of the bars is the number of records for each case. In all cases, travel time is longer than the NFPA 1710 objective of 240 seconds. When no units are engaged, the 90th percentile travel time is 480 seconds and the average travel time is 251.9 seconds. When 1 unit is engaged, the 90th percentile travel time increases from to 540 seconds and the average travel time increases to 279.8 seconds. Increases in travel time also occur when two, three, and four units are engaged. When five units are engaged, the 90th percentile and average travel times increase to 720 seconds and 420 seconds, respectively. If the ARUs are taken out of service, meeting travel time objectives will be increasingly difficult, and travel times are likely to further increase given the likely increase in responses made by the engines and the likely increase in the number of back-to-back responses.

Mapping Analysis of the Spokane Fire Department

In creating this document, it was important to ascertain where stations were located and if they were located to provide fair and equitable coverage to the citizens. In order to make this assessment, the IAFF created maps of the department's response area and plotted the fire stations. Computer modeling was then used to determine the distance apparatus could travel in four, and eight, and ten minutes and ten seconds.

Travel times were modeled using ESRI ArcGIS version 10.5.1. Fire stations were identified on Geographic Information System (GIS) maps as starting points with apparatus traveling at posted road speeds.

Prior to drawing conclusions from the mapping analysis, the following points should be taken into consideration:

- Modeled travel speeds are based on reasonable and prudent historical traffic speeds occurring on Wednesdays at 5:00 PM.[74] Actual response speeds may be slower, and the associated travel times greater, with any unpredictable impedances including, but not limited to:
    - Traffic Incidents: Collisions and vehicle breakdowns causing lane blockages and driver distractions.
    - Work Zones: Construction and maintenance activity that can cause added travel time in locations and times where congestion is not normally present.
    - Weather: Reduced visibility--road surface problems and uncertain waiting conditions result in extra travel time and altered trip patterns.
    - Special Events: Demand may change due to identifiable and predictable causes.
    - Traffic Control Devices: Poorly timed or inoperable traffic signals, railroad grade crossings, speed control systems, and traveler information signs contribute to irregularities in travel time.
    - Inadequate Road or Transit Capacity: The interaction of capacity problems with the aforementioned sources causes travel time to expand much faster than demand.[75]

[74] Historical traffic data as contained in ESRI's StreetMap Premium, Version 17.2.
[75] David Shrank and Tim Lomax, The 2003 Urban Mobility Report, (Illinois Transportation Institute, Illinois A&M University: September 2003).

- Larger emergency vehicles are generally more cumbersome and require greater skill to maneuver. Therefore, response by these vehicles may be more negatively affected by weight, size, and in some cases, inability to travel narrow surface streets.

- Computer modeling only considers travel time of apparatus. Decision makers should understand that once apparatus and personnel arrive on the incident scene there are other essential tasks that must be completed which require additional time before access, rescue, and suppression can take place. Tasks such as establishing a water supply, forcible entry (access), and deployment of an attack line are not considered in the computer modeling.

- The reliability of a community's hydrant system to supply water to fire apparatus.

- Weather conditions

Emergency Response Capabilities – Current Station Locations and Staffing

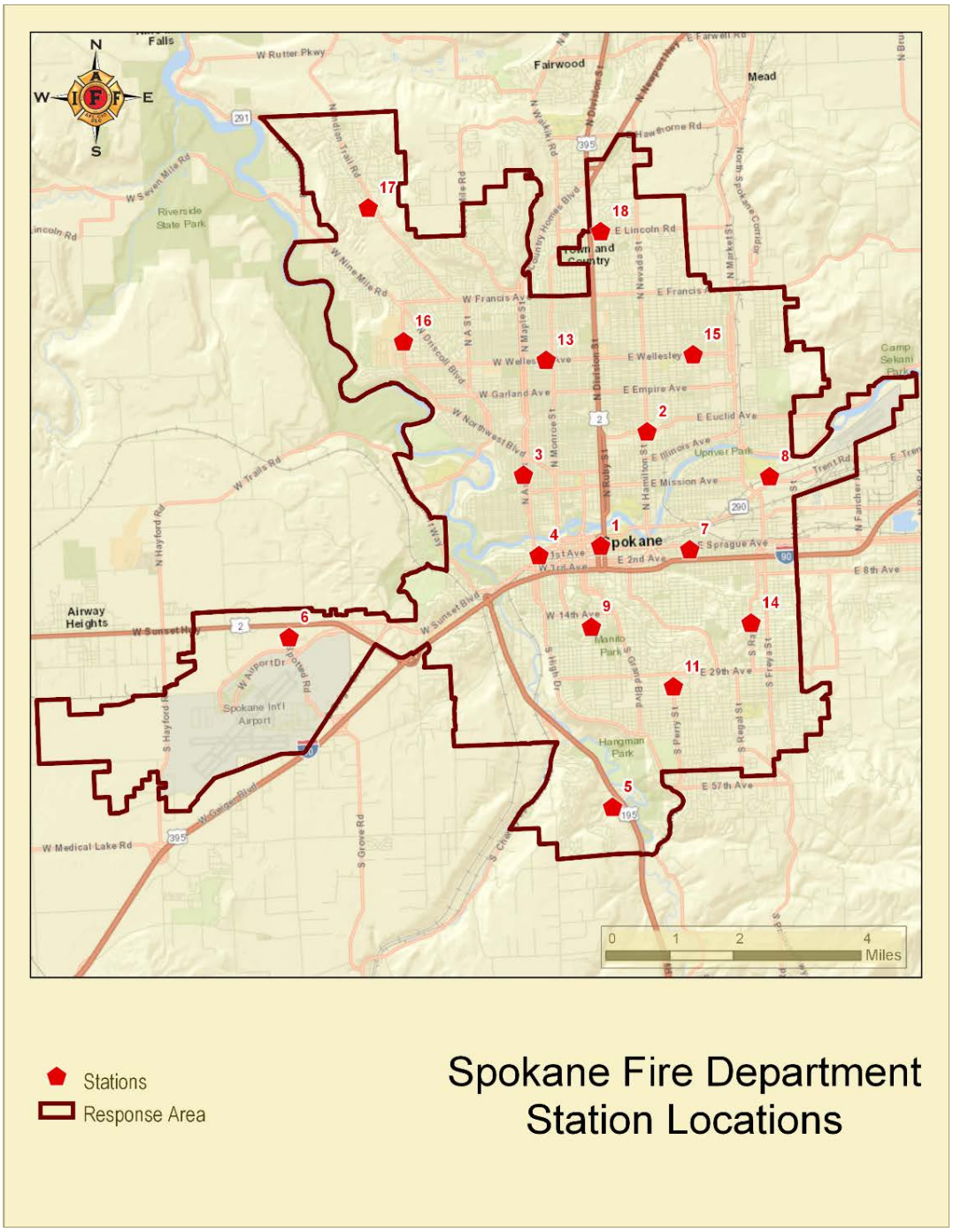
For this portion of the study, fire department capabilities were examined when deploying from current station locations and staffed at current levels.

Station	Address	Apparatus	Min. Staffing
Station 1	44 W Riverside Ave.	Ladder 1 Engine 1 ARU 1 S20 Haz Mat 1	**4 FF** **3 FF** **2 FF** **1 Battalion Chief** **Special Request**
Station 2	1001 E North Foothills Dr.	Tower 2 Engine 2 Water 2	**4 FF** **3 FF** **Special Request**
Station 3	1713 W Indiana Ave.	Engine 3 ARU 3	**3 FF** **2 FF**
Station 4	1515 W 1st Ave	Ladder 4 Engine 4 Rescue 4 USAR 4	**4 FF** **3 FF** **Special Request** **Special Request**
Station 5	115 W Eagle Ridge Blvd.	Attack 5	**3 FF**
Station 6	1615 S Spotted Rd.	Engine 6 Brush 6	**3 FF** **Special Request**
Station 7	1901 E 1st Ave.	Engine 7 Decon 7 Brush 7	**3 FF** **Special Request** **Special Request**
Station 8	1608 N Rebecca St.	Engine 8 S30 Support Unit 8	**3 FF** **1 Safety Officer** **Special Request**
Station 9	1722 S Bernard St.	Engine 9 Haz Mat 9	**3 FF** **Special Request**
Station 11	3214 S Perry St.	Quint 11 Brush 11	**4 FF** **Special Request**

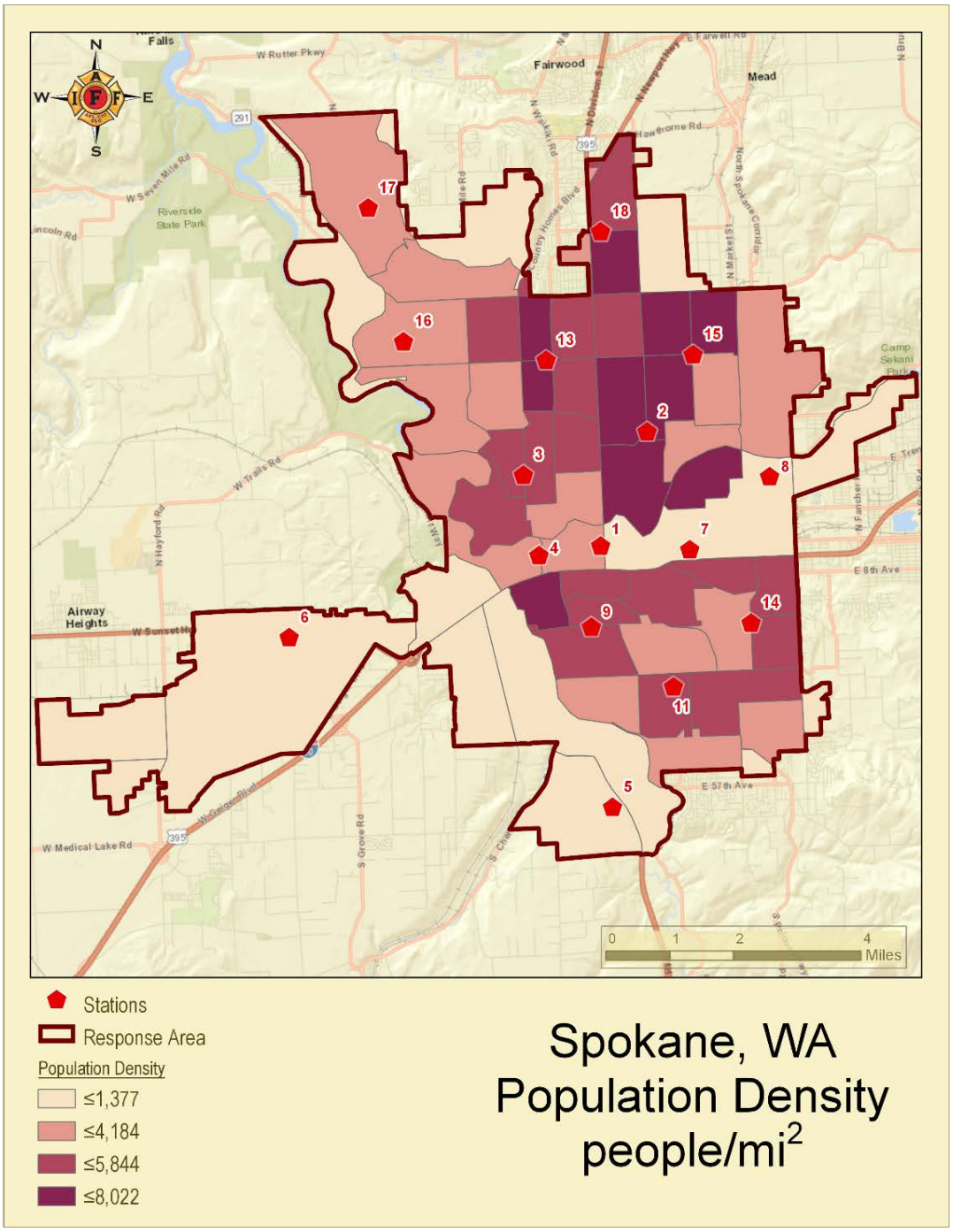
Table 6: Current Fire Station Location and Staffing. The above table displays where apparatus are housed and the typical on-duty staffing. The minimum daily staffing level is 71 firefighters including 2 battalion chiefs, and 1 safety officer.

Station (Continued)	Address (Continued)	Apparatus (Continued)	Min. Staffing (Continued)
Station 13	1118 W Wellesley Ave.	Quint 13 S21	**4 FF** **1 Battalion Chief**
Station 14	1807 S Ray St.	Engine 14 Brush 14	**3 FF** **Special Request**
Station 15	2120 E Wellesley Ave.	Engine 15 ARU 15 Brush 15	**3 FF** **2 FF** **Special Request**
Station 16	5225 N Assembly St.	Engine 16 Water 16 Brush 16	**3 FF** **Special Request** **Special Request**
Station 17	5121 W Lowell Ave.	Engine 17 Brush 17	**3 FF** **Special Request**
Station 18	120 E Lincoln Rd.	Engine 18	**3 FF**

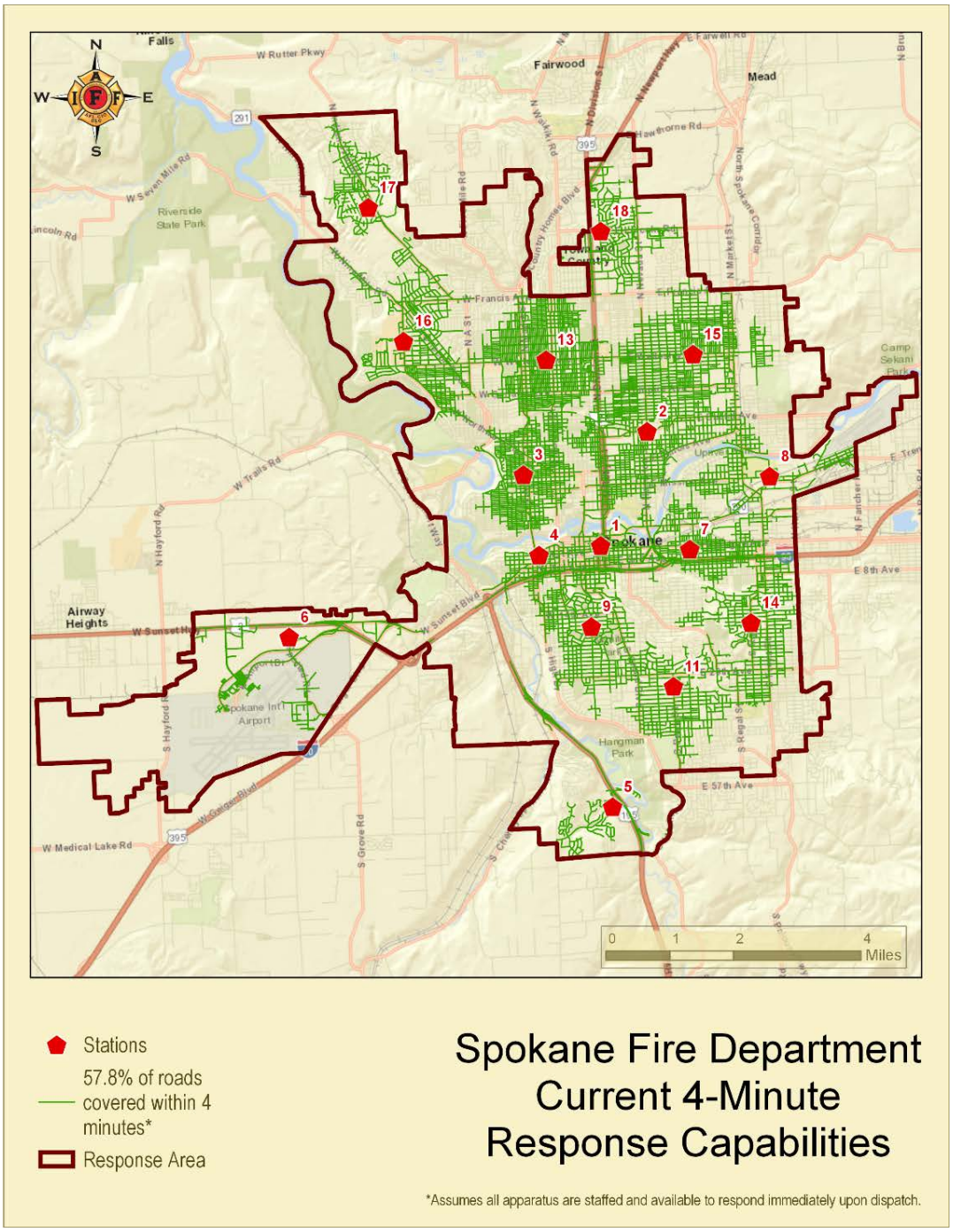
Table 6 (Continued): Current Fire Station Location and Staffing. The above table displays where apparatus are housed and the typical on-duty staffing. The minimum daily staffing level is 71 firefighters including 2 battalion chiefs, and 1 safety officer.



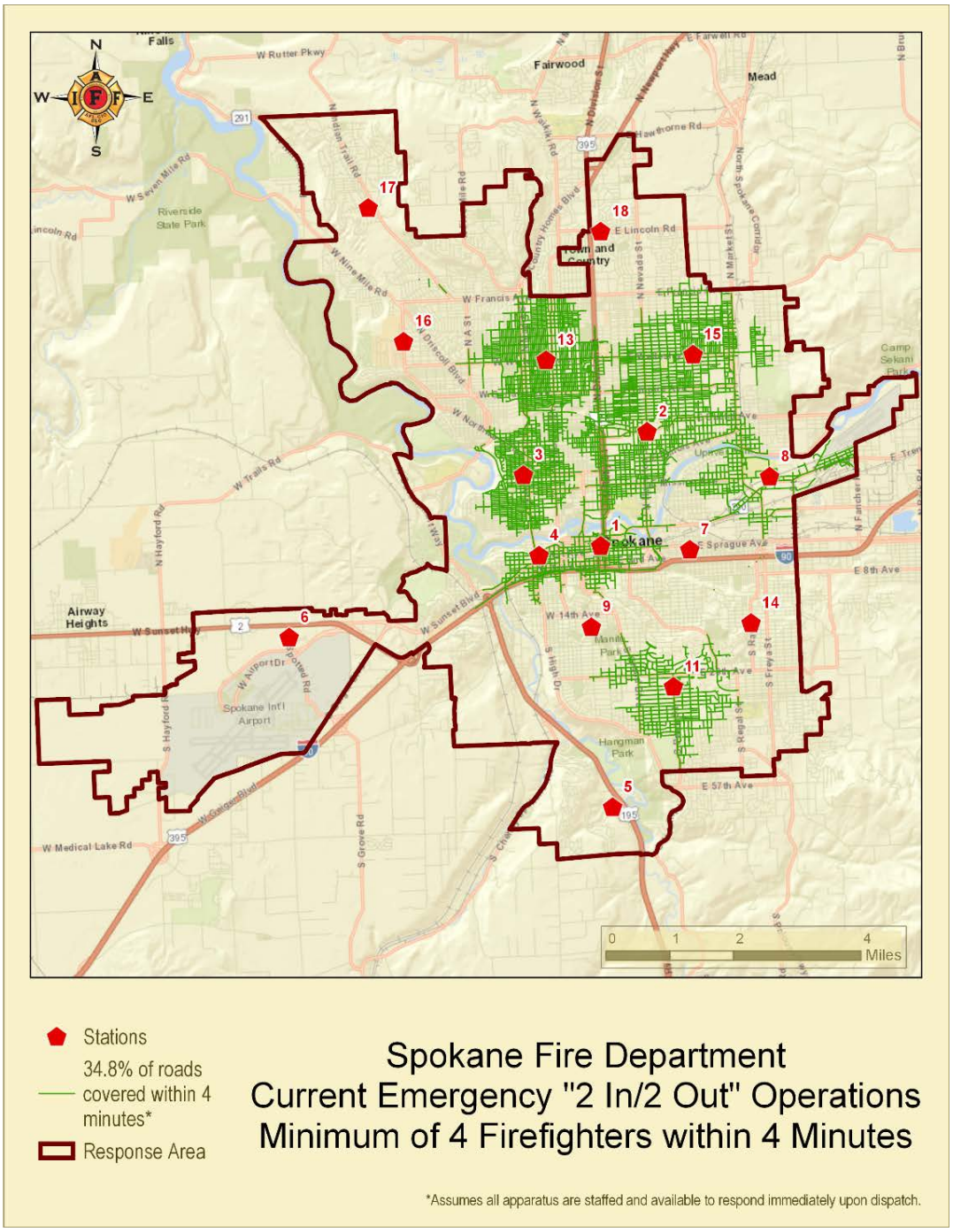
Map 1: Station Locations. Map 1 depicts the Spokane Fire Department's response boundary and current fire station locations.



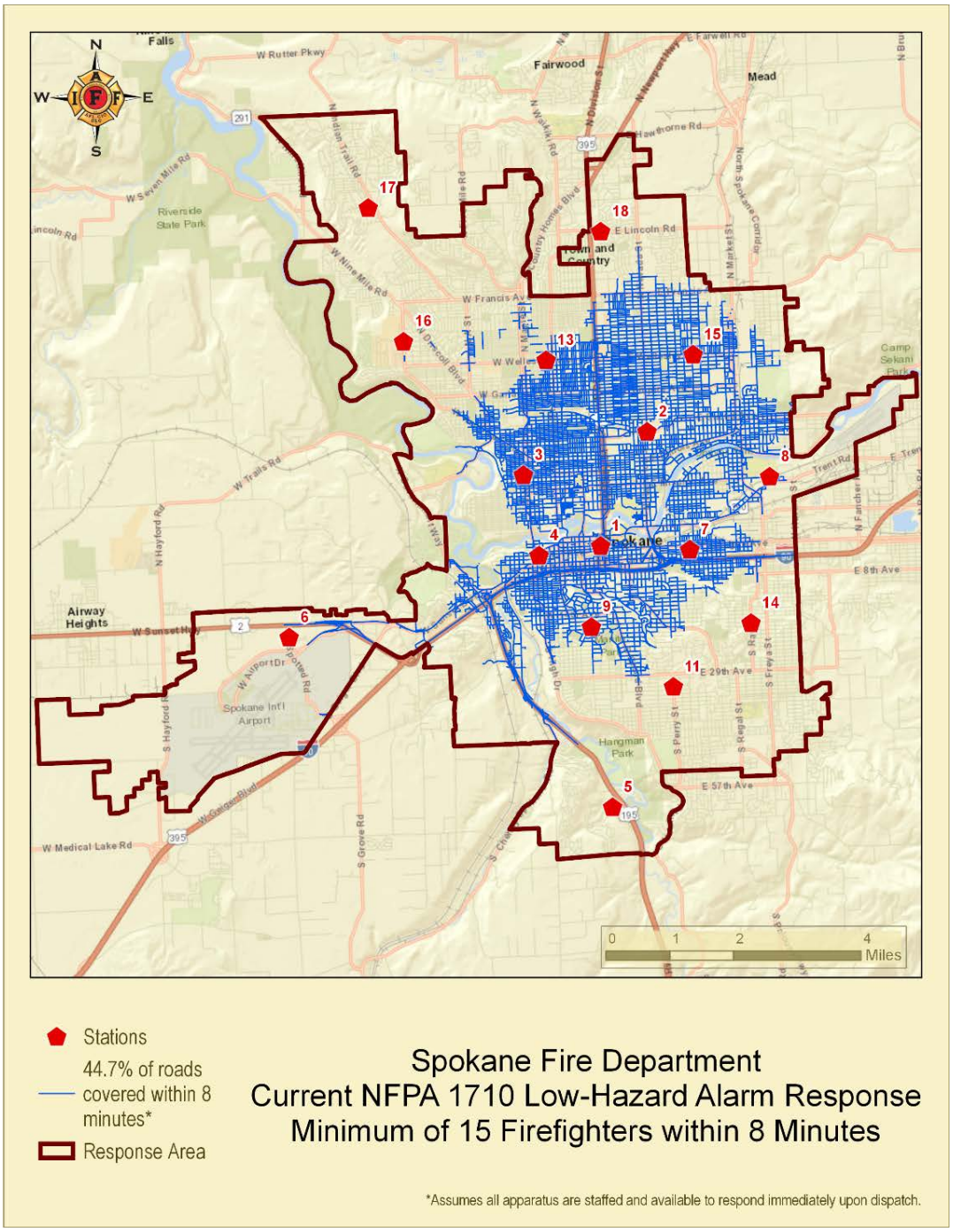
Map 2: Population Density, people/mi^2. Map 2 shows the 2016 Spokane, WA population density in people per square mile.



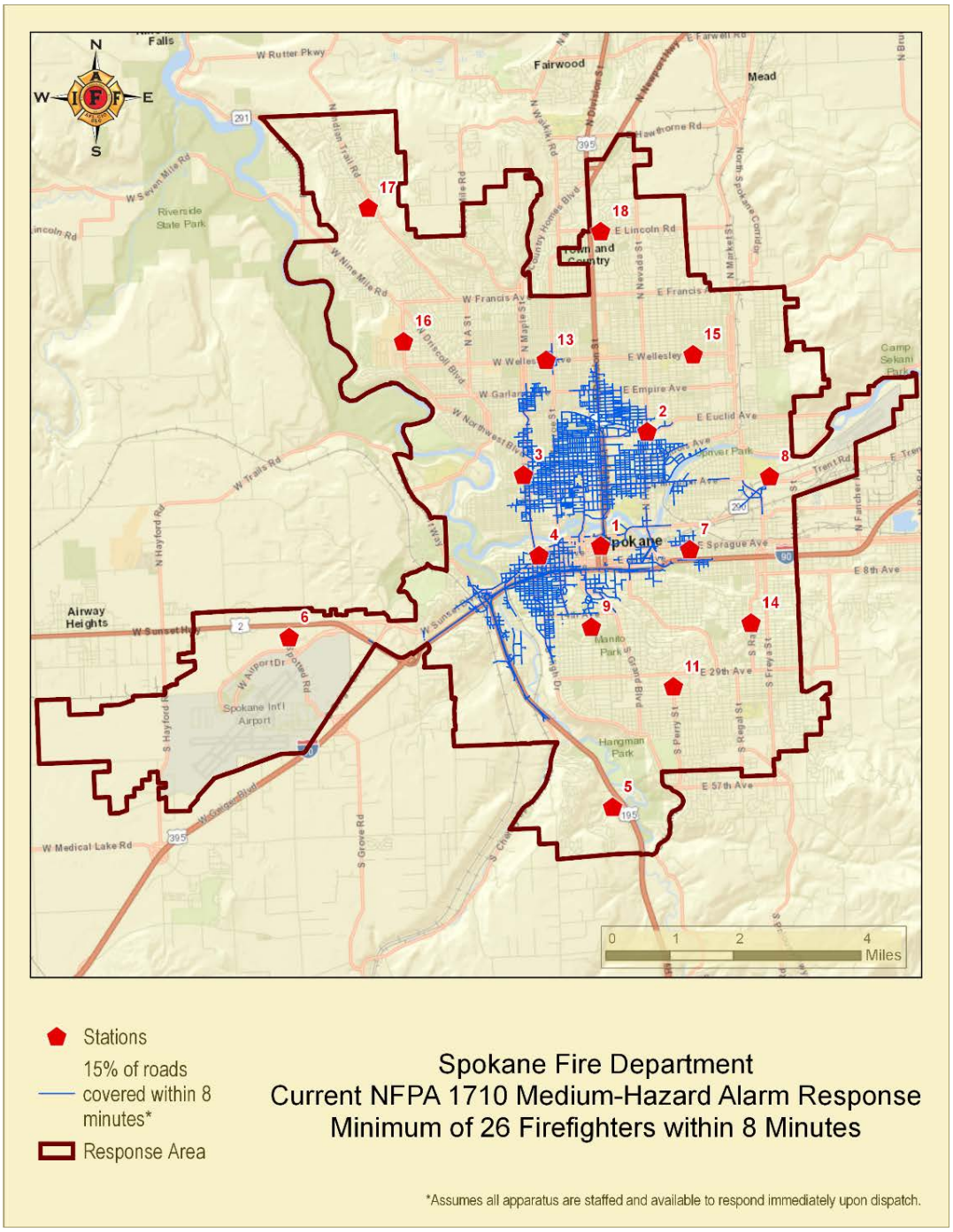
Map 3: Current 4-Minute Response Capabilities. Map 3 identifies those roads that can be reached within four minutes of travel. Currently, the Spokane Fire Department can respond with on 57.8% of roads within the response area within four minutes.



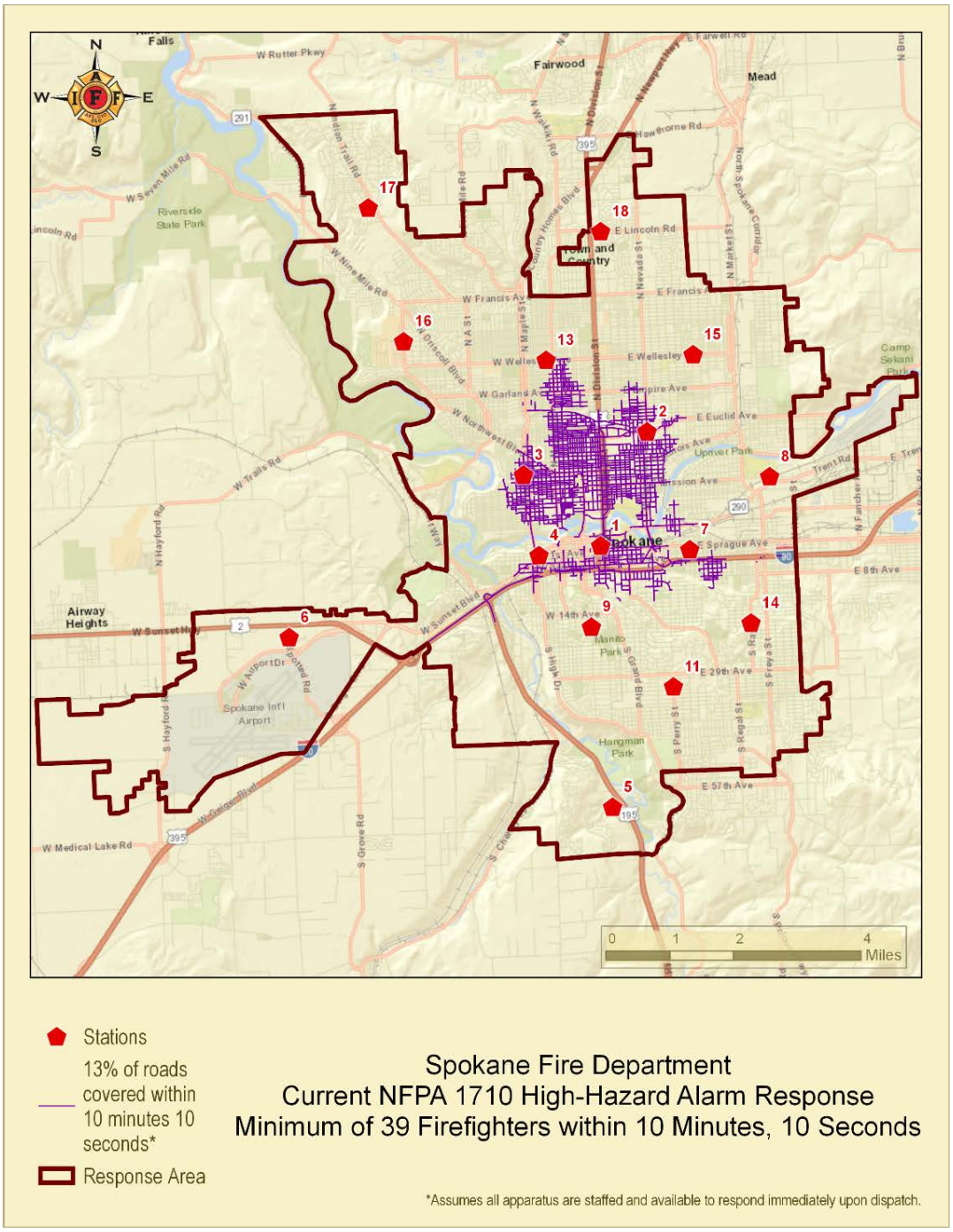
Map 4: Current Emergency "2 In/2 Out" Operations, Minimum of 4 Firefighters within 4 Minutes. Map 4 identifies those roads in the response area that can be reached within four minutes from the current fire stations and where a minimum of four firefighters are able to assemble on scene within four minutes of travel. The Spokane Fire Department is only capable of arriving on scene on 34.8% of roads within Spokane with four firefighters within four minutes.



Map 5: Current NFPA 1710 Low-Hazard Alarm Response, Minimum of 15 Firefighters within 8 Minutes. Map 5 identifies those roads where a minimum of 15 firefighters are able to assemble on scene within 8 minutes of travel. Currently, the Spokane Fire Department is capable of assembling a minimum of 15 firefighters on 44.7% of roads within the response area within eight minutes.



Map 6: Current NFPA 1710 Medium-Hazard Alarm Response, Minimum of 26 Firefighters within 8 Minutes. Map 6 identifies those roads where a minimum of 26 firefighters are able to assemble on scene within 8 minutes of travel. Currently, the Spokane Fire Department is capable of assembling a minimum of 26 firefighters on 15% of roads within the response area within eight minutes.



Map 7: Current NFPA 1710 High-Hazard Alarm Response, Minimum of 39 Firefighters within 10 Minutes, 10 Seconds. Map 7 identifies those roads where a minimum of 39 firefighters are able to assemble on scene within 10 minutes, 10 seconds of travel. Currently, the Spokane Fire Department is capable of assembling a minimum of 39 firefighters on 13% of roads within the response area within 10 minutes and 10 seconds.

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Emergency Response Capabilities – Proposed Staffing

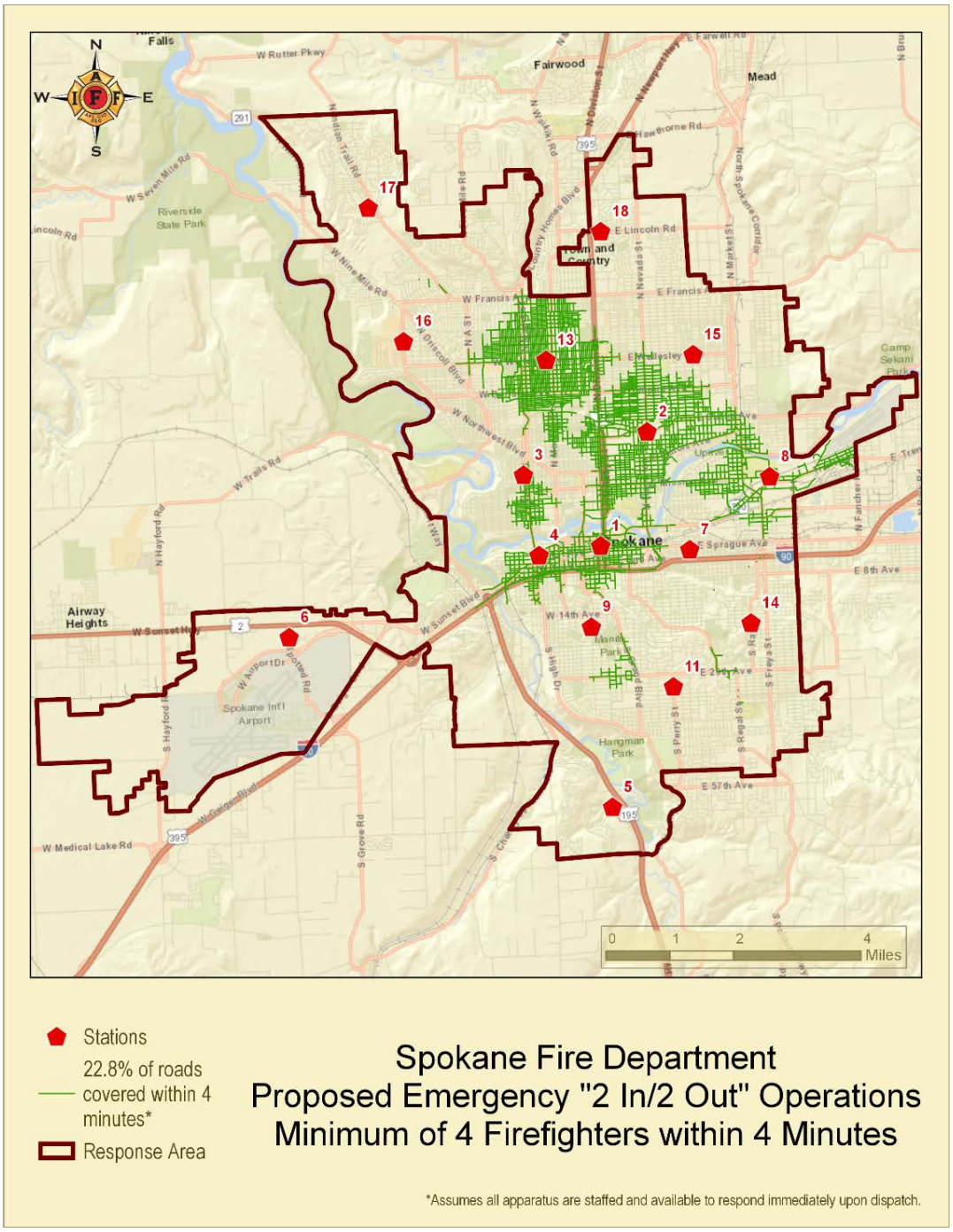
For this portion of the study, fire department capabilities were examined according to the city's plan for reductions in staffing and apparatus, as detailed in Table 7, below. The maps presented in this section display the results of a four-, eight-, and 10-minute, 10-second travel time analysis representing potential response capabilities of the department which would likely result if the proposed reductions are implemented.

Station	Address	Apparatus	Min. Staffing
Station 1	44 W Riverside Ave.	Ladder 1 Engine 1 ~~ARU 1~~ S20 Haz Mat 1	**4 FF** **3 FF** **Out of Service** **1 Battalion Chief** **Special Request**
Station 2	1001 E North Foothills Dr.	Tower 2 Engine 2 Water 2	**4 FF** **3 FF** **Special Request**
Station 3	1713 W Indiana Ave.	Engine 3 ~~ARU 3~~	**3 FF** **Out of Service**
Station 4	1515 W 1st Ave	Ladder 4 Engine 4 Rescue 4 USAR 4	**4 FF** **3 FF** **Special Request** **Special Request**
Station 5	115 W Eagle Ridge Blvd.	Attack 5	**3 FF**
Station 6	1615 S Spotted Rd.	Engine 6 Brush 6	**3 FF** **Special Request**
Station 7	1901 E 1st Ave.	Engine 7 Decon 7 Brush 7	**3 FF** **Special Request** **Special Request**
Station 8	1608 N Rebecca St.	Engine 8 ~~S30~~ Support Unit 8	**3 FF** **No Safety Officer** **Special Request**
Station 9	1722 S Bernard St.	Engine 9 Haz Mat 9	**3 FF** **Special Request**
Station 11	3214 S Perry St.	Quint 11 Brush 11	**3 FF** **Special Request**

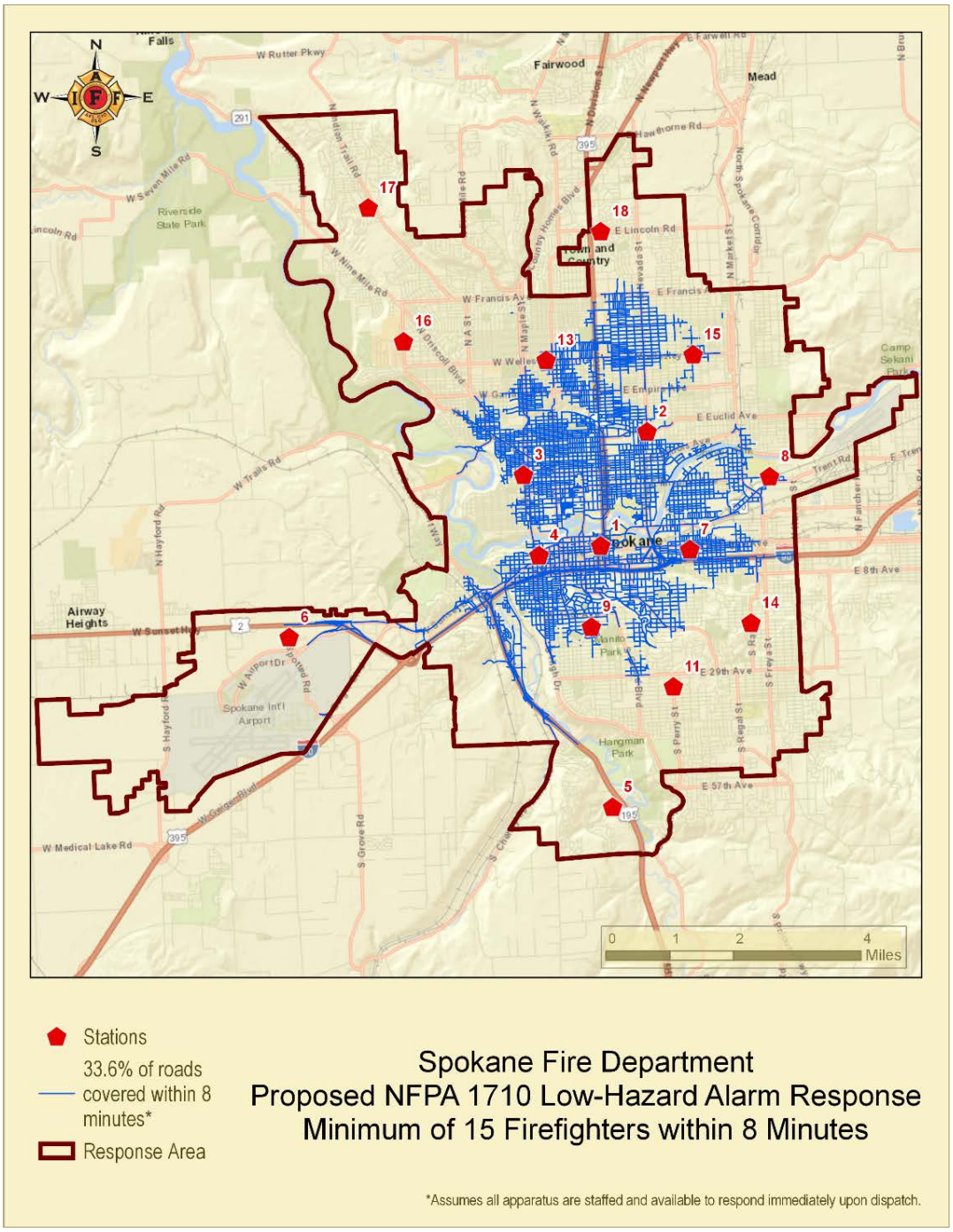
Table 7: Proposed Staffing and Deployment. The above table displays where apparatus will be housed and how they would be staffed. This table shows the proposed minimum on-duty staffing for Spokane if the reductions are implemented. Minimum daily staffing would be reduced to 62 firefighters including 2 Battalion Chiefs. Each of the two quints would lose one firefighter, the three ARUs would be removed from service, and the safety officer would be eliminated.

Station (Continued)	Address (Continued)	Apparatus (Continued)	Min. Staffing (Continued)
Station 13	1118 W Wellesley Ave.	Quint 13 S21	**3 FF** **1 Battalion Chief**
Station 14	1807 S Ray St.	Engine 14 Brush 14	**3 FF** **Special Request**
Station 15	2120 E Wellesley Ave.	Engine 15 ~~ARU 15~~ Brush 15	**3 FF** **Out of Service** **Special Request**
Station 16	5225 N Assembly St.	Engine 16 Water 16 Brush 16	**3 FF** **Special Request** **Special Request**
Station 17	5121 W Lowell Ave.	Engine 17 Brush 17	**3 FF** **Special Request**
Station 18	120 E Lincoln Rd.	Engine 18	**3 FF**

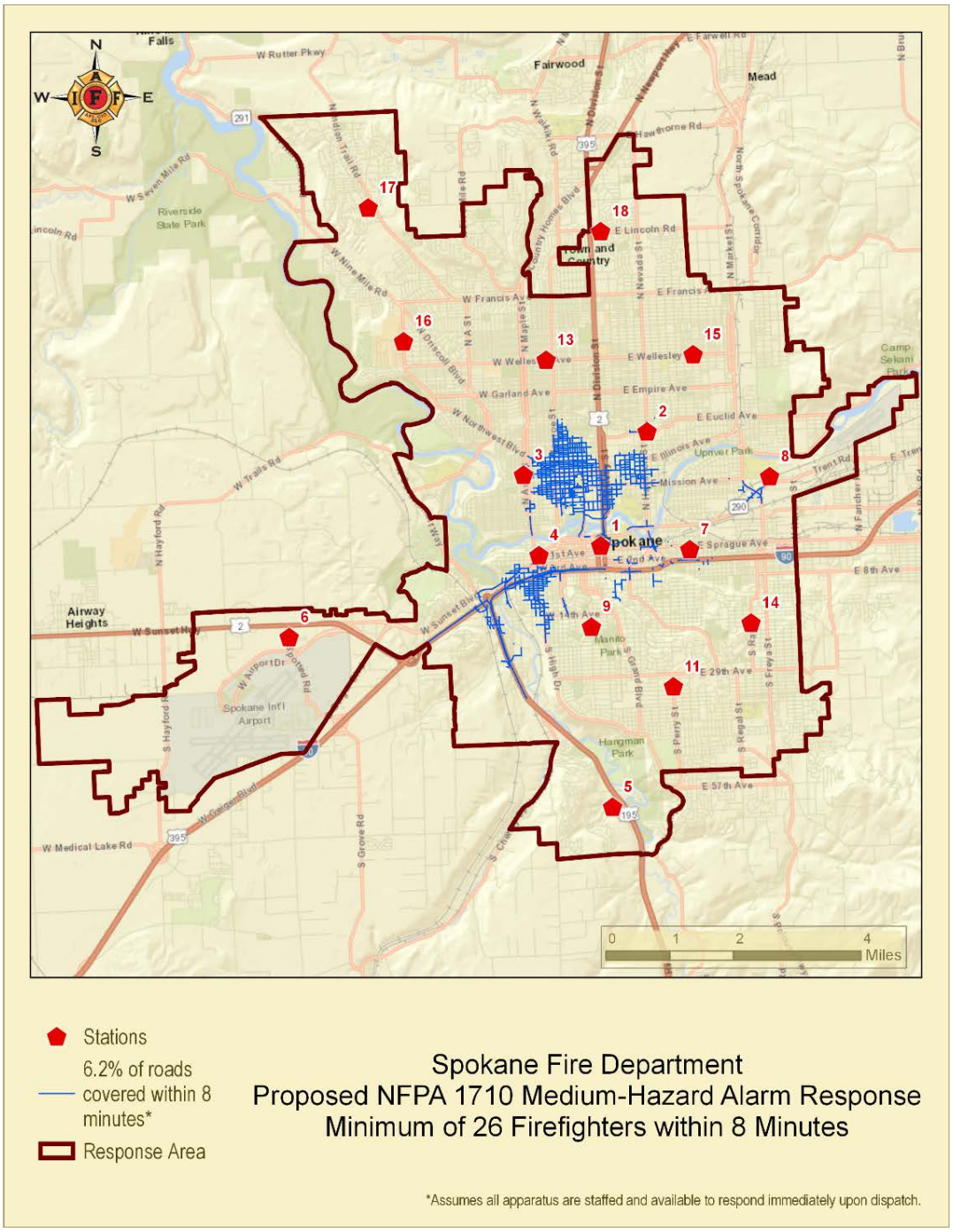
Table 7 (Continued): Proposed Staffing and Deployment. The above table displays where apparatus will be housed and how they would be staffed. This table shows the proposed minimum on-duty staffing for Spokane if the reductions are implemented. Minimum daily staffing would be reduced to 62 firefighters including 2 Battalion Chiefs. Each of the two quints would lose one firefighter, the three ARUs would be removed from service, and the safety officer would be eliminated.



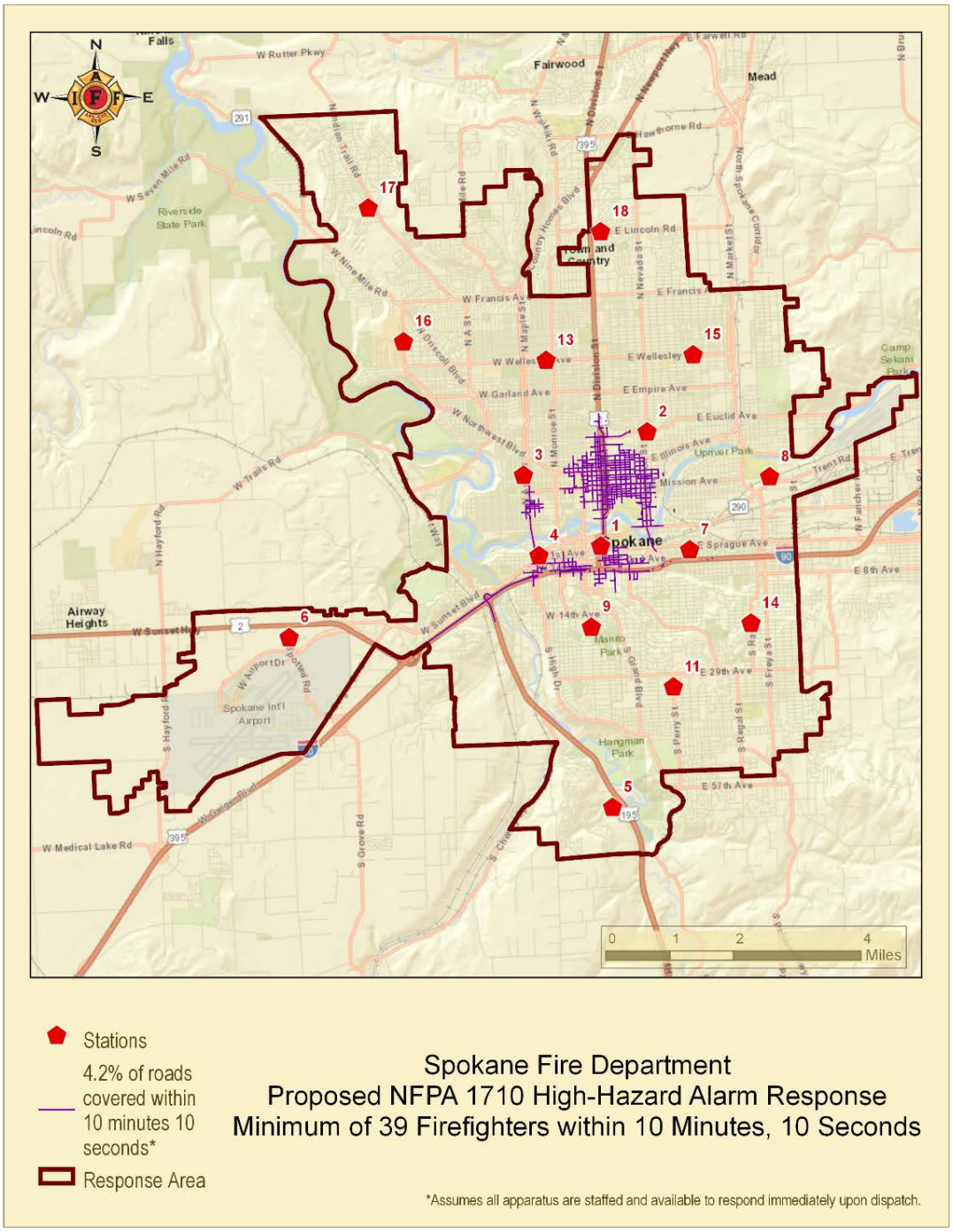
Map 8: Proposed Emergency "2 In/2 Out" Operations, Minimum of 4 Firefighters within 4 Minutes. Map 8 identifies those roads in the response area that would likely be reached within four minutes and where a minimum of four firefighters would likely be able to assemble on scene within four minutes of travel under the proposed staffing and deployment plan. The Spokane Fire Department will only likely be capable of arriving on scene on 22.8% of roads within Spokane with four firefighters within four minutes, a *34.3% decrease* below current capabilities.



Map 9: Proposed NFPA 1710 Low-Hazard Alarm Response, Minimum of 15 Firefighters within 8 Minutes. Map 9 identifies those roads where a minimum of 15 firefighters would likely be able to assemble on scene within 8 minutes of travel. Under the proposed staffing and deployment plan, the Spokane Fire Department would likely be capable of assembling a minimum of 15 firefighters on 33.6% of roads within the response area within eight minutes, a *24.9% decrease* below current capabilities.



Map 10: Proposed NFPA 1710 Medium-Hazard Alarm Response, Minimum of 26 Firefighters within 8 Minutes. Map 10 identifies those roads where a minimum of 26 firefighters would likely be able to assemble on scene within 8 minutes of travel. Under the proposed staffing and deployment plan, the Spokane Fire Department would likely be capable of assembling a minimum of 26 firefighters on 6.2% of roads within the response area within eight minutes, a *58.4% decrease* below current capabilities.



Map 11: Proposed NFPA 1710 High-Hazard Alarm Response, Minimum of 39 Firefighters within 10 Minutes, 10 Seconds. Map 11 identifies those roads where a minimum of 39 firefighters would likely be able to assemble on scene within 10 minutes, 10 seconds of travel. Under the proposed staffing and deployment plan, the Spokane Fire Department would likely be capable of assembling a minimum of 39 firefighters on 4.2% of roads within the response area within 10 minutes and 10 seconds, a *67.2% decrease* below current capabilities.

Conclusion

In conclusion, Spokane's fire suppression companies are not currently staffed to meet the objectives of industry standards for safe, efficient, and effective response to fires or rescue situations. The department staffs all engines with less than four firefighters, which is the minimum number required for effective and efficient fireground operations. Should the city remove the ARUs from service, discontinue the Safety Officer position, and reduce quint staffing to three firefighters per quint, the department will be even further from meeting the objectives contained in industry standards. The department should maintain quint and Safety Officer staffing and keep the ARUs in service to continue to provide the level of service that Spokane has received since being awarded the SAFER grant.

Currently, only 34.8% of Spokane's roads can be served by a minimum of four firefighters assembling on the scene of a fire within four minutes, assuming all units are available to respond immediately upon dispatch. However, as apparatus become engaged in response, this statistic would likely be significantly reduced. With the reduction of staff as proposed, this figure would be reduced by 34.4% to 22.8%. Additionally, by implementing these staffing decreases, 15 firefighters would likely only be able to assemble on 33.6% of roads within 8 minutes, a 24.9% decrease; 26 firefighters would likely only be able to reach 6.2% of roads within 8 minutes, a 58.4% decrease in capabilities; and 39 firefighters would likely only be able to assemble on 4.2% of roads within 10 minutes and 10 seconds, a 67.2% decrease below current capabilities. By reducing staff and removing ARU units from service, Spokane would be endangering their citizens and firefighters by reducing coverage, increasing response times, and increasing the number of back-to-back responses.

Deficiencies in staffing and apparatus utilization contribute to delays in fire suppression, rescue, and response. The city and department should remedy current deficiencies, as it is essential that departmental resources are able to meet demand. The department's current insufficiencies indicate the need to maintain current resources. As resources become scarce as demand increases, performance will worsen. This increases the risk of death or injury due to fire for both citizens and firefighters of Spokane. It also increases the risk of considerable property loss for housing units and businesses in many areas of the city.

While it is impossible to predict where most of a jurisdiction's fire and medical emergencies will occur, the Spokane Fire Department should examine where emergencies have typically occurred in the past and make efforts to ensure all areas of the city continue to receive appropriate levels of coverage, while adjusting resources and deployment as needed in an effort to meet requirements contained in industry standards. Areas with accelerated development and population growth will require additional coverage in the future. Any projected increase in

emergency response demands should also be considered before changes are implemented, focusing on associated hazard types and planned response assignments.

As explained by the Commission on Fire Accreditation International, Inc. in its Creating and Evaluating Standards of Response Coverage for Fire Departments manual, "If resources arrive too late or are understaffed, the emergency will continue to escalate…What fire companies must do, if they are to save lives and limit property damage, is arrive within a short period of time with adequate resources to do the job. To control the fire before it reaches its maximum intensity requires geographic dispersion (distribution) of technical expertise and cost-effective clustering (concentration) of apparatus for maximum effectiveness against the greatest number and types of risks." Optimally, there needs to be a balance between both elements.

The ramifications of low staffing levels, as they pertain to the loss of life and property within a community, are essential to understand when considering a fire department's deployment configuration. A fire department should be designed to adequately respond to a number of emergencies occurring simultaneously in a manner that aims to minimize the loss of life and the loss of property that the fire department is charged with protecting. Any proposed changes in staffing, deployment, and station location should be made only after considering the historical location of calls, response times to specific target hazards, compliance with departmental Standard Operating Procedures, existing industry standards including NFPA 1500 and NFPA 1710, and the citizens' expectation of receiving an adequate number of qualified personnel on appropriate apparatus within acceptable time frames to make a difference in their emergency.

Glossary

The following definitions were created to identify terminology used in the department's CAD reporting system and specific characteristics used to evaluate the department's performance

Arrival time: refers to the time when the assigned units and personnel arrive at the incident location.

Back-to-Back Responses: refers to occurrences where mobile and personnel resources are dispatched to an incident within 10 minutes of becoming available from the previous incident.

Dispatch Time: refers to the time when units and personnel are assigned to an incident.

En route Time: refers to the time when assigned units and personnel leave their current location to travel to the incident location.

Hour: refers to the 60-minute period between whole numbers on a clock, for example, 1:00 to 2:00 or 15:00 to 16:00, unless otherwise stated.

Incident(s): refers to an emergency, or emergencies, to which individual or multiple fire department mobile and personnel resources are dispatched to intervene and mitigate an emergent situation. The total time spent on an incident includes the time from dispatch until the assigned units (apparatus and personnel) complete all tasks and become available for service. An incident may require a single or multiple apparatus.

Response: refers to an individual apparatus being dispatched and traveling to the scene of an incident.

Response Time: refers to the total time between when the unit is dispatched until arrival at the incident location.

Travel Time: refers to the total time spent between en route time and on-scene arrival time.

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Appendix A

Performance Standards

The National Fire Protection Association (NFPA) produced NFPA 1710 *Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments*. NFPA 1710 is the consensus standard for career firefighter deployment, including requirements for fire department arrival time, staffing levels, and fireground responsibilities.[76]

Key Sections included in the 1710 Standard that are applicable to this assessment are:

- 4.3.2
  - The fire department organizational statement shall ensure that the fire department's emergency medical response capability includes personnel, equipment, and resources to deploy at the first responder level with AED or higher treatment level.

- 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 & 5.2.3.1.1
  - Fire companies, whose primary functions are to pump and deliver water and perform basic firefighting at fires, including search and rescue… shall be staffed with a minimum of four on-duty members.

- 5.2.3.2 & 5.2.3.2.1
  - 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 staffed with a minimum of four on-duty members.

[76] NFPA 1710, 2016

- 5.2.3.1.2 & 5.2.3.2.2
    - In jurisdictions with tactical hazards, high hazard occupancies, high incident frequencies, geographical restrictions, or other factors as identified by the AHJ[77], these companies shall be staffed with a minimum of five or six on-duty members.

- 5.2.3.4.1
    - A fire company that deploys with quint apparatus designed to operate as either an engine company or a ladder company, shall be staffed as specified in 5.2.3.

- 5.2.3.4.2
    - If the company is expected to perform multiple roles simultaneously, additional staffing, above the levels specified in 5.2.3, shall be provided to ensure that those operations can be performed as required.

- 5.2.4.1.1
    - The fire department's fire suppression resources shall be deployed to provide for the arrival of an engine company within a 240-second travel time to 90 percent of the incidents.

- 5.2.4.2.1
    - The fire department shall have the capability to deploy an initial full alarm assignment within a 480-second travel time to 90 percent of the incidents.

[77] AHJ- Authority Having Jurisdiction

- 5.2.4.1.1
    - The initial full alarm assignment to a structure fire in a typical 2000 ft^2 … two-story single-family dwelling without basement and with no exposures shall provide for the following

Assignment	***Minimum Required Personnel***
Incident Command	1 Officer
Uninterrupted Water Supply	1 Pump Operator
Water Flow from Two Handlines	4 Firefighters (2 for each line)
Support for Handlines	2 Firefighters (1 for each line)
Victim Search and Rescue Team	2 Firefighters
Ventilation Team	2 Firefighters
Aerial Operator	1 Firefighter
Initial Rapid Intervention Crew (IRIC)	2 Firefighters
Required Minimum Personnel for Full Alarm	**14 Firefighters & 1 Scene Commander**

- 5.2.4.2.1
    - The initial full alarm assignment to a structure fire in a typical open-air strip shopping center ranging from 13,000 ft^2 to 196,000 ft^2 (1203 m^2 to 18,209 m^2) in size

- 5.2.4.3.1
    - The initial full alarm assignment to a structure fire in a typical 1200 ft^2 (111 m^2) apartment within a three-story, garden-style apartment building shall provide for the following:

Assignment	***Minimum Required Personnel***
Incident Command	1 Incident Commander 1 Incident Command Aide
Uninterrupted Water Supply (2)	2 Firefighters
Water Flow from Three Handlines	6 Firefighters (2 for each line)
Support for Handlines	3 Firefighters (1 for each line)
Victim Search and Rescue Teams	4 Firefighters (2 per team)
Ladder/Ventilation Teams	4 Firefighters (2 per team)
Aerial Operator	1 Firefighter
Rapid Intervention Crew (RIC)	4 Firefighters
EMS Transport Unit[78]	2 Firefighters
Required Minimum Personnel for Full Alarm	**27 Firefighters** **1 Incident Commander**

[78] The Standard further states, "Where this level of emergency care is provided by outside agencies or organizations, these agencies and organizations shall be included in the department plan and meet these requirements."

- 5.2.4.4.1
  - Initial full alarm assignment to a fire in a building with the highest floor 75 ft. (23 m) above the lowest level of fire department vehicle access shall provide for the following:

Assignment	***Required Personnel***
Incident Command	1 Incident Commander 1 Incident Command Aide
Uninterrupted Water Supply	1 Building Fire Pump Observer 1 Fire Engine Operator
Water Flow from Two Handlines on the Involved Floor	4 Firefighters (2 for each line)
Water Flow from One Handline One Floor Above the Involved Floor	2 Firefighters
Rapid Intervention Crew (RIC) Two Floors Below the Involved Floor	4 Firefighters
Victim Search and Rescue Team	4 Firefighters
Point of Entry/Oversight Fire Floor	1 Officer 1 Officer's Aide
Point of Entry/Oversight Floor Above	1 Officer 1 Officer's Aide
Evacuation Management Teams	4 Firefighters (2 per team)
Elevator Management	1 Firefighter
Lobby Operations Officer	1 Officer
Trained Incident Safety Officer	1 Officer
Staging Officer Two Floors Below Involved Floor	1 Officer
Equipment Transport to a Floor Below Involved Floor	2 Firefighters
Firefighter Rehabilitation	2 Firefighters (1 must be ALS)
Vertical Ventilation Crew	1 Officer 3 Firefighters
External Base Operations	1 Officer
2 EMS ALS Transport Units	4 Firefighters
Required Minimum Personnel for Full Alarm	**36 Firefighters** **1 Incident Commander** **6 Officers**

- 5.3.3.2.2
    - EMS staffing requirements shall be based on the minimum levels needed to provide patient care and member safety.

- 5.3.3.2.2.2 & 5.3.3.2.2.3
    - Units that provide BLS (ALS re: 5.3.3.2.2.3) transport shall be staffed and trained at the level prescribed by the state or provincial agency responsible for providing EMS licensing.

- 5.3.3.3.3
    - When provided, the fire department's EMS for providing ALS shall be deployed to provide for the arrival of an ALS company within a 480-second travel time to 90 percent of the incidents, provided a first responder with AED or BLS unit arrived in 240 seconds or less travel time as established in Chapter 4.

International Association of Fire Fighters
1750 New York Ave., NW, Washington, DC 20006
www.iaff.org

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