USING MOBILE MAPPING FOR WILDFIRE MITIGATION

IN LOS ANGELES COUNTY

by

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Dedication

I want to dedicate this thesis to my parents and sister for their endless love and support.

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All maps created by Brice Cameron Burkett

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Abstract

Los Angeles County is home to devastating wildfires that burn hundreds of thousands of acres and destroy many homes every year. There are a variety of reasons why some homes burn and others do not. For example, homes located along a Wildland-Urban Interface (WUI) usually means that the home is in what the Los Angeles County Fire Department calls a "Very High Fire Hazard Severity Zone" (VHFHSZ). Homes can burn due to the defensible space of surrounding vegetation and the types of structural materials. It is important to understand why certain homes burn and others remain unharmed.

This thesis uses mobile mapping in GIS to capture different fire risk attributes of homes located in Los Angeles County's VHFHSZ. The purpose of this study is to determine which homes have the greatest risk of burning so that improved mitigation techniques can be implemented to prevent those homes from igniting during future wildfires. The spatial video data is archived for post-wildfire analyses to conclude if a burnt home was damaged due to its building materials and surrounding vegetation.

Results of the analyses have shown clusters of fire hazardous homes and have determined individual homes with high fire risk attributes. Ultimately, this research provides the Los Angeles County Fire Department with timely relevant data to improve mitigation plans and conduct post-fire investigations if a wildfire burns in the studied areas.

Chapter 1

Introduction

1.1 Purpose

The emergency response cycle consists of four phases that occur with natural disasters: mitigation, preparedness, response, and recovery. This thesis will explore the concept of mitigation, which limits the destruction caused by natural hazards (Godschalk et al., 1999; Mileti, 1999; Pearce, 2003). This thesis will use geographic information systems (GIS) to examine several mitigation techniques which may be used to prevent homes from igniting during Los Angeles County wildfires, and that might also be used to forensically determine if a burnt home was damaged due to its building materials, defensible space, and surrounding vegetation. Data collected in this thesis cover November 2010 to February 2011.

The purpose of this study is to acquire a better understanding of why certain homes burn and others remain unharmed. Understanding each home's construction materials and style, defensible space, and surrounding vegetation types could prove invaluable in determining possible reasons why it burned or remained untouched, and therefore falls within the sentiment of Cohen: "Research using modeling, experiments, and wildland-urban interface (WUI) case studies indicates that home ignitability during wildland fires depends on the characteristics of the home and its immediate surroundings" (Cohen, 2000). The results of this study could also inform homeowners about fire-resistant building materials and proper fuel management, while assisting the

Los Angeles County Fire Department by providing timely relevant data that could be used to help improve mitigation plans for future wildfires.

1.2 Why Use GIS to Study Home Mitigation for Wildfires?

In 2003, Southern California had devastating wildfires that destroyed over 4,000 homes and caused more than two billion dollars in damages (Radeloff et al., 2005). Wildfires have become more hazardous over the past 25 years because people have chosen to live in scenic but hazardous areas. This is compounded by an increase in population, which has caused homes to continue to be built along mountainous terrain that contains dry vegetation (Keeley et al., 2009). As a result, “It’s not a question of “if” but “when” the next major wildfire will occur in Los Angeles County” (Freeman, 2009). It is therefore important to study Los Angeles County because its topography, weather, and vegetation combine to significantly increase the risk of severe wildland fires within this densely populated environment.

This study focuses on the building materials and surrounding vegetation of homes located in Los Angeles County’s wildland-urban interfaces and shows that mobile mapping technologies can provide useful information for wildfire mitigation. Spatially referenced videos of homes in fire prone areas were captured to establish baselines for analysis after any future fires.

1.3 Organization of the Thesis

This thesis is composed of six chapters, the first being this introductory chapter.

Chapter 2 provides a review of the literature examining the processes that contribute to destruction caused by Southern California wildfires. This chapter also discusses how geospatial technologies and neogeography can be utilized throughout the different stages of a disaster.

Chapter 3 presents an overview of how a spatial video system works and provides multiple case studies involving mobile mapping techniques for natural disasters.

Chapter 4 explains the methodology of the thesis and describes the a) study area, b) materials, c) spatial video technology, and d) coding techniques. This chapter also provides images of homes extracted from the spatial video system to depict the different rankings for fire risk.

Chapter 5 presents the fire risk maps and results of the statistical analysis performed using the construction and vegetation data collected during this study.

Chapter 6 discusses the findings and provides input from the Los Angeles County Fire Department. An explanation of how this spatial video data can be used for potential wildfires and future research is also presented.

Chapter 2

Literature Review

This chapter discusses the processes of wildfires with a focus on Southern California's susceptibility to fires. Damage statistics from recent California wildfires are analyzed to show the need for improved mitigation techniques that can save lives and property. This chapter also explains how geospatial technologies and neogeography can be used before, during, and after natural disasters.

2.1 Wildfire in Southern California

2.1.1 Wildfires

There are three key components that must occur simultaneously for a fire to ignite: appropriate fuel, adequate oxygen, and enough heat (Cottrell, 1989; Fuller, 1991; Halsey, 2008; Teie, 1994). Fuel consists of any substance that will ignite and burn. Fire involves a chemical reaction called rapid oxidation, which occurs from the quick release of energy stored in fuel. This chemical reaction mixes fuel and oxygen to create heat and light (Cottrell, 1989; Teie, 1994). A wildfire ignites once a plant is heated past its combustion level. This occurs when the carbon and hydrogen bonds are broken down to form new bonds between carbon and oxygen and new bonds between hydrogen and oxygen (Halsey, 2008).

Wildfire behavior can be determined by fuel, terrain, and weather. There are three types of fuels: aerial fuel, surface fuel, and ground fuel (Cottrell, 1989). Aerial fuels are combustible materials that stand taller than one meter above ground level, surface fuels consist of all combustibles below one meter and above ground level, and ground fuels include substances below the surface. Each one of these fuel categories produces their own type of wildfires, which are commonly combined to create massive wildland fires (Cottrell, 1989). Crown fires occur from aerial fuel, surface fires burn surface fuel, and ground fires smolder ground fuel. Topography and wind are key factors in the spread of wildland fires. Fuller explains that fire always travels faster when burning uphill because warm air rises, which preheats the elevated fuels in front of the fire (Fuller, 1991). Wind can also cause fire to travel uphill or downhill by carrying floating embers, resulting in unpredictable fire spread across the terrain (Cottrell, 1989; Halsey, 2008).

Wildfires produce mosaic vegetation patterns that are essential for wildland ecosystems (Callaway and Davis, 1993). The varied patterns are developed because fires burn different patches of land at various intensities due to fuel moisture and weather. "Fire and regrowth are part of a cyclic process like that of the seasons" (Fuller, 1991). Succession occurs after a wildfire when plants resprout and germinate from seed. These plants have either survived or their seeds have been carried and dispersed by the fire (Halsey, 2008). This allows a young, dynamic ecosystem to develop and replace dead vegetation. There are also fire-dependent ecosystems consisting of vegetation types like chaparral and pine, which require fires to create healthy growth environments. Some seeds must reach 113° F for eight minutes in order to germinate (Fuller, 1991). Other plants require fire to destroy specific chemicals that cause growth enzymes to remain dormant. Fires are also responsible for adding minerals to the soil, which benefit animals that eat the new vegetation. While wildfires may be destructive to surrounding human environments, many ecosystems require wildfire to sustain life.

2.1.2 Southern California Wildfires

Southern California continues to endure intense wildfire seasons. There are three main factors contributing to Southern California's susceptibility to wildfires. The first reason is rapid fire spread due to the Santa Ana winds. The high pressure in the Great Basin pushes winds toward a low pressure in Southern California (Halsey, 2008). The winds are forced through mountain passes including the Santa Ana Canyon on their path to Southern California. This process results in an increase in both speed and temperature. Moritz et al. (2010) combined previous Santa Ana wind data with wildfire history data to calculate areas that have the highest severity of wind and fire risk (Figure 2.1). The fast dry Santa Ana winds make it easier for wildfires to ignite and more difficult for firefighters to control.

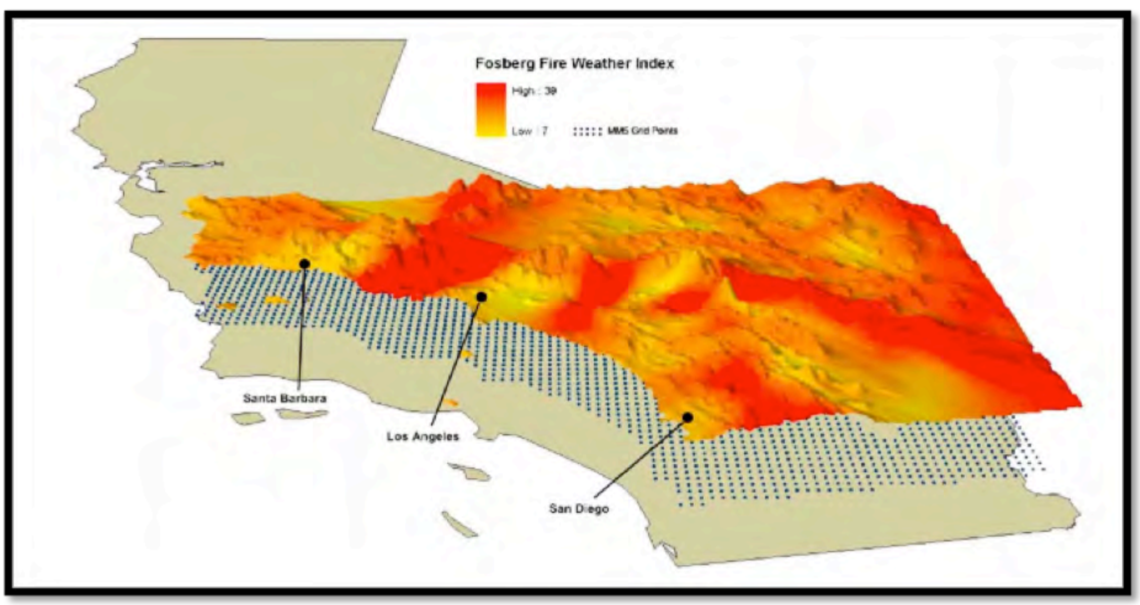

Figure 2.1: Fosberg Fire Weather Index (FFWI) showing severe fire weather areas. (Moritz et al., 2010).

The second reason for California's almost annual problem with wildfires has to do with fuel. The Mediterranean climate results in drought conditions during the summer and rain in the winter (Moritz et al., 2010; Mooney and Dunn, 1970). The lack of rainfall during the summer months makes the fuel exceptionally arid, which in combination with high temperatures and low humidity not only causes the fuel to be very dry, but the fuel itself is hot as well (Cafferata and Munn, 2008). The majority of fuel in Southern California consists of chaparral ecosystems. Chaparral is associated with summer drought and is California's most common plant community (Halsey, 2008). The dryness of the plants provides the perfect "tinder box" for fire ignition, while the Santa Ana winds spread the flames extremely quickly.

Another component of the spatial pattern of wildfires is California's topography. The slope aspect of a valley results in differential drying of fuel, and therefore variation in fire spreading rates (Fuller, 1991; Teie, 1994). In addition, the large hills cause wildfires to spread rapidly because fire always travels faster uphill during the day. It is tremendously difficult to contain a wildfire traveling uphill because firefighters cannot predict how quickly the spread speed is going to increase, resulting in potentially dangerous firefighting conditions and a general increased risk to homes built on slopes (Halsey, 2008).

The most common wildfires in Southern California are surface and spot fires. Surface fires burn the low ground vegetation, including grasses, shrubs, small trees, and other plants (Fuller, 1991). These fires can spread extremely quickly because the fuel is very dry. Spot fires occur when the Santa Ana winds are present. The winds carry embers considerable distances to cause large fire “jumps,” called heading fire fronts (Cottrell, 1989). The heading fire front spreads quickly in the direction of the wind, burning surface and aerial fuels. Spot fires are difficult for firefighters to extinguish because the fires can jump roads and firebreaks.

2.1.3 Wildland-Urban Interface

The wildland-urban interface (WUI) is the area where human-built structures infiltrate undeveloped natural vegetation (Mutch et al., 2011). A WUI can be a dangerous place to live because these areas are composed of flammable vegetation that can easily be ignited. California’s WUI environments have experienced a large increase in population growth (Platt, 2010). As of 2005, California has 5.1 million WUI housing units, which is the highest in the United States (Radeloff et al., 2005). Communities expand as the population continues to increase, which creates a demand for the development of open land. This has caused homes to be built further away from urban centers, pushing into the WUI. Figure 2.1 shows two WUI neighborhoods that are located in Altadena, California.

Figure 2.2: Wildland-urban interface neighborhoods in Altadena, California.
(U.S. Geological Survey, 2010).

It is important for homeowners living in a WUI to maintain a defensible home. Defensible homes are defined as those that are in compliance with local brush clearance requirements and have been built in accordance with fire zone building standards (Cohen, 2000; Freeman, 2009; Plummer, 2007). Many WUIs have a Fuel Modification Program developed by the fire department to create defensible space (See Appendix B). Defensible space is the area around a home that is free of flammable plants and objects

(Roian, 2005). This creates a zone for firefighters to safely protect a home during a wildfire. The Los Angeles County Fire Department has established four zones (A to D) of defensible space (Freeman, 2009). Zone A is a 20-foot wide area surrounding the home with low growing plants of high moisture content. This 20-foot firebreak reduces the risk of flame impingement on the home. Zone B consists of irrigated and spaced vegetation that extends up to 100 feet from the structure. This zone is designed to slow fire spread by removing continuous fuels. Zones C and D continue from Zone B and increase up to 200 feet from the home. These final zones focus on eliminating dead vegetation and thinning native plants up to 50 percent in Zone C and 30 percent in Zone D. Figure 2.2 displays the four zones of defensible space according to the Los Angeles County Fire Department.

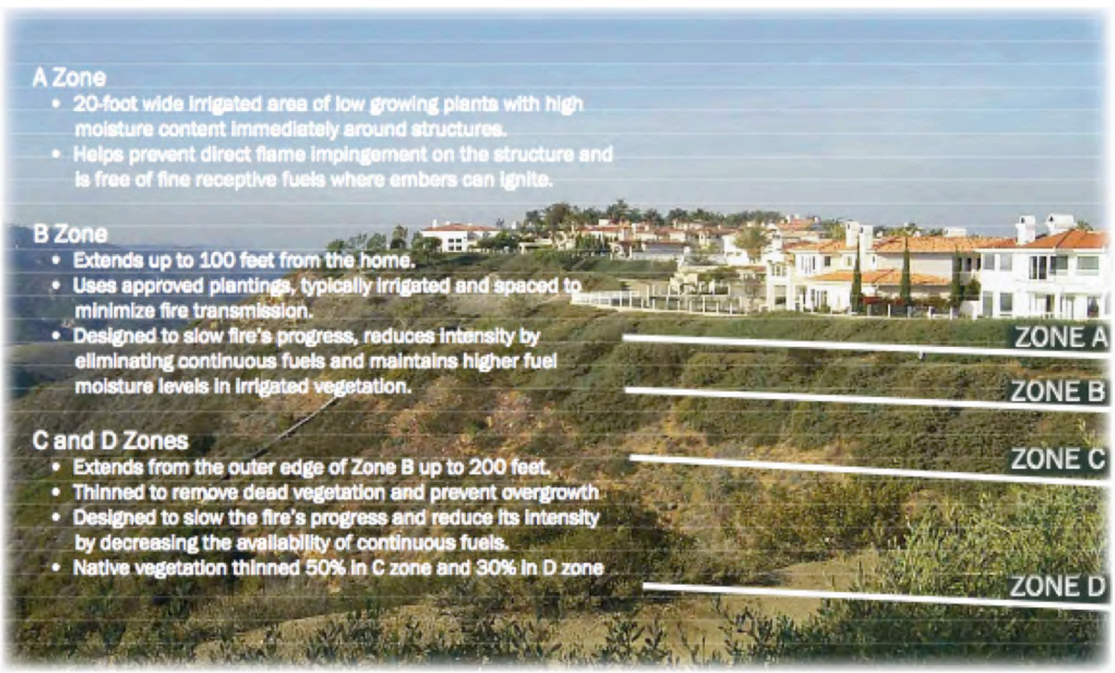

Figure 2.3: Four zones of defensible space in Los Angeles County.
(Freeman, 2009).

Another crucial factor for a WUI home to survive a wildfire is the building's construction materials. A "hardened" home reduces the risk of igniting because it follows the building code for materials, including roofs, eaves, decks, vents, windows, and walls (Watts and Solomon, 2002). The roof must be Class "A" approved because this is the most vulnerable surface on which embers can land and ignite. A Class "A" roof is fire-retardant and resistant to the most severe category of exposure (California Fire Code, 2007). A hardened home avoids the build up of combustible materials under eaves and decks. The vents and windows of a hardened home have screens to prevent embers from entering the home. Finally, the building code recommends the use of brick, cement, or stucco for the wall siding because they are not flammable (Freeman, 2009; Roian, 2005). WUI homeowners that mitigate by following the building code and allowing defensible space will have less risk of losing their home to a wildfire

2.1.4 2007-2009 Southern California Wildfires

The 2007 San Diego County wildfires consisted of multiple surface and spot fires that burned almost 369,000 acres and destroyed 2,587 structures (CAL FIRE, 2008). These wildland fires followed a hot, dry summer and were combined with the strong seasonal Santa Ana winds.

Date (2007)	Fire Name	Acres Burned	Structures Destroyed
10/21 – 10/31	Witch Creek	197,990	1,650
10/21 – 10/31	Harris	90,440	472
10/23 – 11/10	Poomacha	49,410	217
10/23 – 10/29	Horno	21,084	0
10/22 – 10/28	Rice	9,472	248

Table 2.1: 2007 San Diego County wildfires.
(CAL FIRE, 2007).

According to the California Department of Forestry and Fire Protection (CAL FIRE), the Witch Creek Fire is ranked third highest and the Harris Fire tenth in terms of number of structures destroyed in California since 1932. The Witch Creek Fire is also the fourth largest California wildland fire by acreage burned since 1932. The 2007 San Diego County wildfires are excellent examples of the danger that fires present today to Southern California neighborhoods.

Los Angeles County has also had its share of large wildland fires. The Sesnon Fire in 2008 lasted from October 13th until October 18th, burning 14,703 acres (CAL FIRE, 2008). This started as a surface fire that transformed into a spot fire due to the Santa Ana winds. The Sesnon Fire destroyed 15 homes and 63 outbuildings causing 12.6 million dollars in damage (CAL FIRE, 2008). Captain Hamel of the Los Angeles Fire Department (Personal Interview, December 5, 2010) explained that the Sesnon fire became unpredictable when the wind speeds increased and spotting distances up to one mile were observed. The Station Fire 2009 ignited on August 26th and was extinguished on October 16th, burning 160,577 acres. This devastating fire destroyed 209 structures, including 89 homes, costing approximately 95.3 million dollars and resulting in two Los Angeles County firefighter fatalities (CAL FIRE, 2009). The California Department of Forestry and Fire Protection has ranked the Station Fire as the tenth largest California wildland fire by acreage burned since 1932. The destruction caused by these Los Angeles County wildfires illustrates the importance of implementing improved mitigation strategies throughout Southern California.

2.2 Geographic Techniques

2.2.1 Geospatial Studies of Historical Southern California Wildfires

The use of geographic data and geospatial technologies with regard to wildfires can be broadly split into three focus areas: mitigation support, academic interest, and public response. Geographic information systems can be extremely helpful when developing wildfire mitigation techniques. The National Park Service created the Santa Monica Mountains Plan to implement "strategic fuels treatment," which locates areas of vegetation that need to be removed to limit future fire spread (Witter and Taylor, 2008). A GIS analysis by Witter and Taylor (2008) uses vegetation type, vegetation age, slope, and distance to structures to analyze and choose appropriate areas for the fire department to conduct prescribed burns or mechanically remove fuel. "GIS allows the entire landscape to be plotted based on information gathered by satellite and other sources" (Witter and Taylor, 2008). GIS maps produced by the National Park Service provide fire departments surrounding the Santa Monica Mountains with current information that will ensure better mitigation strategies to save lives and property.

Remote sensing and GIS are important tools that allow geographers to study present and post-wildfire hazards (Yool, 2007). The intense Yellowstone wildfires of 1988 required scientists and geographers to participate in the containment efforts. Scientists at the Intermountain Research Station's Fire Sciences Laboratory in Missoula, Montana developed maps to show how far the Yellowstone wildfires spread each day (Fuller, 1991). These provisional maps were digitized and overlaid with terrain and fuel maps of Yellowstone. The scientists also used satellite imagery to create fire-severity maps. These digital overlay maps revealed that the main fire influences in Yellowstone were fuel moisture, slope steepness, and wind speed.

Recent federal policies have reallocated fuel reduction resources from communities located in wildland-urban interfaces and have directed efforts towards reducing fuel on federal lands in the western United States (Medler, 2007). This puts high-risk WUI neighborhoods in greater danger of wildfires. Medler, (2007) used GIS to create 500-meter buffers around populated WUI areas in the 11 western states of the conterminous United States. State ownership data within the 500-meter buffers and 30-meter pixel resolution imagery from the U.S. Forest Service were then added to determine land ownership patterns around these populated places (Medler, 2007). This GIS analysis confirmed that only 17.7 percent of the buffered land belonged to the federal government (Medler, 2007). This proved that the majority of fuel reduction resources should be applied to non-federal lands to protect communities from wildfires.

Geospatial information also provides data for emergency managers and responders, which allows them to make informed assessments to limit the risk to life, property, and the environment (Castagna, 2008). The 2007 Southern California wildfires burned hundreds of thousands of acres and destroyed thousands of homes causing families to become homeless. The Federal Emergency Management Agency (FEMA) utilized the United States Army Corps of Engineers GIS team to assist with the wildfire destruction (Castagna, 2008). The Corps produced maps in a timely manner that assisted FEMA in identifying burned areas and providing shelter for displaced people. Castagna explains that the maps showed the clustered locations of residents applying for FEMA assistance and allowed FEMA to understand the safe areas sooner, and thus respond more rapidly in establishing Disaster Recovery Centers (DRCs).

Alerting residents and choosing between mandatory, recommended, and voluntary evacuations during a wildfire is a challenging task. Incident commanders must have up to date evacuation trigger point positions to efficiently evacuate the most threatened neighborhoods (Cova et al., 2005). An evacuation trigger point is a location where if a wildfire crosses, emergency responders immediately recommend an evacuation. A GIS-based wildfire evacuation trigger method was first developed by Cova et al. (2005) using fire spread modeling, which takes into account fuel, wind, and topography to estimate the rate of fire spread. This GIS technique could be used to develop wildfire evacuation trigger buffers around fire prone neighborhoods for diverse meteorological and topographic conditions. The 1996 Calabasas Fire that occurred in the Santa Monica Mountains of Southern California was used as a case study simulation to ground truth the concept of using GIS-based wildfire evacuation triggers. Cova et al. (2005) explained that while evacuation trigger buffers were successfully developed from the Calabasas Fire, advances in fire-spread modeling will improve the accuracy of the buffers.

2.2.2 Neogeography and Natural Disasters

While the professional use of geospatial technologies has proved to be helpful during natural disasters, the addition of neogeography has provided more assistance for mitigation, response, and recovery. Neogeography has been defined as use of geography tools and techniques that do not conform to the traditional practices of professional geographers (Graham, 2009). A global positioning system (GPS) device is an example of a tool that has allowed non-professional geographers to capture spatial data to create personalized maps. These maps can be uploaded and shared with the advent of Web 2.0 technologies, which have permitted Internet users to become producers of information as well as consumers (Graham, 2009; Crutcher & Zook, 2009; Zook et al., 2010). The combination of neogeography and the Internet lets the general public construct and utilize geospatial information in real-time.

Volunteered geographic information (VGI) allows the general public to make use of tools to voluntarily create and disperse geographic data (Goodchild, 2007). This is important during disasters, such as wildfires, because VGI informs people of current fire locations, contained fires, damaged homes, and shelters (Liu and Palen, 2010). VGI usually focuses on basic GIS techniques, which allows GIS professionals to concentrate on the more advanced procedures necessary during a disaster. Volunteered geographic data can be presented as map “mashups,” which combine multiple sources of Internet-based spatial information to display them together in a geographic form (Liu and Palen, 2010). Google Earth is an example of an extremely popular VGI software program, which gives anyone access to the basic capabilities of GIS (Graham, 2009). Places of interest are tagged with descriptions, reviews, advice, hyperlinks, and photographs to provide the user with a better understanding of locations around the world. In addition, Google Earth allows users to exercise the basic functions of GIS by providing tools, which permit the construction of points, lines, and polygons. Volunteered geographic information is not only important for understanding life at a local level, but it is extremely useful during natural disasters in geographic locations that lack adequate mapping coverage of critical infrastructure. The following two examples, though not wildfire related, show the importance of VGI in a disaster context.

The magnitude 7.0 earthquake that devastated Haiti in 2010 sparked an urgent need for maps of the impacted areas to show emergency responders the locations of people in need and how to get assistance to them (Zook et al., 2010). Haiti is an extremely poor country and did not have sufficient existing map coverage for web mapping response applications. Zook et al. (2010) explains that Google, GeoEye, and DigitalGlobe worked together to obtain high-quality satellite imagery of Haiti immediately following the earthquake. The post-earthquake imagery was made available to the public within twenty-four hours of the disaster, ultimately facilitating emergency services in providing relief to some areas of Haiti. However, since Haiti did not have any established informational databases, the geographic information had to be compiled from scratch and completed within the first few days following the disaster, a critical time period for saving lives. VGI communities around the world began to participate by using basic web-based tools to help develop the required data infrastructure (Zook et al., 2010). The volunteered contributions immediately following the earthquake allowed GIS professionals to develop faster, more accurate maps to help with the relief efforts in Haiti.

The release of Google Earth arrived just before the devastating Hurricane Katrina and acted as an essential tool for dispersing damage information throughout New Orleans (Crutcher and Zook, 2009). The general public was able to create placemarks in Google Earth that included place specific information and photographs to inform citizens of damaged or flooded areas. Google Earth users took the flood images that were provided by the news media and overlaid the imagery next to the appropriate flooded area so anyone could compare the new flood photographs with the original pre-flood imagery (Crutcher and Zook, 2009). However, since the media's flood photographs were limited, not all flooded regions had up-to-date images. In response to this problem, imagery was obtained from the National Oceanic and Atmospheric Administration (NOAA) and inserted into the Google Earth interface so the public could view recent, high quality aerial imagery of the flooding (Cramer, 2005; Ewalt, 2005). This allowed Google Earth to display post-Katrina flooding images within twenty-four hours of the disaster. Hurricane Katrina was Google Earth's first real natural disaster response test involving volunteered geographic information, proving the software program to be an important tool for bringing awareness to the general public.

Since then, the growth of Web 2.0 has allowed volunteered geographic information to be helpful and informative during a variety of natural disasters. “Given the immediate need for reliable maps in volatile disaster response situations, the model of peer produced mapping provides a number of new avenues for producing and accessing spatial data, apart from the traditional models of top-down geographic information system provision” (Zook et al., 2010). VGI was also used to provide updates for the general public during the 2009 Los Angeles County wildfires. A Google My Maps mashup was created to inform Los Angeles County citizens of current wildfire perimeters, fire containment percentages, contained fire locations, safe zones, and disaster shelters (Liu and Palen, 2010). This mashup was constantly updated using information from a variety of Internet sources. Thus these examples show that the concept of neogeography has opened the door for valuable volunteered geographic information that can help save lives.

Chapter 3

Mobile Mapping and Disasters

3.1 Spatial Video Systems

Spatial video, also known as mobile mapping, is a significant advancement in geospatial technologies for all phases of the emergency management cycle. A spatial video system collects geo-referenced video data in the field that is both spatial and temporal. The concept of combining video data with positional information simultaneously was first made possible in the 1990s (McCarthy et al., 2007). Global positioning system (GPS) encoders can attach geographic information to images and video to capture information that remotely sensed data cannot provide (Curtis et al., 2010). Remotely sensed imagery usually presents an aerial view at different resolutions, whereas spatial video systems allow the GIS user to view objects at a human scale. A spatial video system also has several advantages over georeferenced photographs taken from the ground. The total area that photographs can cover is limited by the amount of photographers and cameras, whereas capturing spatial video data only requires one vehicle with two to three people (Curtis and Mills, 2011b). The spatial video acquires multiple images at specific intervals, which improves consistency by eliminating individual variability in photographs.

A typical spatial video system captures video imagery onto which geographic coordinates are encoded on the audio channel. After processing these video files, the coordinate data can be readily imported into Google Earth and Esri’s ArcGIS (Red Hen Systems, 2011). Figure 3.1 shows the two cameras and the GPS antenna that are attached to a vehicle in the field.

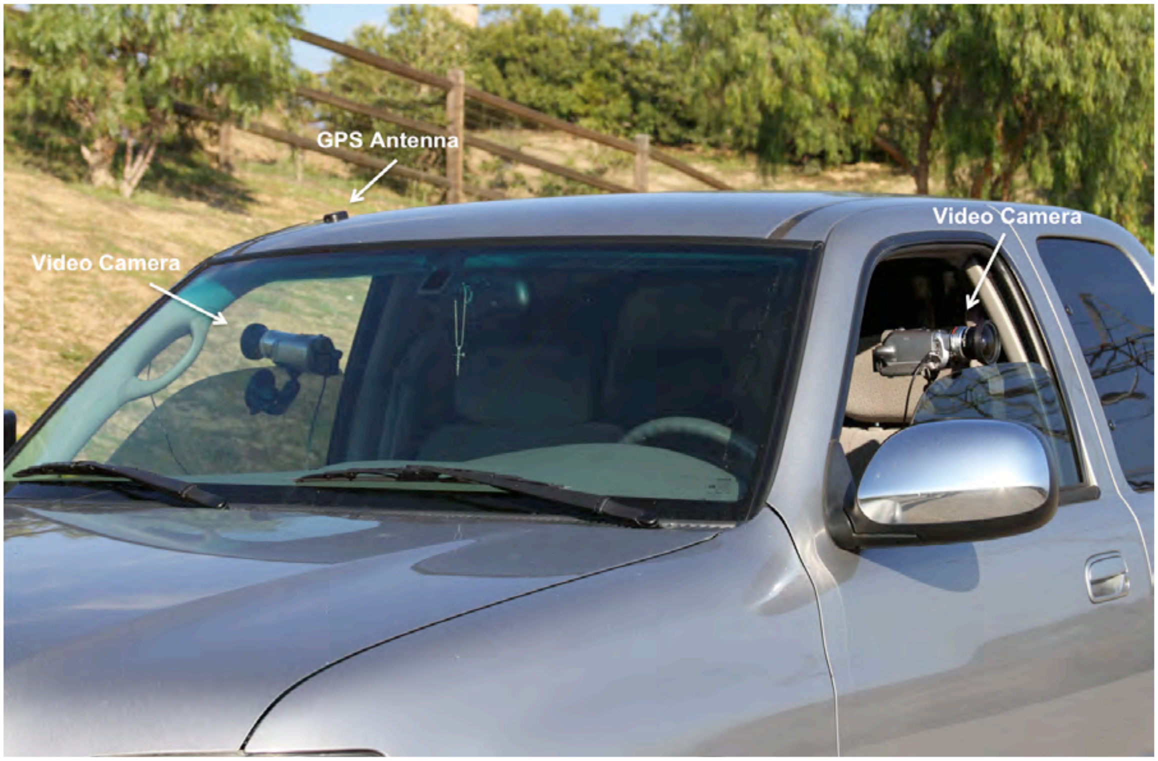

Figure 3.1: Spatial Video Acquisition System.

The playback of the spatial video, typically within a GIS time-enabled map, allows the user to simultaneously watch the video while following a marker on the map that displays the temporal variation in GPS locations.

3.2 Mobile Mapping for Disasters

The growth of mobile mapping can assist emergency responders and government officials in the event of a disaster. The use of spatial video for disasters is commonly utilized for recovery efforts in an impacted region. For example, the devastation from Hurricane Katrina made it the costliest natural disaster in the history of the United States (Andrews, 2011). The massive destruction made the concept of recovery seem impossible. Mobile mapping was used to determine how long it would take to rebuild different neighborhoods in New Orleans (Curtis and Mills, 2011a). The spatial video footage captured flattened structures, blighted buildings, and overgrown vegetation. Curtis believes that some returnees will endure ongoing stress from their surrounding environments because the spatial video documented that residents were rebuilding next to blighted buildings and untamed vegetation (Andrews, 2011). Repeated data acquisition in these neighborhoods months later can allow researchers to determine how much change has occurred (Curtis et al., 2010). The geo-referenced video data was used to create maps for the recovering neighborhoods, which helped spatially prioritize rebuilding efforts so that residents could return to the healthiest surrounding conditions.

The aftermath of Hurricane Katrina caused an increase in crime throughout the disaster-impacted neighborhoods of New Orleans, which acted as an impediment to recovery (Curtis and Mills, 2011a). A mobile mapping system was used to capture georeferenced data of damaged areas located in the Holy Cross neighborhood. Crime data and associated locations reported by the New Orleans Police Department (NOPD) were digitized alongside the spatial video data to determine if there were any relationships between crime and post-disaster damage (Curtis and Mills, 2011a). The results indicated that crime locations were usually concentrated in areas of blighted and abandoned buildings (Curtis and Mills, 2011a).

Spatial video can also be used as a damage assessment tool. On April 28th, 2011 the state of Alabama suffered 53 tornadoes, while Tuscaloosa County endured four tornadoes. One devastating tornado that occurred in Tuscaloosa County damaged approximately 7,371 homes, destroyed 2,375 homes, and resulted in at least 41 fatalities (Jones, 2011). A spatial video system was used to acquire data three weeks following the disaster for areas of interest to local home and business owners. Georeferenced data of the devastation caused by the tornadoes was captured for six sample areas, which covered about 50 percent of the damaged streets (Curtis and Mills, 2011b). The spatial video footage was analyzed for each sample area to determine the types of structures, degree of visible damage, expected wind speeds, Enhanced F Scale ranking based on visible damage, and recovery predictions (Curtis and Mills, 2011b). The spatial video collected also displayed the different recovery processes occurring three weeks after the tornadoes. Such fine scale mobile mapping data collections can provide a better understanding of how a post-disaster landscape might rebuild homes and communities (Curtis and Mills, 2011b). Thus these geospatial techniques provide vital information that government officials can use to plan efficiently and sustainably.

Spatial video has been used in several types of disasters (hurricanes, tornadoes, and wildfires) and in various stages of the disaster cycle (damage assessment and recovery). This study is one of the first to use mobile mapping specifically for predisaster mitigation purposes. Mobile mapping is useful for wildfire mitigation because it captures important features of homes, including structural materials and vegetation type. The video footage can be used to improve mitigation strategies because the spatial data allow for an analysis to determine which homes have a greater risk of burning due to these two risk criteria, building materials and vegetation. This spatial video data can also be archived so fire departments can examine homes after a fire to establish why some homes burned and others did not, an opportunity to improve upon existing mitigation techniques in order to help prevent homes from burning in future wildfires.

Chapter 4

Methods

4.1 Study Areas

Three cities located along the wildland-urban interface of Los Angeles County were chosen to capture spatial video for this study. Multiple neighborhoods were documented within each city. Altadena and Bradbury each had two study areas and Santa Clarita had three study areas (See Appendix A). These specific communities were identified in collaboration with Los Angeles County Fire Department experts and were studied because they are located in what the Los Angeles County Fire Department refers to as a “Very High Fire Hazard Severity Zone” (VHFHSZ). In addition, Google Street View does not provide imagery for these neighborhoods, which increases the need for mobile mapping. Appendix A displays the original VHFHSZ maps provided by the Los Angeles County Fire Department. Homes situated in a VHFHSZ are considered to have the highest risk of burning because they are usually within a close proximity to a WUI that contains dry vegetation that could ignite at any moment. The seven Los Angeles County study areas are extremely important because their surrounding vegetation has not burned for over 20 years, which has made the fuel abundant as well as arid.

The first data collection for this study took place in Altadena, California (Figure 4.1). Spatial video captured the structural materials and surrounding vegetation of homes located in two adjacent neighborhoods within a WUI. These study areas were considered to have an extremely high risk of burning because both neighborhoods were positioned alongside a mountain with vegetation that has not ignited for over 20 years, as mentioned previously. A large canyon covered with dry fuel separate these two study areas. While both communities were within a close proximity to each other, one neighborhood consists of older construction while the other is new. This allowed the spatial video system to compare and contrast the fire risk for each home in two nearby yet dissimilar communities.

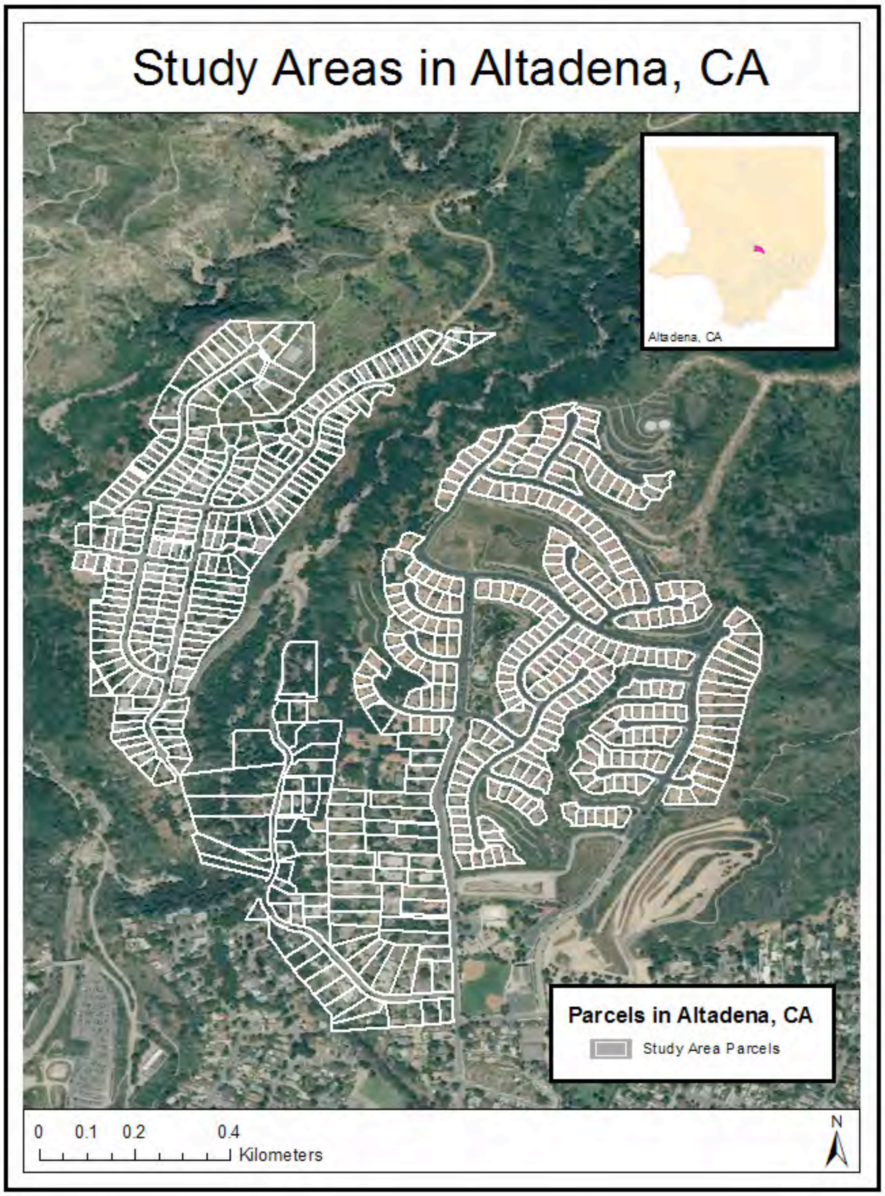

Figure 4.1: Study Areas in Altadena, California.

The next two study areas were located at the north end of the city of Bradbury, California (Figure 4.2). These two neighborhoods are similar to the Altadena communities because they are directly adjacent to each other and border a similar WUI 20 kilometers east of Altadena, California. A similar canyon divides these Bradbury neighborhoods. These neighborhoods are densely built, containing only modern homes expected to be constructed in compliance with current building and fire codes.

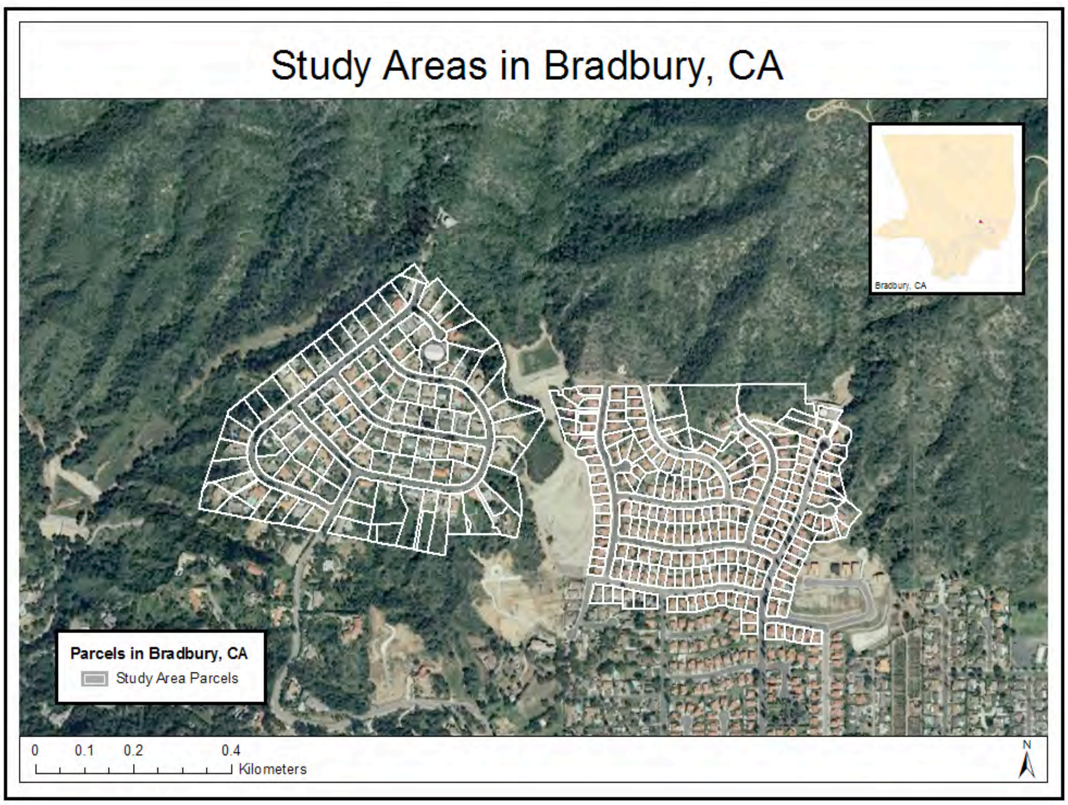

Figure 4.2: Study Areas in Bradbury, California.

The final spatial video collection occurred in three different study areas within Santa Clarita, California. The first study area consisted of four new, developing communities that were located along a WUI directly connected to the Angeles National Forest (Figure 4.3). These neighborhoods are interesting because some homes were newly developed while others were still under construction. The spatial video captured the improved building and landscaping techniques that were involved with these new homes.

Figure 4.3: Study Area 1 in Santa Clarita, California.

The second Santa Clarita study area resembled track home neighborhoods, which were positioned deeper in the Angeles National Forest WUI than the first study area (Figure 4.4).

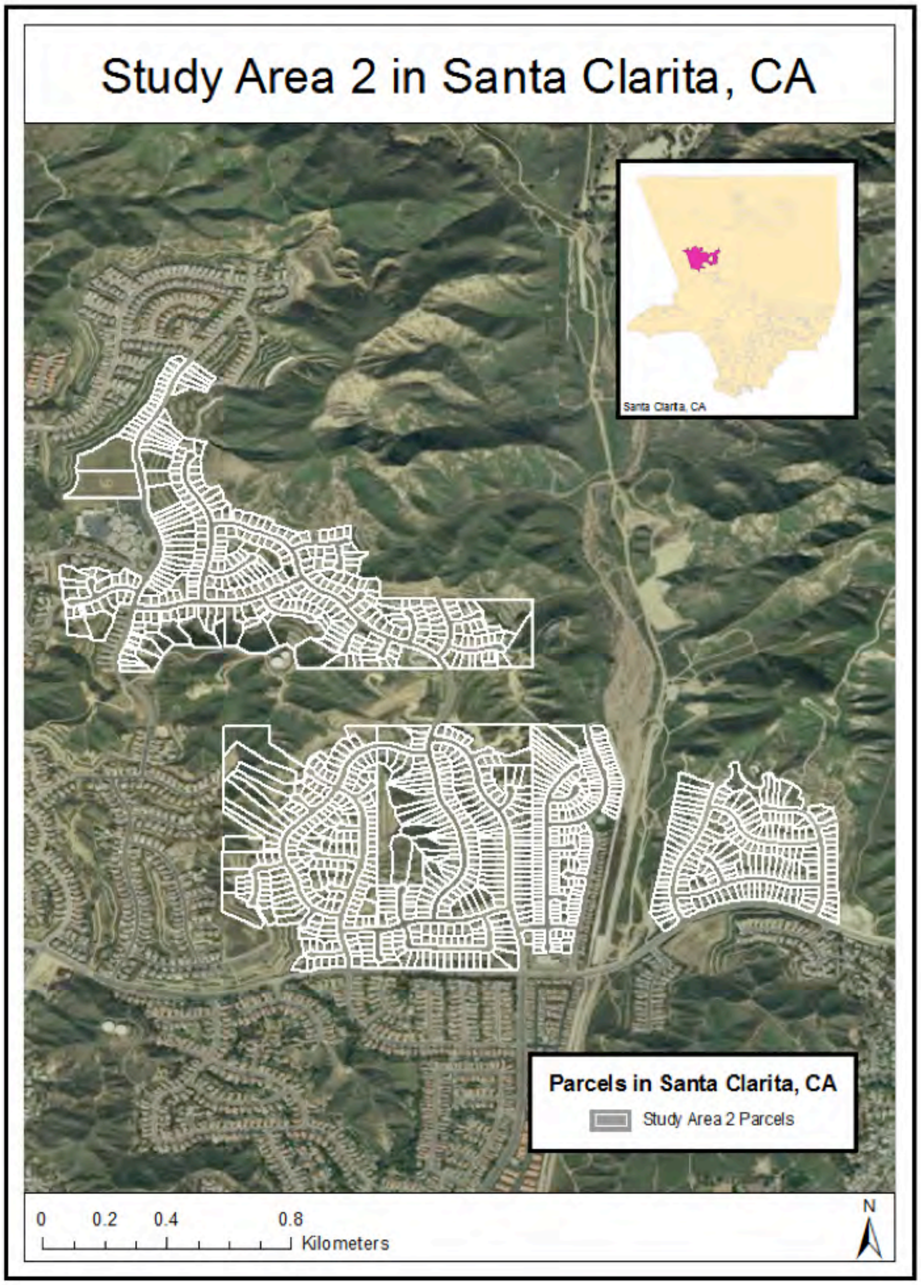

Figure 4.4: Study Area 2 in Santa Clarita, California.

The third Santa Clarita study area was completely different from any of the other communities in the other study areas. Many of the homes were situated on large ranch parcels, which required driving the mobile mapping vehicle off road to collect video data (Figure 4.5).

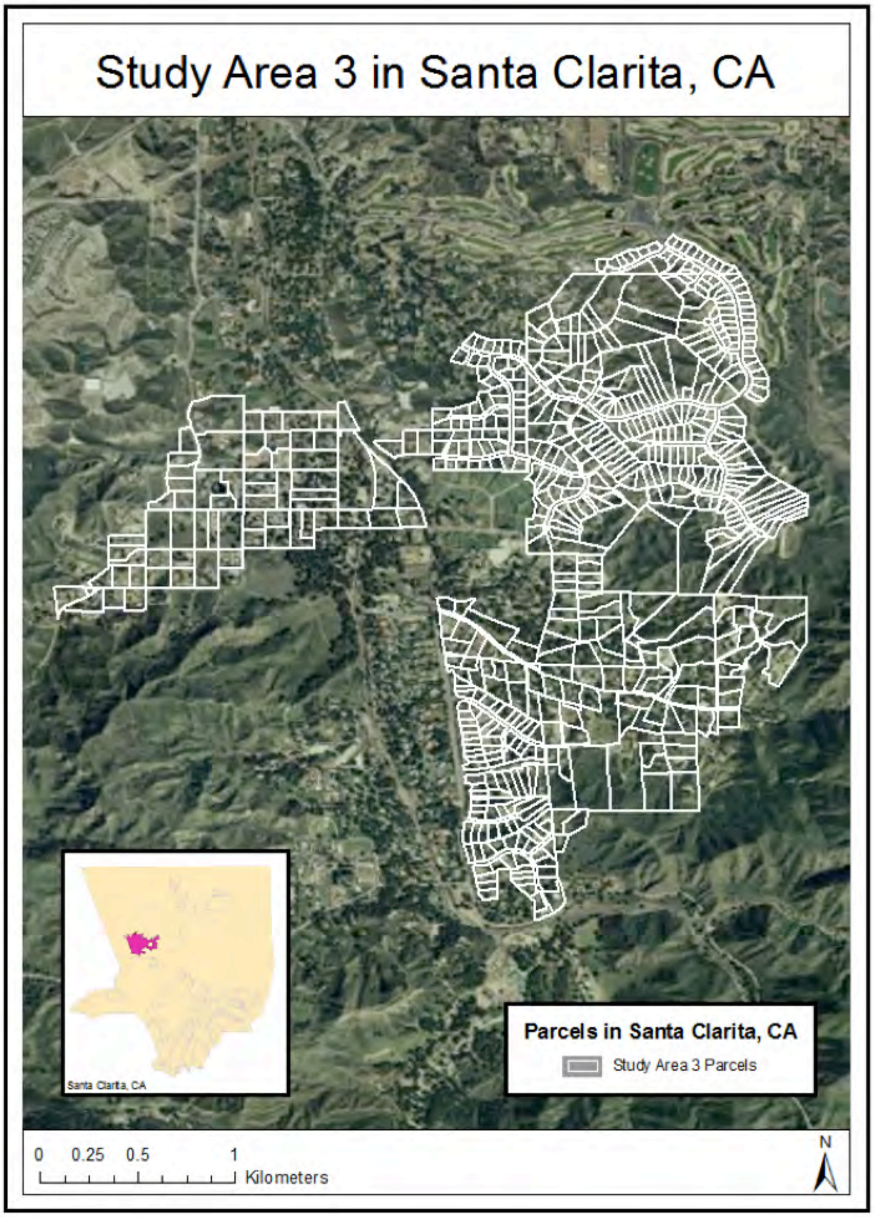

Figure 4.5: Study Area 3 in Santa Clarita, California.

4.2 Spatial Video Technology

The spatial video system used for the collection of data from different Los Angeles County wildland-urban interface neighborhoods consisted of a GPS encoder and two digital camcorders with car window mounts and power units. As the car moved, the camcorders recorded video footage while the GPS unit encoded the geographic coordinates onto an audio channel. The GPS receiver remained inside the car connected to a GPS antenna on the roof and two digital camcorders that were attached to each side of the car. While data acquisition was underway, the vehicle was driven at approximately 10-15 miles per hour through Los Angeles County neighborhoods that were located in Very High Fire Hazard Severity Zones (VHFHSZ). The video data was processed using a GPS decoder, which replayed the video footage and created tracks of point shapefiles in Esri's ArcMap 9.3.1 to display the recorded GPS locations. Finally, the video footage was viewed in a media window while a tracking marker traveled along the recorded geographic coordinates in the ArcMap window (Figure 4.5).

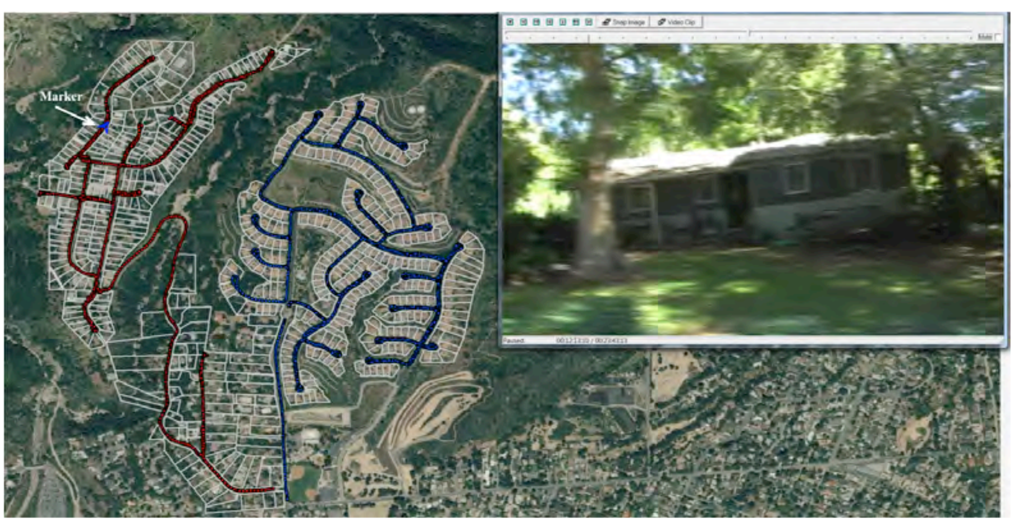

Figure 4.6: Esri's ArcMap 9.3.1 window displaying spatial video tracks (red and blue point shapefiles) with media window simultaneously playing the video footage.

4.3 Parcel Selection

Parcel boundaries were used as reference points while the spatial video marker moved along the GPS tracks, providing a better understanding of which home was being analyzed in the media window. After data acquisition was completed, the 3,827 parcels used for the five study areas were extracted from the total 2,377,744 parcels within Los Angeles County.

Study Area	Number of Parcels
Altadena	585
Bradbury	317
Santa Clarita – Area 1	1250
Santa Clarita – Area 2	1073
Santa Clarita – Area 3	602

Table 4.1: Number of parcels per study area.

The first step in the parcel selection process was to select out rectangular perimeters around each study area and export the data as new shapefiles. Once the general study areas were chosen, the left over parcels were individually selected and deleted from the data sets so that only the parcels connected to the spatial video tracks remained. Only the specific parcel sections that were captured by the mobile mapping system were utilized in the subsequent analysis.

4.4 Coding Techniques

The collaboration with the Los Angeles County Fire Department allowed for the development of a proper coding scheme. This process involved input from Brad Weisshaupt and J. Lopez of the Los Angeles County Fire Department. They provided suggestions and examples for visually interpreting proper structural materials, defensible space, and surrounding vegetation. Developing an accurate coding scheme for this study required multiple meetings with fire experts to understand how they rank a home's fire risk.

The original coding scheme ranked a home's fire risk on a 1 – 3 scale (1 = low risk, 2 = moderate risk, and 3 = high risk). Fire experts from the Los Angeles County Fire Department were given the same spatial video footage of one street from each study area. The experts coded the fire risk of each home using the 1 – 3 scale and produced maps to determine if their ranking systems were consistent with other Los Angeles County Fire Department rankings. The map comparisons proved that there were discrepancies between the "moderate" and "high" risk characteristics. The solution was to add a fourth category to the original coding scheme creating a "very high" risk ranking in order to minimize the confusion between the "moderate" and "high" risk homes. The fire experts applied the new 1 – 4 scale system to the same streets as before and created new maps, which showed that the 1 – 4 scale was accurate and consistent.

The next step was to establish ranking classifications for other types of parcels. For example, some homes had long driveways or elevated foundation, which obstructed the digital camcorder's view. Other parcels were located in developing neighborhoods with homes under construction and empty parcels lots. The fire experts analyzed the video footage of these parcels to help classify how each type of parcel should be ranked. After much debate with the fire department, it was established that four ranking classifications would be added to the original 1 – 4 fire risk scale to account for the different parcel types.

There were a variety of coding techniques that were applied to this study following data acquisition. Coding classifications and color schemes were applied to each risk ranking. A total of eight coding classifications were developed for the spatial video analysis. The first four rankings categorize each home's fire risk based on structural materials and surrounding vegetation. A 1 – 4 scale with 1 = low risk, 2 = moderate risk, 3 = high risk, and 4 = very high risk, was used to manually code each visible home. After determining the ranking names, a color scheme was created so each parcel would have a specific color relating that home to its wildfire risk: 1 = dark green, 2 = light green, 3 = light red, and 4 = dark red. This color scheme allowed the low risk and very high-risk homes to stand out on the maps, providing a visualization of which homes are safe and which homes are more susceptible to fire. Figure 4.6 displays example images of homes in each fire risk classification, extracted from the spatial video system in the field.

(a) Low Risk

(b) Moderate Risk

(c) High Risk

(d) Very High Risk

Figure 4.7: Fire risk classification snapshots of homes extracted from spatial video.

The final four code rankings classified other types of parcels in the study areas: 5 = hidden from video, 6 = open land, 7 = under construction, and 8 = empty parcel lot (Figure 4.7). Many homes within the wildland-urban interface had long driveways and elevated foundations for privacy. This limited what the digital camcorders could capture and these parcels were coded with the “hidden from video” classification. Other parcels simply consisted of open land, homes under construction, and empty graded parcel lots. It was important that the parcel colors for these parcel types did not conflict with the fire risk rankings. The color format for the final four codes were: 5 = hollow with white outline, 6 = grass fill, 7 = dark blue, and 8 = light gray. These simpler colors did not detract visually from the green and red wildfire risk color scheme on the resulting maps.

(a) Hidden From Video

(b) Open Land

(c) Under Construction

(d) Empty Parcel Lot

Figure 4.8: Other examples of parcel classification snapshots.

Chapter 5

Results

This chapter presents the maps and analyses for each study area. The maps were created using a coding scheme that was developed in collaboration with the Los Angeles County Fire Department. Visual interpretations of homes' structural materials, defensible space, and surrounding vegetation were extracted from the spatial video footage. Fire risk rankings were applied to homes before overlaying aerial imagery because the spatial video system only captured front and side yard attributes. Maps with "A, B, C" markings represent groups of fire hazardous parcels. This chapter also uses a difference of proportions test to statistically compare the fire risk for each study area.

5.1 Fire Risk Map Interpretations

5.1.1 Altadena Study Areas

The fire risk rankings for each parcel in the two Altadena study areas are shown in Figure 5.1, based on visual interpretation of images extracted from the spatial video footage.

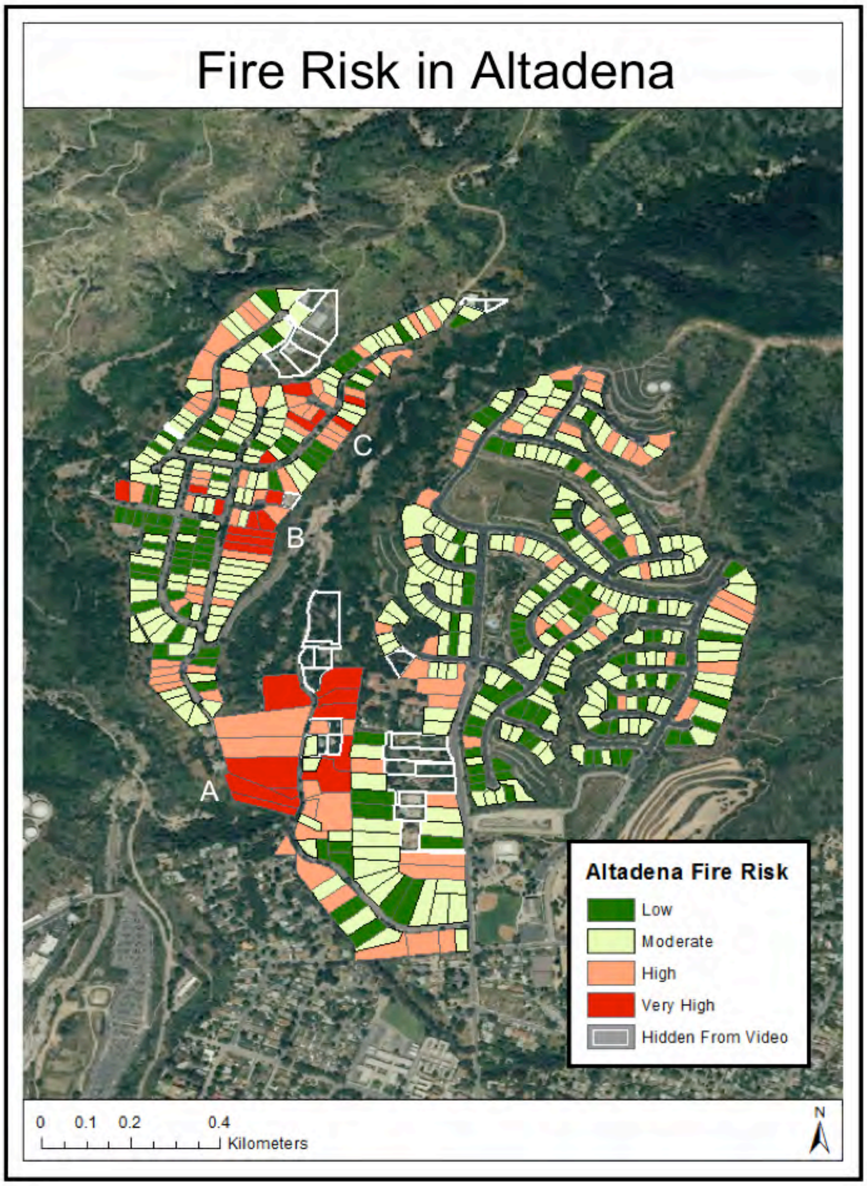

Figure 5.1: Wildfire risk in Altadena, California.

The Altadena study areas display three dangerous groupings (though not statistically tested for) that have a very high risk of burning. Group A is the largest collection of homes consisting of 10 “very high risk” and 11 “high risk” parcels. All of these parcels are positioned directly inside the canyon that divides the two study areas. This canyon contains a vast amount of dry, overgrown vegetation that has not burned for over two decades. The majority of the homes in this group are situated on the largest parcels of the two study areas, which implies that the parcels have a lot of land. There are also homes in the northern section of group A that are built on parcels that are “hidden from video.” These parcels could not be captured by the spatial video system because the long driveways and overgrown vegetation obstructed the camcorder’s view. However, it is likely that these hidden homes are at high or very high risk due to their overgrown vegetation and proximity to the other “very high risk” parcels nearby. Group A has a very high risk of burning because it consists of large parcels with homes constructed of hazardous structural materials, and overgrown vegetation located within a canyon with dry fuel.

Groups B and C are smaller arrangements of homes each composed of about 5-6 “very high risk” and 6-8 “high risk” parcels that border the opposite side of the group A canyon. Both of these groupings connect to cul-de-sacs located at the top of an extremely dry and overgrown mountain ridge. The cul-de-sacs increase the risk of burning by connecting the already “very high risk” and “high risk” parcels, such that they are positioned within a close proximity to each other. Groups B and C have a very high fire risk because they represent dense groupings situated along the ridge of an arid canyon that again, has not burned for decades.

5.1.2 Bradbury Study Areas

The wildfire risk for each parcel in the two Bradbury study areas are displayed in Figure 5.2.

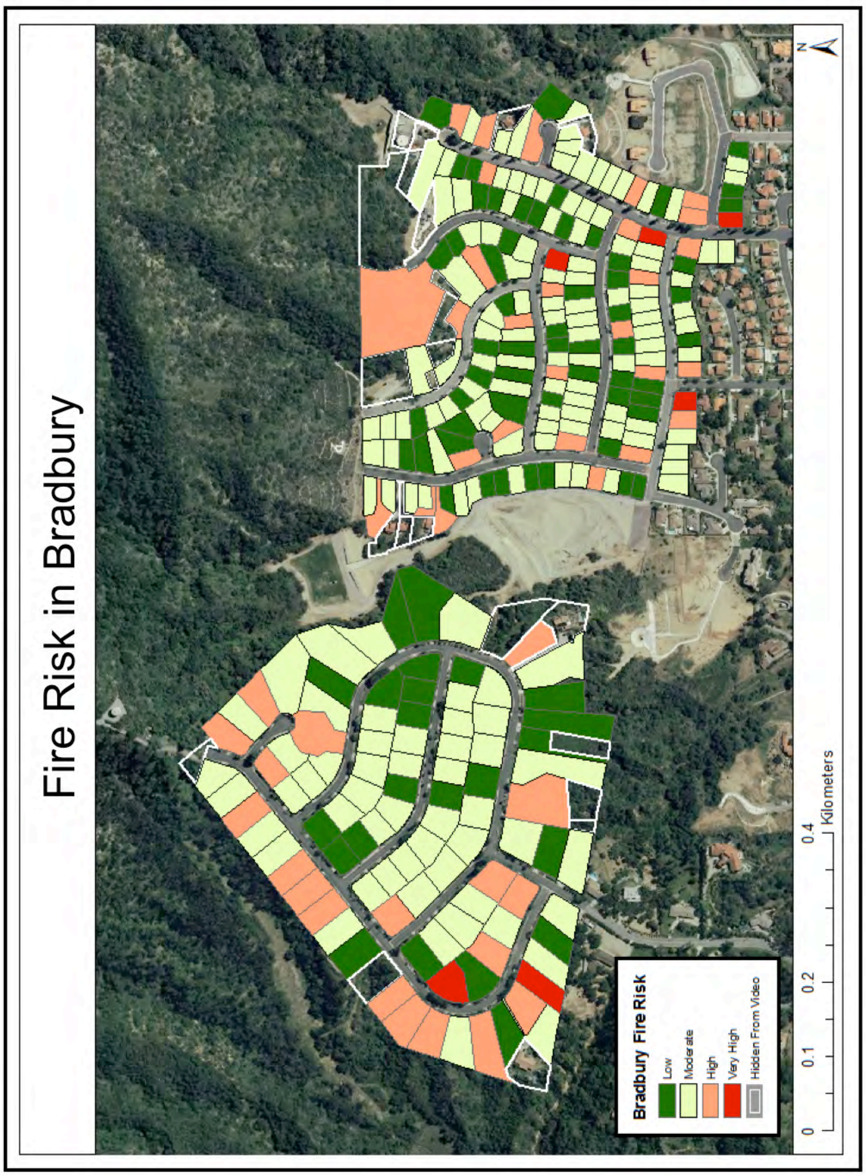

Figure 5.2: Wildfire risk in Bradbury, California.

The Bradbury study areas have individual "very high risk" parcels that are not positioned directly against the WUI's vegetation. Usually when "very high risk" parcels are grouped together, they are likely to burn during a wildfire because the vegetation around the homes overlap and become overgrown. However, when "very high risk" homes are not surrounding each other, as seen in the Bradbury study areas, it indicates that these homes are at the highest risk of fire because homeowners have not been mitigating properly. These two neighborhoods are fairly new and although the structural materials appear to be in compliance with current building codes, these were still classified as high risk because homeowners have planted an excessive amount of vegetation within the defensible space zones.

The study area on the left has "high risk" parcels bordering the majority of the neighborhood's west side, which is situated directly in the wildland-urban interface. These homes have a high risk of catching fire because they are surrounded by front yard, side yard, and WUI vegetation. Most of the parcels that are located in the center of both study areas are "low risk" and "moderate risk." These homes are surrounded by less vegetation because the other homes and streets separate them from the mountain's vegetation.

5.1.3 Santa Clarita Study Area 1

The fire risk rankings for the parcels located in the first study area of Santa Clarita are illustrated in Figure 5.3.

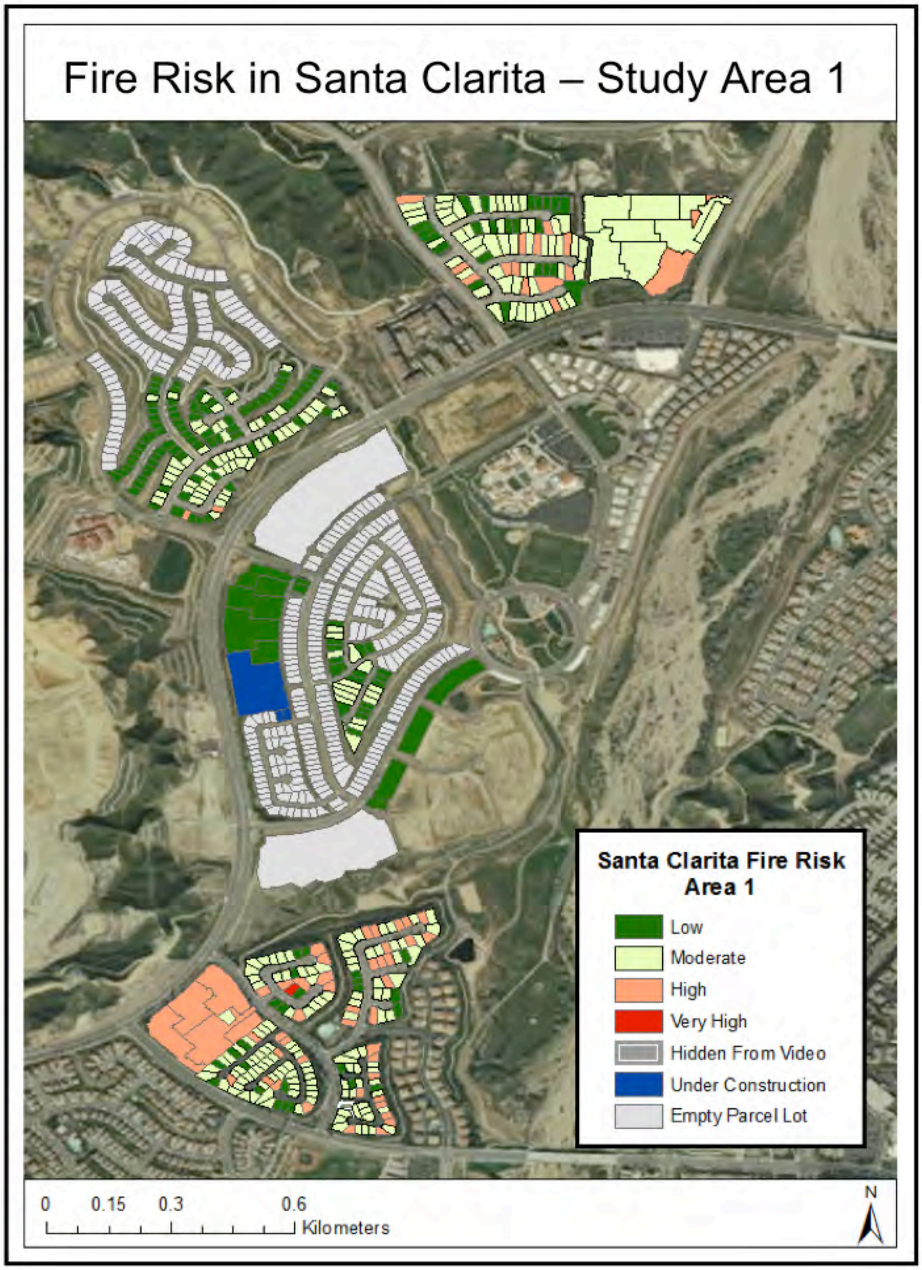

Figure 5.3: Wildfire risk in Santa Clarita, California – study area 1.

The first study area in Santa Clarita consists of new developing neighborhoods bordering the Angeles National Forest. The southern neighborhood has a grouping of "high risk" parcels that contain many townhomes. These townhomes have a high fire risk because they are densely packed into a small area and have tall trees that divide each home. This is a fire hazard because the trees are extremely close to the homes and the branches hang over many of the roofs.

The aerial imagery shows that most of this study area is covered in dirt. This is because the parcel lots have been graded so that new homes can be built. The light gray parcels show all of the empty lots that are waiting to be developed. The two neighborhoods with empty parcel lots have many "low risk" and "moderate risk" parcels as well. These homes have recently been built, which means that they were constructed with building materials compliant with current building codes. Since the new homes in these neighborhoods were built on graded land they have little or no vegetation surrounding them. It will be interesting to see if these homeowners plant large amounts of vegetation in the future, or if they limit the vegetation growth since they are built in a wildland-urban interface.

5.1.4 Santa Clarita Study Area 2

The fire risk categories for the parcels located in the second study area of Santa Clarita are shown in Figure 5.4.

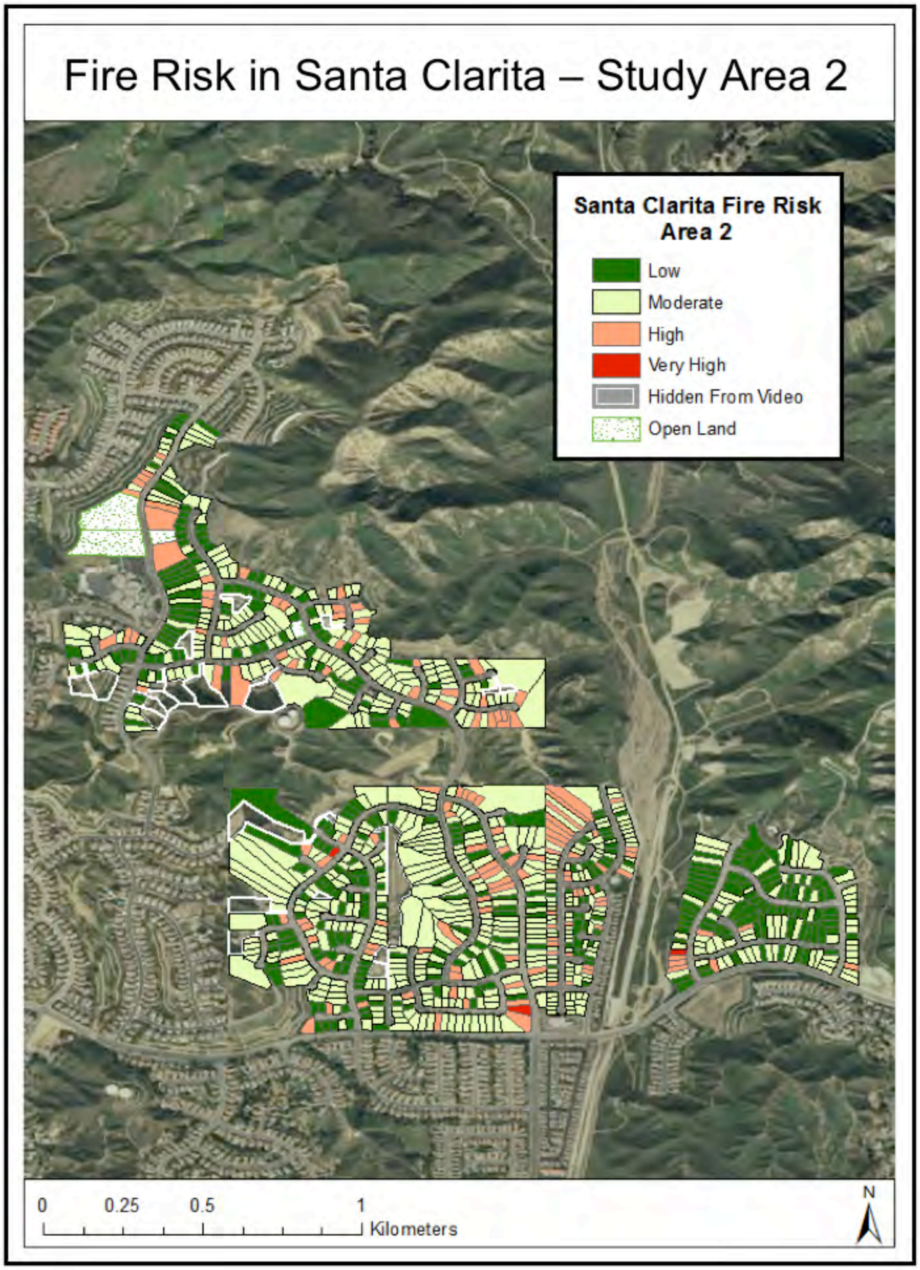

Figure 5.4: Wildfire risk in Santa Clarita, California – study area 2.

The parcels in Santa Clarita's second study area are 84% "low risk" and "moderate risk." There are only three "very high risk" parcels in these neighborhoods and they are not near each other. However, all three "very high risk" homes are positioned directly next to 2-3 "high risk" parcels, which increase their risk. There is a group of "high risk" parcels in the center of the study area located at the north end of the southern community. These parcels appear to be situated adjacent to a mountain within the Angeles National Forest that is connected to the northern community, which contains a smaller grouping of "high risk" parcels about 0.25 kilometers north of the original high-risk group. The homeowners on these dangerous hillsides must mitigate the fire hazard by creating defensible space, limiting vegetation growth, and making sure that their building materials are in accordance with the fire codes.

Another interesting thing to consider is the possible fire risk of the homes located on the "hidden from video" parcels in the southwestern area of the northern community. There are 6 large parcels that could not be captured by the spatial video system because the homes were positioned towards the back of the parcels and had long, steep driveways. These parcels border a dry hillside and are adjacent to other large parcels that have "high risk" attributes. It is likely that these hidden homes have an increased fire risk due to their close proximity to hillside vegetation and other nearby "high risk" parcels.

5.1.5 Santa Clarita Study Area 3

The fire risk rankings for each parcel in Santa Clarita's third study area are displayed in Figure 5.5.

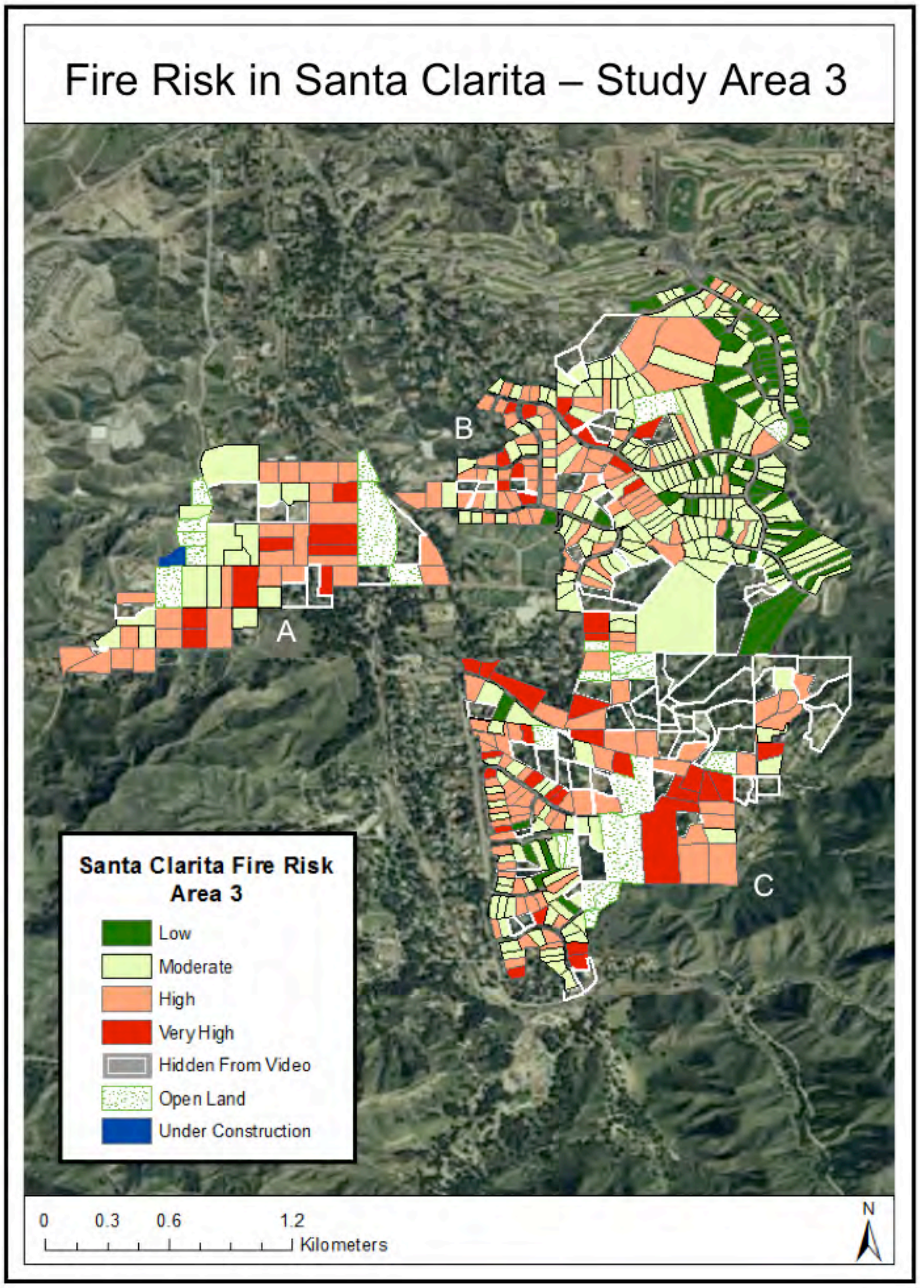

Figure 5.5: Wildfire risk in Santa Clarita, California – study area 3.

The third study area in Santa Clarita has the greatest amount of fire risk out of all the study areas considered. Approximately 25% of the parcels are ranked as “high risk” and 8% are considered to be “very high risk.” The “hidden from video” parcels also make up 12% of Santa Clarita’s third study area, which could potentially add to the wildfire danger in these neighborhoods. Although there are “very high risk” and “high risk” parcels throughout the entire study area, there appears to be three dangerous parcel groupings (A, B, C) with “very high” and “high” risk attributes.

Group A consists of large parcels that have grazing land for horses and cattle. The majority of the homes are ranked as “very high risk” and “high risk” because the parcels include trees and shrubs from the WUI. Most of these homes do not have the appropriate amount of defensible space, which could allow a wildfire to spread quickly from the surrounding mountains and burn the homes. There are also several “open land” parcels that do not have homes but do contain natural vegetation that could ignite and spread into the developed parcels.

Group B is a collection of smaller parcels that are separated from the mountains by a golf course, and several “low risk” and “moderate risk” homes. Although these homes are not positioned directly on the mountain, they are classified as “very high risk” and “high risk” because of their surrounding vegetation. These homeowners have not mitigated properly, allowing large amounts of overgrown vegetation to border their homes. Most of these parcels contain tall trees in excess of approximately 30 feet tall that separate each home, and long branches rest on the roofs of the homes. Some parcels in group B also have fuel ladders, defined as grasses and shrubs that grow close to tree branches, allowing a potential fire to climb into the tree canopy directly above a home. Creating defensible space around each home would eliminate all fuel ladders.

Group C has different size parcels with “very high risk” and “high risk” rankings. This group has larger parcels with homes that are located on the mountain and smaller parcels that are situated at the base of the mountain. The homes on the mountain have parcels with more land, and the WUI’s natural vegetation grows onto the homeowners’ property. In addition, these homes are adjacent to “open land” parcels that are not developed and contain overgrown vegetation. Therefore, these large parcels do not have any firebreaks and are connected to the natural vegetation. The collection of smaller parcels at the base of the mountain is similar to the parcels in group B. The homeowners have not mitigated appropriately by not generating defensible space around their homes. There are 6 “hidden from video” homes in the center of these smaller high-risk parcels that have long driveways, which obstructed the view of the digital camcorders. These 6 homes may also be considered high fire risk since they are surrounded by other “very high risk” and “high risk” parcels.

5.2 Statistical Analysis

The total 3,827 homes documented by the spatial video system are listed in Table 5.1 according to fire risk, for each study area.

Parcel Ranking	**Altadena**	**Bradbury**	**Santa Clarita Area #1**	**Santa Clarita Area #2**	**Santa Clarita Area #3**
Low	139	80	264	320	68
Moderate	291	160	365	583	238
High	101	47	187	139	153
Very High	25	6	1	3	45
Hidden From Video	29	24	1	24	72
Open Land	0	0	0	4	25
Under Construction	0	0	74	0	1
Empty Parcel Lot	0	0	358	0	0
Total Parcels	585	317	1250	1073	602

Table 5.1: Number of parcels per study area, ranked according to risk.

Santa Clarita’s #1 and #3 study areas are misleading because parcels without homes are included in the total parcels. The first study area of Santa Clarita is composed of 29% empty parcel lots and 6% homes under construction. Therefore, this study area has 818 homes with potential fire risk. Santa Clarita's third study area has 25 "open land" parcels, which could potentially contribute to the threat to the surrounding homes since most of the "open land" parcels contain natural vegetation from the WUI.

Each study area's parcel rankings are displayed in Figure 5.6. The 358 "empty parcel lots" and 74 "under construction" parcels were excluded from Santa Clarita - Study Area 1 in order to calculate accurate percentages.

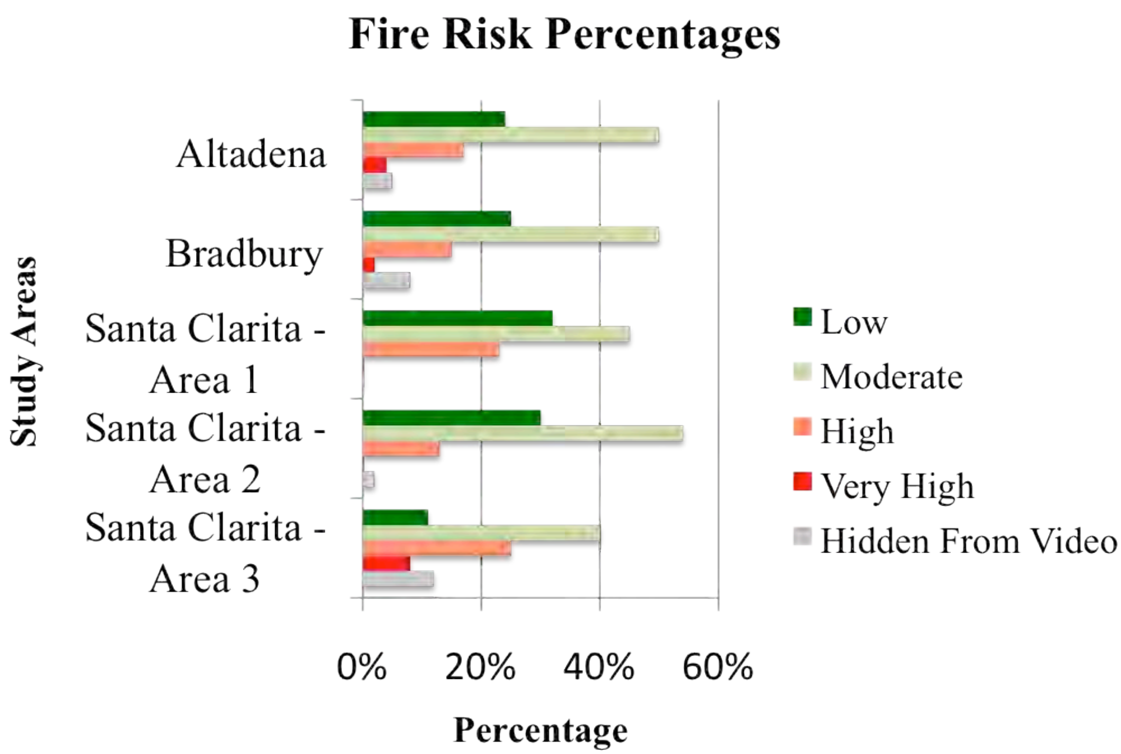

Figure 5.6: Percentage of fire risk according to assigned fire risk ranking, for each study area.

A difference of proportions test was run using a 95% confidence level on the different categories between study areas. The Altadena and Bradbury areas have similar percentages of fire risk, which means that the differences are not statistically significant at a 95% level. The Santa Clarita – Area 3 "high risk" percentage is statistically greater than the “high risk” of Altadena, Bradbury, and Santa Clarita – Study Area 2 (p=0.05). The difference between the “very high risk” ranking of Santa Clarita – Area 3 and the “very high risk” of all the other study areas is statistically significant at a 95% confidence level, meaning that the pattern of “very high risk” parcels in Santa Clarita – Area 3 are unlikely to occur by chance alone. The results indicated that Santa Clarita – Area 3 is potentially the most at risk to wildfire because it has the least percentage of “low” and “moderate” risk homes and the greatest percentage of “high” and “very high” risk homes.

Chapter 6

Conclusion

This study was conducted in continual collaboration with Brad Weisshaupt and J. Lopez of the Los Angeles County Fire Department. Their fire expertise was utilized throughout this study from start to finish. Weisshaupt and Lopez provided the study areas to ensure that the Los Angeles County communities with the highest fire risk would be analyzed. Their recommendations were used to help create effective coding schemes and analyzing methods. The results of this study will be used to further develop this technical approach to wildfire mitigation.

As mentioned previously the study areas were chosen as having an increased risk of burning during a wildfire because they are located in the Los Angeles County Fire Department's, "Very High Fire Hazard Severity Zone." The spatial video system was used to capture almost six hours of video footage documenting the important fire risk attributes of homes in these neighborhoods. Each parcel was assigned a fire risk ranking that was later represented on a map. The maps were used to visually interpret where the highest concentrations of fire prone homes are located so that improved mitigation techniques can be established prior to a wildfire.

There are similarities and differences between all of the study areas. For example, Altadena and Santa Clarita's third study area both have large groupings of "very high risk" homes while Bradbury and the first study area of Santa Clarita do not have any groups of "very high risk." Both Santa Clarita's second study area and Bradbury contain individual parcels that are ranked as "very high risk," indicating that these homeowners may not be mitigating properly. The first study area of Santa Clarita is different from the others because it consists of new, developing neighborhoods. The homes that have been recently built are ranked as “low risk” and “moderate risk” because their structural materials are assumed to be in compliance with the current fire code and they are constructed on graded parcel lots with small amounts of surrounding vegetation. Santa Clarita’s third study area has the greatest amount of wildfire risk out of all the study areas. About 8% of the homes are ranked as “very high risk” and 25% are considered to be “high risk.” The third study area of Santa Clarita statistically has the most “very high risk,” “high risk,” and “hidden from video” parcels, thus it is considered the most fire hazardous area relative to the other study areas.

While there are many factors that can influence structure loss from wildfires, some homes burn by chance. Embers from spot fires can be carried by winds and land under a home’s eaves or enter attic vents to ignite combustible material. Other homes may be damaged because an adjacent home caught fire. This is why it is important to study why some homes burn and others remain unharmed. Figure 6.1 displays the aftermath of the 2007 San Diego County wildfires in a Rancho Bernardo neighborhood located in San Diego, California.

Figure 6.1: Destroyed homes in Rancho Bernardo, California.
(Dillon & Siemaszko, 2007).

Consistent mitigation techniques are critical in preventing homes from burning during a wildfire. Figure 6.2 shows the structure loss in a Rancho Bernardo neighborhood after the 2007 fires. As discussed before, some of these burnt homes are clustered together and others are individually scattered. If this neighborhood had been mapped using a spatial video system prior to the wildfire, fire experts may have been able to determine if the destroyed homes had pre-existing high fire risk characteristics.

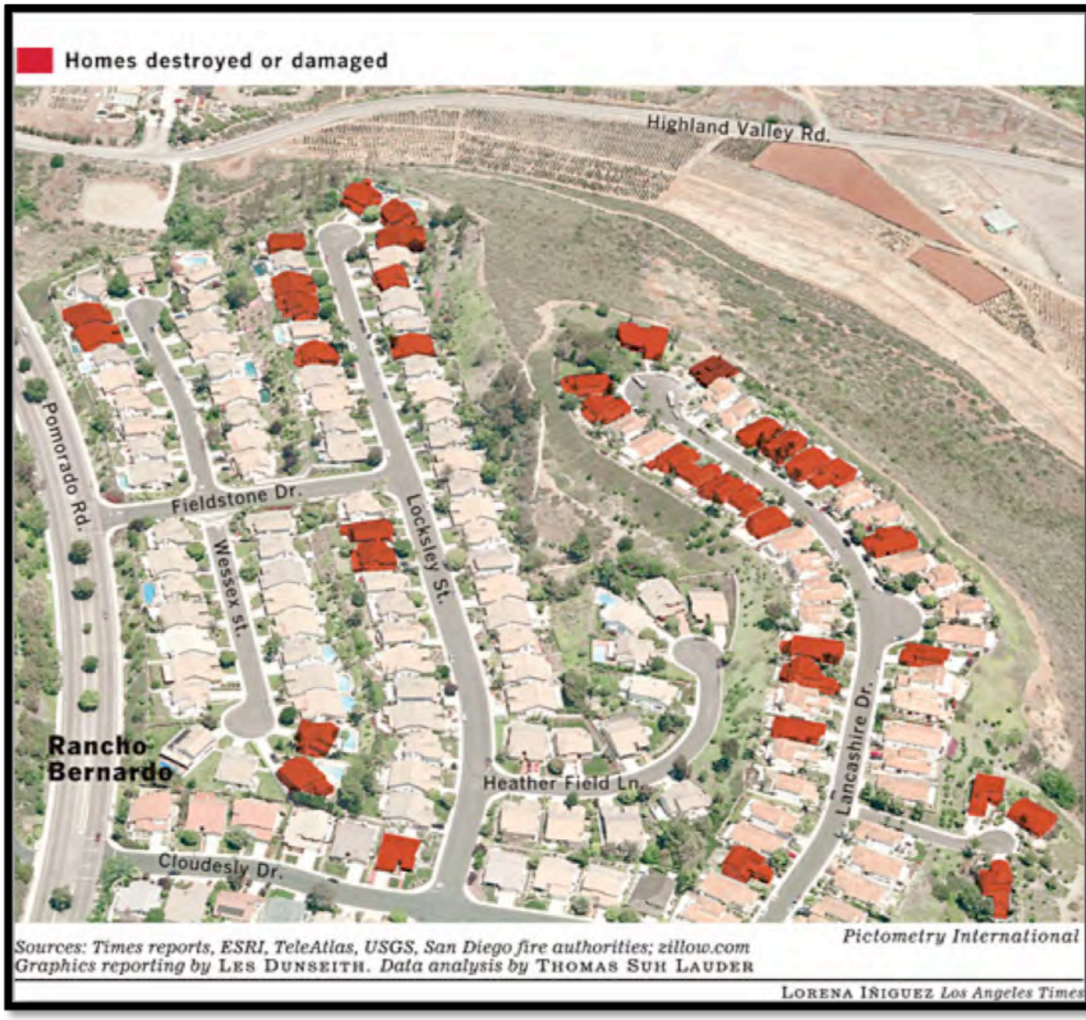

Figure 6.2: Structure loss in a Rancho Bernardo neighborhood.
(Iniguez, 2009).

In conclusion, Southern California wildfires continue to threaten homes situated along the wildland-urban interface. A home's safety during a fire is significantly dependent on its structural materials and surrounding vegetation. Preparing and mitigating for fires decreases the risk of ignition around a home during a wildland fire. The spatial video system successfully captured the diverse fire risk attributes that could potentially damage property and endanger lives. All of the homes in the studied areas have a pre-existing high fire hazard because they are located in a WUI. However, the map analyses show that some homes have a greater fire risk than others based on poor mitigation techniques. Brad Weisshaupt of the Los Angeles County Fire Department (Personal Interview, October 4, 2011) believes that the spatial video data collected for this thesis will be useful for developing future fire prevention methods. This study has proven that mobile mapping in GIS can provide useful information for wildfire mitigation.

The limitation of this study involved the digital camcorders' recording capabilities. The camcorders were unable to capture homes with long driveways and elevated foundations because the camcorders were mounted to the vehicle at eye level. Tall trees and thick vegetation occasionally obstructed the view, making it difficult to analyze specific homes deemed potentially high risk.

Validation of the geo-referenced data collected in this study would allow it to be used in future research. Using secondary data sets in conjunction with the spatial video could increase the integrity of the data. Additional Los Angeles County parcel data was applied to the fire risk rankings to analyze if a home's age relates to its potential fire risk. Figure 6.3 combines the year built with "very high risk" rankings for each home located in the Altadena study areas.

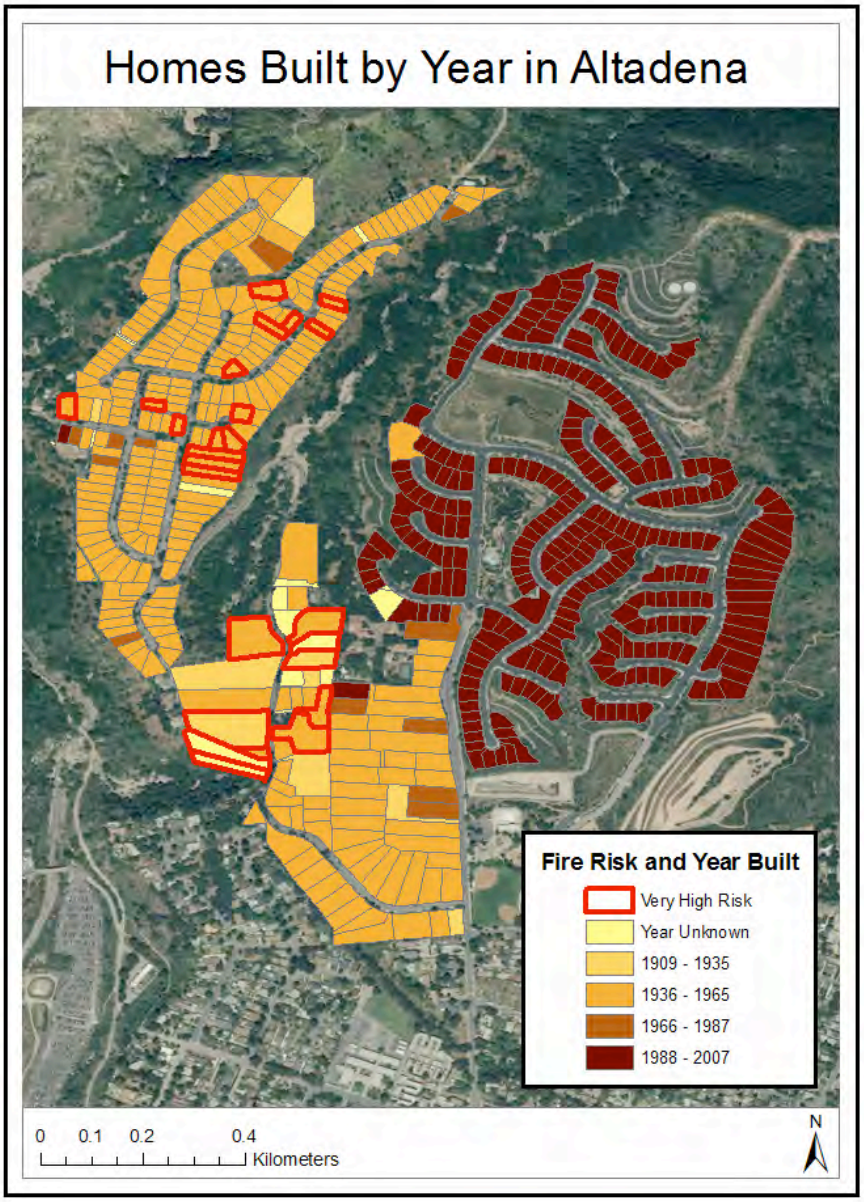

Figure 6.3: Comparison of year built and "very high risk" homes.

This shows that all of the "very high risk" homes are more than 40 years old. However, the concept of older homes being the only fire hazardous structures was not valid when this same technique was applied to the "high risk" parcels. This is an example of how combining different data sources allows for a further analysis.

The data collected for this study could be used for future research in a variety of ways. A cluster analysis could be conducted to determine if high-risk cluster patterns exist or if high-risk parcels are scattered randomly throughout a neighborhood. High-resolution aerial imagery could be used for fire risk assessment by examining backyard vegetation and defensible space. Brad Weisshaupt (Personal Interview, October 4, 2011) suggests combining the fire risk rankings from this study with external risk factors like canyons and wind speed to develop different types of categories for fire risk. The spatial video data collected for this thesis project has been archived in case a future wildfire burns any of the study areas. This would allow the fire department to correlate damaged homes with high-risk characteristics. Similar mobile mapping techniques could also be used to collect spatial data after a wildfire for damage assessment research, recovery assistance, and developing improved methods for predicting high risk areas.

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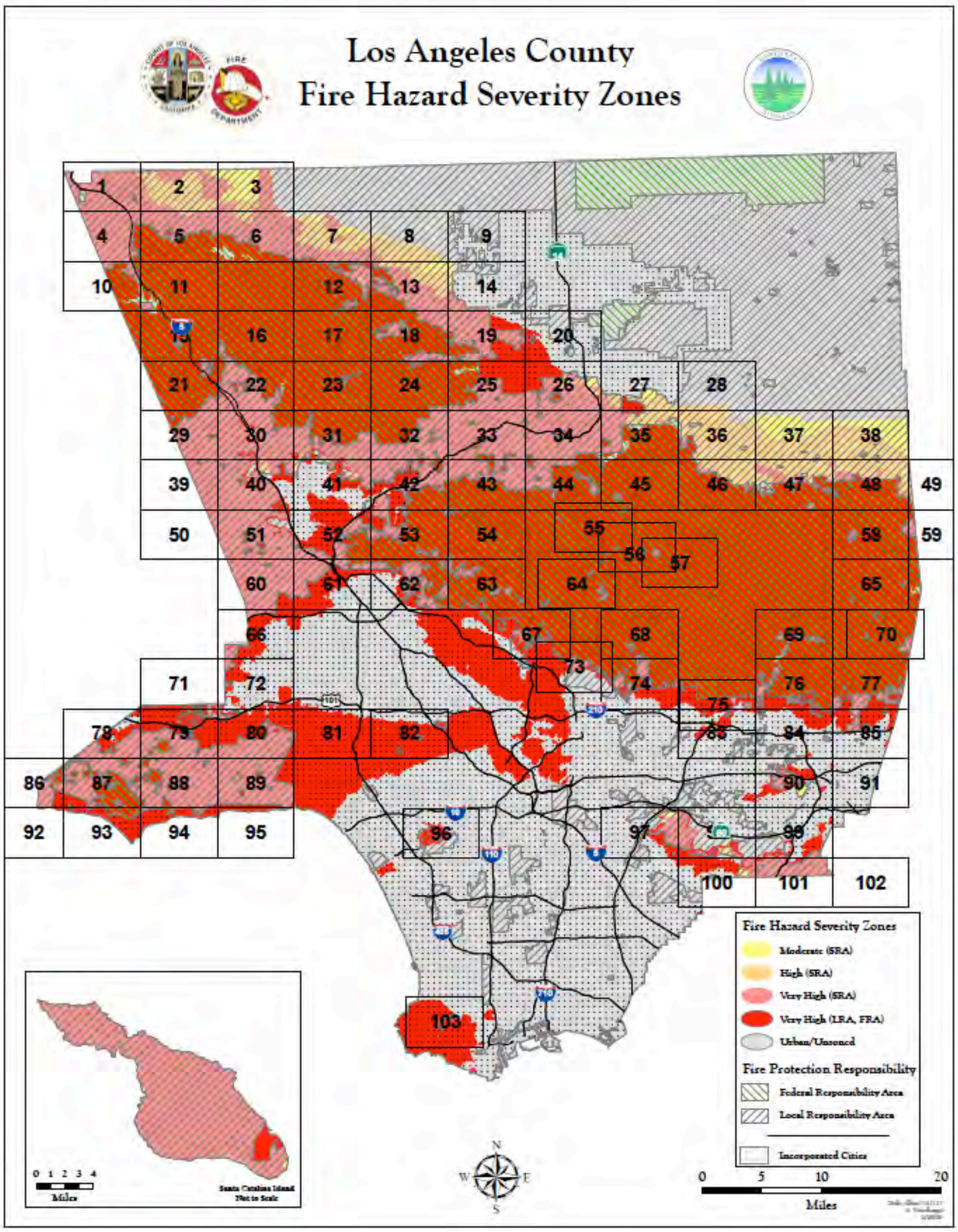
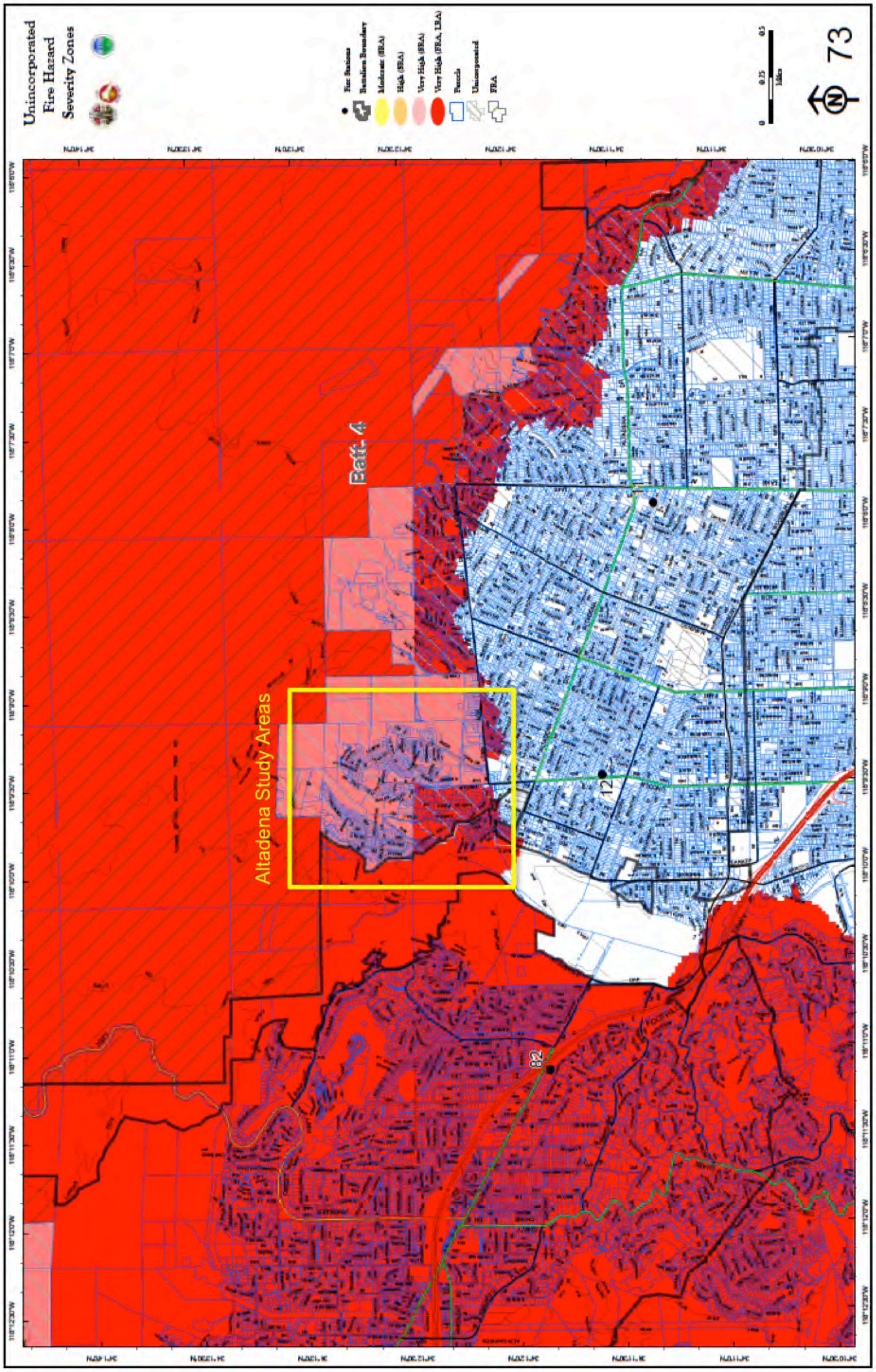
Appendices

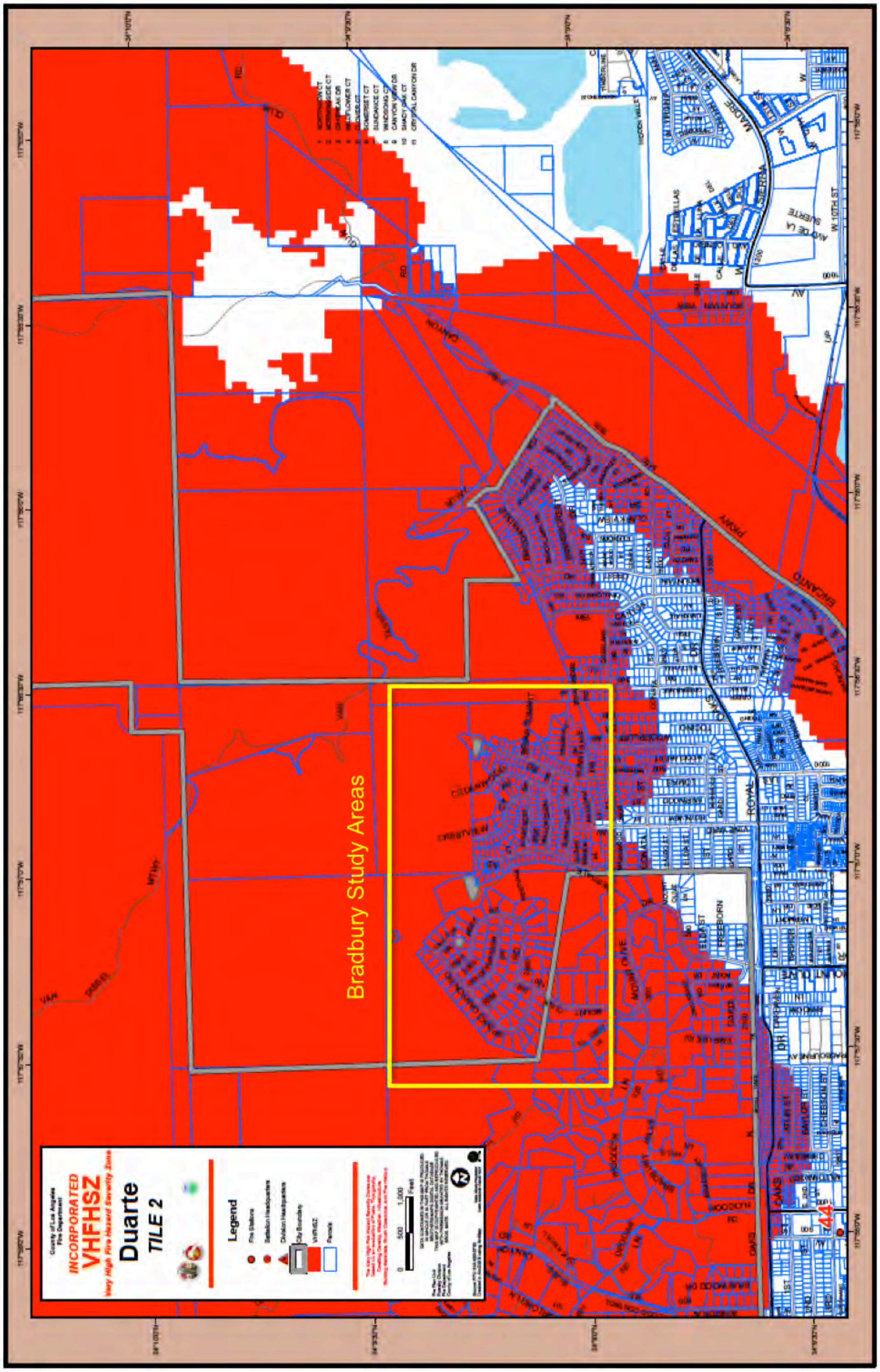
Appendix A

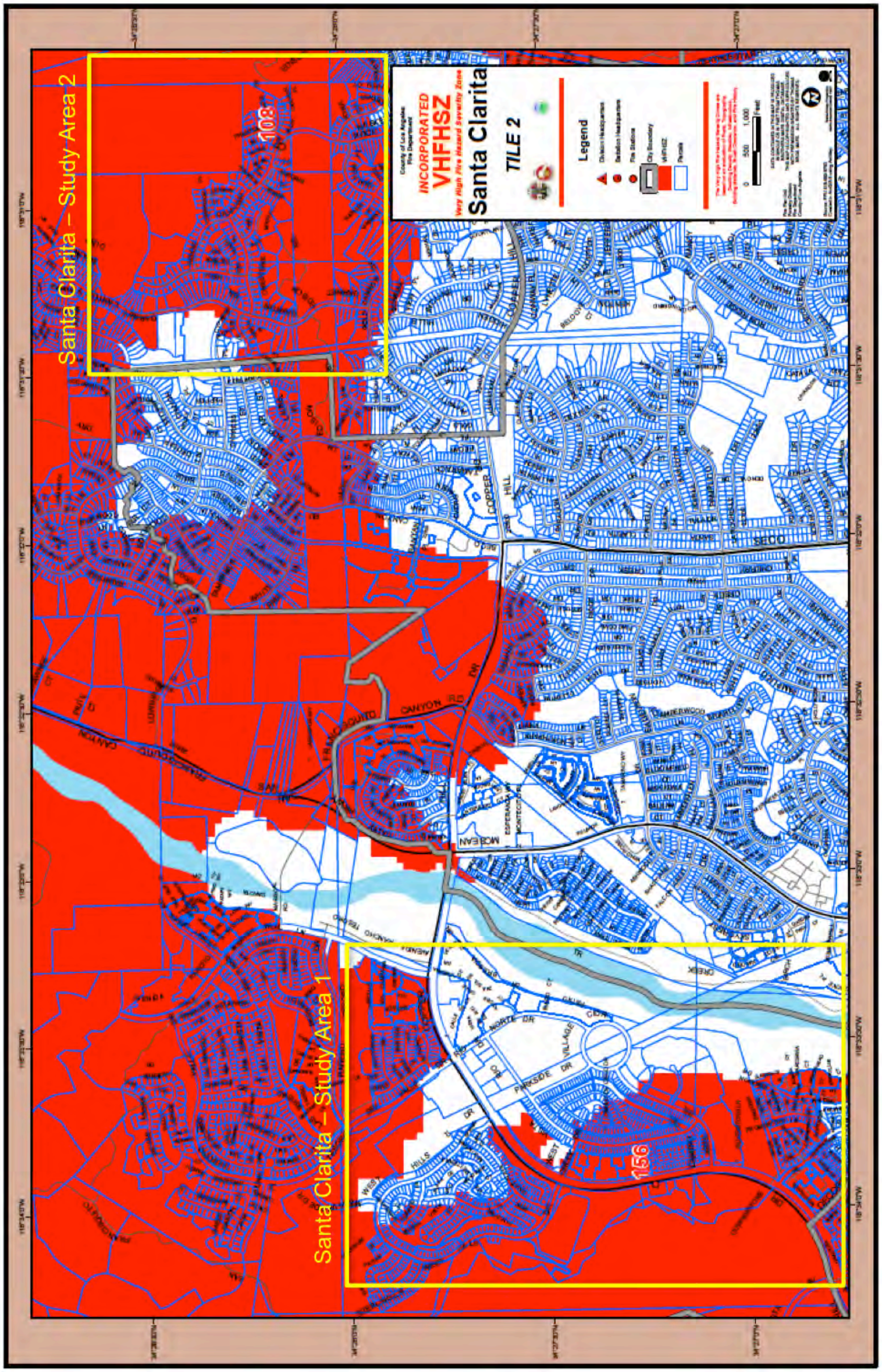
County of Los Angeles Fire Department
"Very High Fire Hazard Severity Zone" Maps





Unincorporated
Fire Hazard
Severity Zones
Fire Stations
Battalion Boundary
Moderate (SRA)
High (SRA)
Very High (SRA)
Very High (FRA, LRA)
Parcels
Unincorporated
FRA
Miles
73
Batt. 4
Altadena Study Areas
12
82


Bradbury Study Areas
County of Los Angeles Fire Department
INCORPORATED
VHFHSZ
Very High Fire Hazard Severity Zone
Duarte
TILE 2
Legend


Santa Clarita – Study Area 2
Santa Clarita – Study Area 1
108
156
INCORPORATED
VHFHSZ
Santa Clarita
TILE 2
Legend
SECO
CANYON RD
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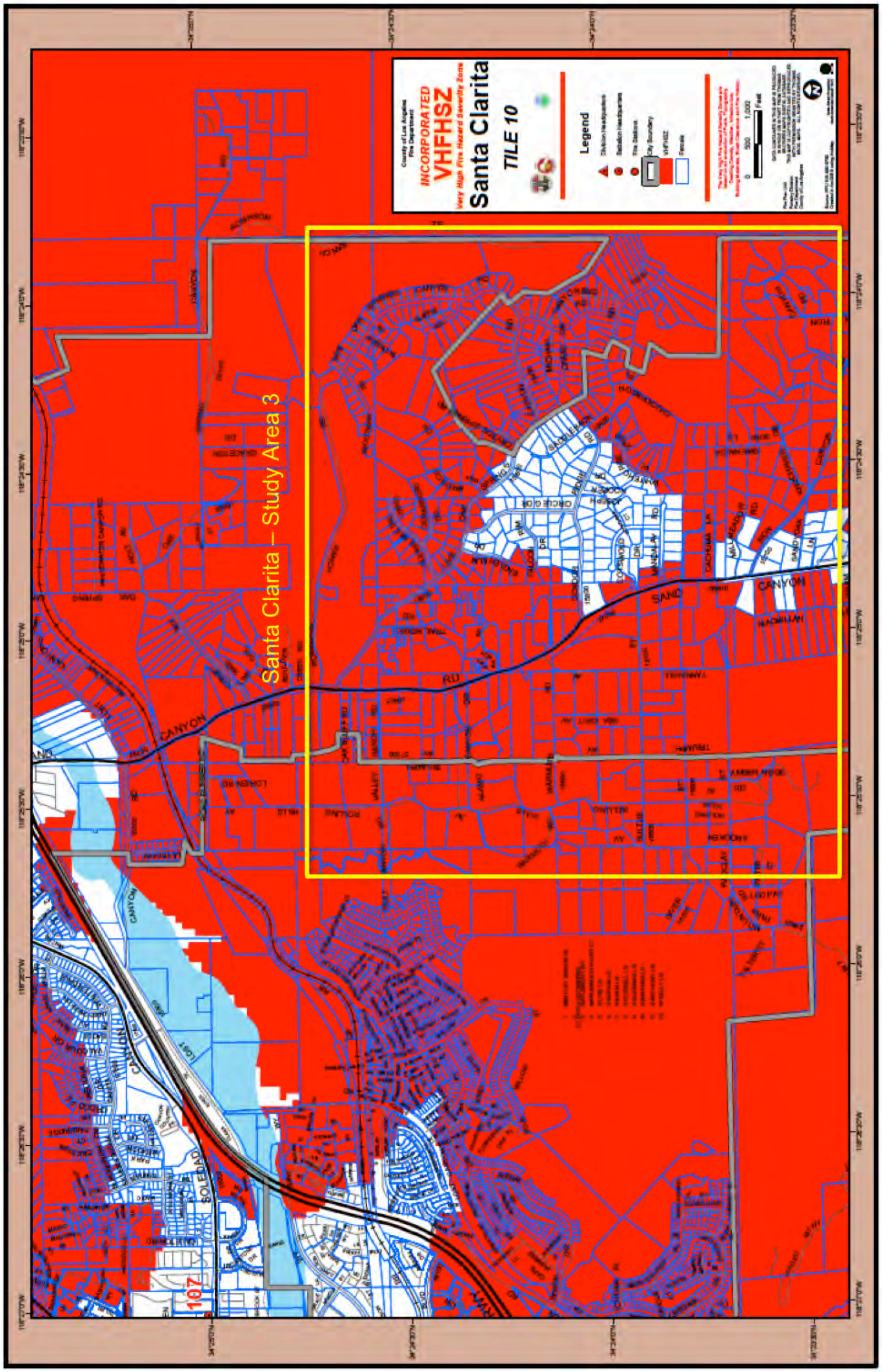
PARKSIDE DR
HILL
COPPER


Santa Clarita – Study Area 3
County of Los Angeles Fire Department
INCORPORATED
VHFHSZ
Very High Fire Hazard Severity Zone
Santa Clarita
TILE 10
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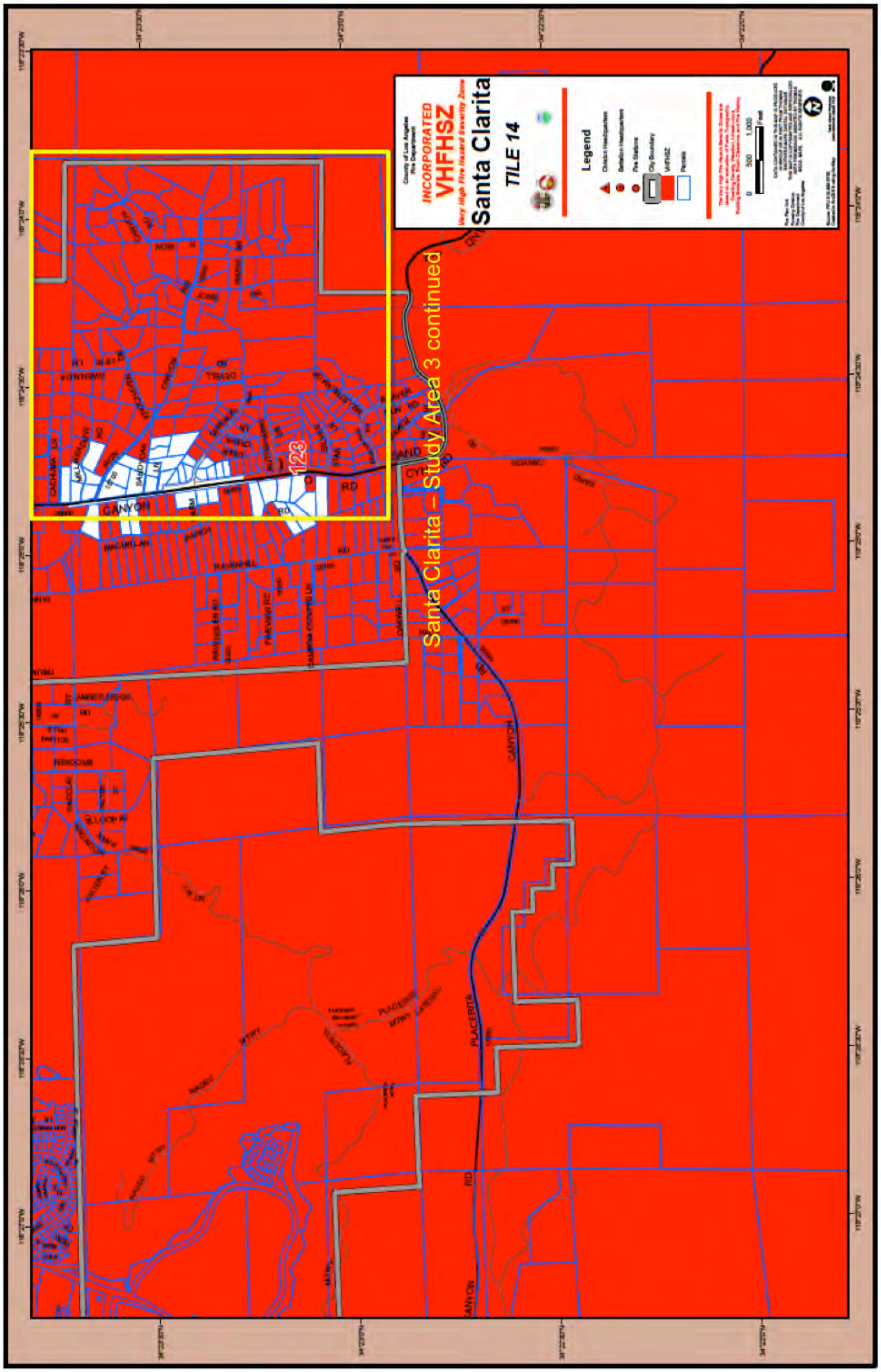
CANYON
RD
SOLEDAD
107


Santa Clarita – Study Area 3 continued
County of Los Angeles Fire Department
INCORPORATED
VHFHSZ
Very High Fire Hazard Severity Zone
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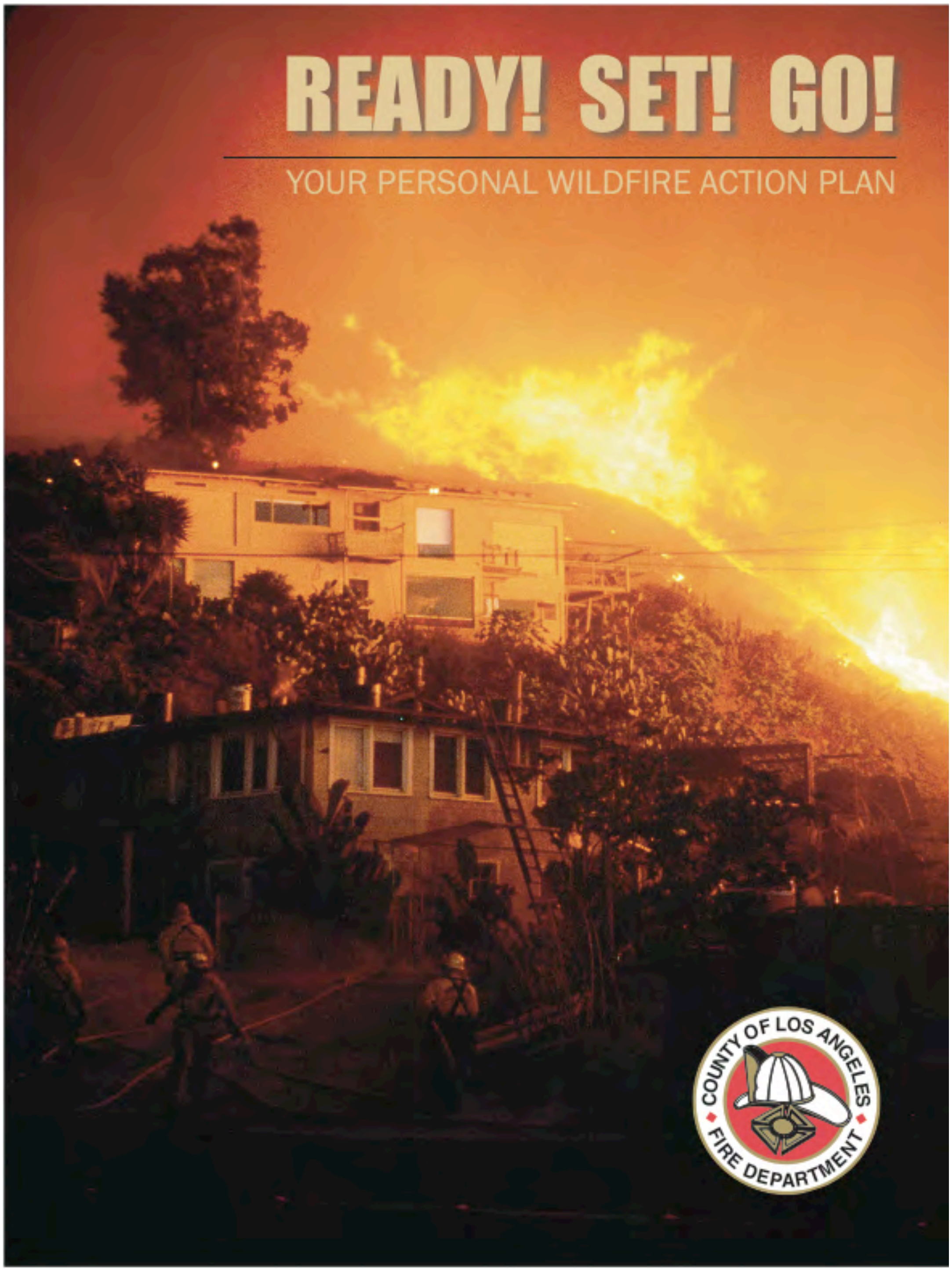
Appendix B

Ready! Set! Go! Your Personal Wildfire Action Plan



READY! SET! GO!

Wildfire Action Plan

Saving Lives and Property through Advance Planning

Dear Resident,

Los Angeles County is one of the most beautiful places to live, but for those living in what are called "urban interface areas," it does not come without risks. Fire is, and always has been, a natural part of this landscape. Many of us have chosen to live in brush-covered canyons and on hillsides which have historically burned long before homes were built. The fire season is now year-round, requiring firefighters and residents to constantly be on heightened alert for the threat of wildfire.

The Los Angeles County Fire Department takes every precaution to help protect you and your property from wildfire. In the event of a major wildfire, however, firefighting resources will be stretched. This reality requires you to take personal responsibility for protecting yourself, your family, and your property.

We have published this Ready, Set, Go! Personal Wildfire Action Plan to give you the tips and tools to successfully prepare for a wildfire. It will give you guidance on retrofitting your home with fire-resistive features. It will help you create the necessary defensible space around your home. This publication will help you prepare your home, yourself, and your family so that you can leave early, well ahead of a fast-approaching wildfire.

In Los Angeles County, wildfires are often fueled by dry vegetation and driven by hot, dry "Santa Ana" winds, making them extremely dangerous and impossible to control. However, many residents have built their homes and landscaped without fully understanding the impact that a wildfire could have on them. Few have adequately prepared their families for a quick evacuation. Many don't fully know the potential consequences of choosing to ignore an evacuation order until it is too late. We always recommend that you comply with any evacuation orders resulting from wildfire.

It's not a question of "if" but "when" the next major wildfire will occur in Los Angeles County. That's why the most important person in protecting your life and property is not the firefighter, but yourself. Through advance planning and preparation, we can all be ready for the next wildfire. I hope that you find the tips included in this publication helpful in creating heightened situational awareness and a more fire-safe environment for you and your family. For more information, visit our website at www.fire.lacounty.gov, or call our Public Information Office at (323) 881-2411.

Stay safe,

Fire Chief, P. Michael Freeman

INSIDE

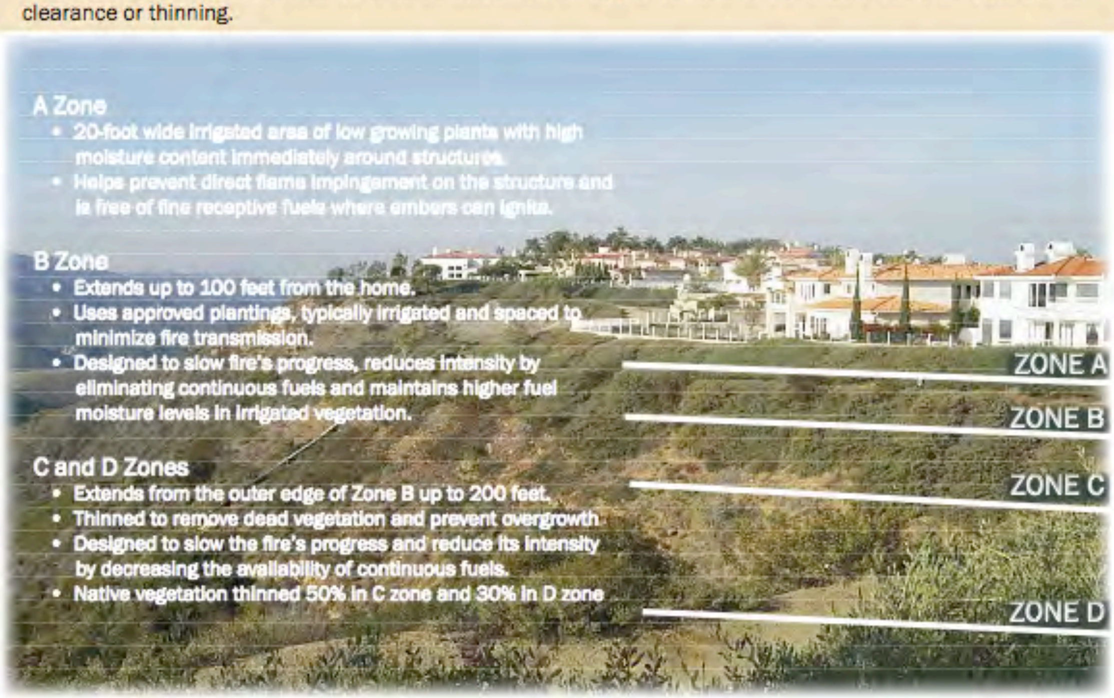
Ready! Set! Go! is also supported by:

Get READY - Create a Defensible Home

A defensible home is a home that has the greatest potential for surviving a wildfire. Defensible homes are those homes that are in compliance with the County of Los Angeles Brush Clearance requirements or have been through the Fire Department's Fuel Modification Program and have been constructed in accordance with the latest building standards for the fire zones.

What is Fuel Modification ?

The Fuel Modification Program affects new structures and developments built in the high fire hazard areas. A plan is approved by the Fire Department that helps protect homes and neighborhoods by requiring vegetation planted in zones around structures to be selected from an approved list and identifies areas that require brush clearance or thinning.



What is Defensible Space ?

Defensible space is the area around a structure free of flammable plants and objects that creates a zone in which firefighters can operate safely in order to help protect a home during a wildfire. This space is wide enough to prevent direct flame impingement and reduce the amount of radiant heat reaching the structure. The defensible space for each structure varies, depending on the type of vegetation and topography.

ZONE 1

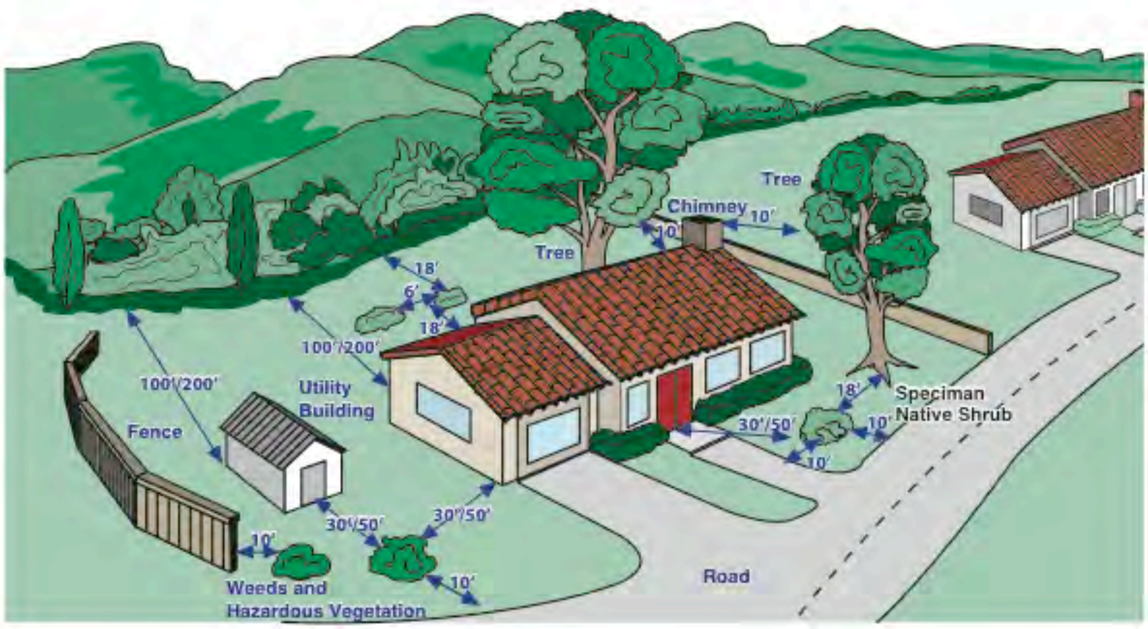
Extends 30 feet out from buildings, structures, decks, etc.

> Remove all flammable vegetation or other combustible growth within 30 feet of any structure or within 50 feet of any structure in areas determined to be high hazard. Single trees, ornamental shrubbery or cultivated ground covers may be permitted provided they are maintained in such a manner that they do not readily transmit fire from native vegetation to the structure.

ZONE 2

Thin out and remove additional vegetation an additional 70 feet from the structure, for a total of 100 feet. The inspecting officer may require an additional 100 feet of thinning or removal, for a total of 200 feet due to high fire hazard.

Note: Special attention should be given to the use and maintenance of ornamental plants known or thought to be high hazard plants when used in close proximity to structures. Examples include Acacia, Cedar, Cypress, Eucalyptus, Juniper, Pine, and Pampas grass. These plantings should be properly maintained and not allowed to be in mass plantings that could transmit fire from the native growth to any structure.



What is a "Hardened" Home ?

The ability of your home to survive wildfire depends on its construction materials and the quality of the "defensible space" surrounding it. Embers from a wildfire will find the weak link in your home's fire protection scheme and gain the upper hand because of a small, overlooked or seemingly inconsequential factor. However, there are measures you can take to safeguard your home from wildfire. While you may not be able to accomplish all of the measures listed below, each will increase your home's, and possibly your family's, safety and survival during a wildfire.

ROOFS
A roof is the most vulnerable surface for embers to land, lodge and start a fire; this includes roof valleys, open ends of barrel tiles, and rain gutters.

EAVES
Embers gather under open eaves and ignite exposed wood or other combustible material.

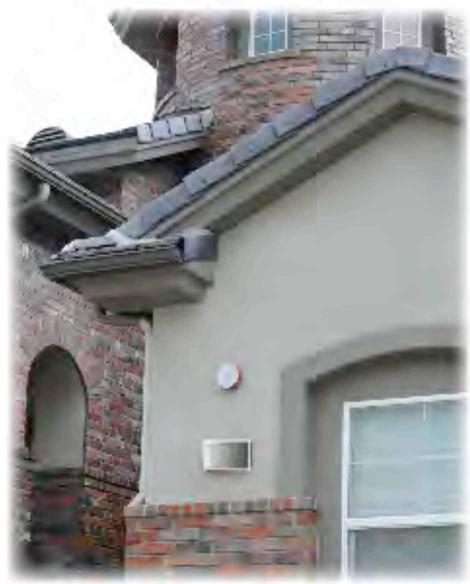
VENTS
Embers enter the attic or other concealed space and ignite combustible materials. Vents in eaves and cornices are particularly vulnerable, as are any unscreened vents.

WALLS
Combustible siding or other combustible or overlapping materials provide a surface and crevice for embers to nestle and ignite.

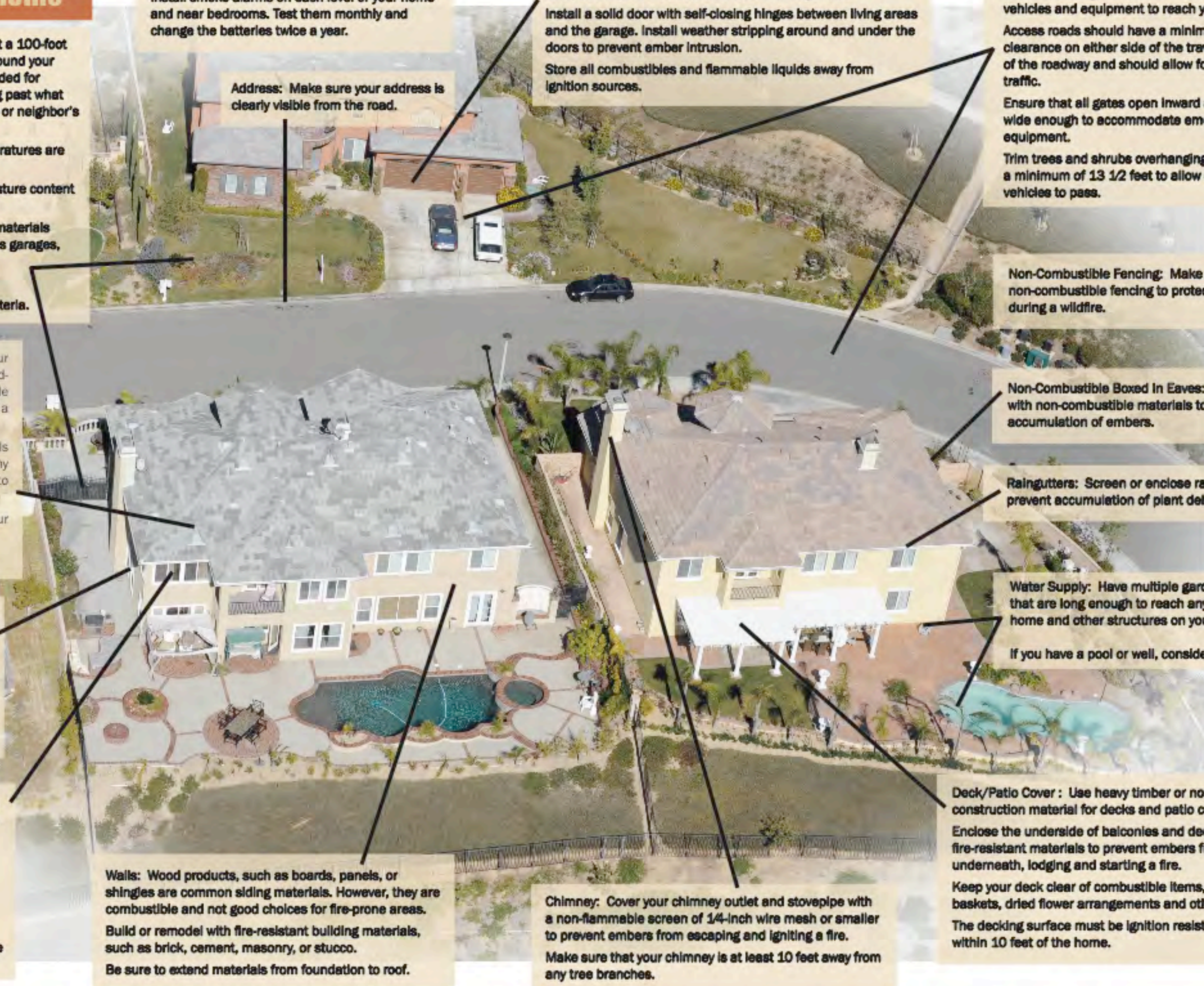
WINDOWS & DOORS
Embers can enter gaps in doors, including garage doors. Plants or combustible storage near windows can be ignited from embers and generate heat that can break windows and/or melt combustible frames.

BALCONIES & DECKS
Embers collect in or on combustible surfaces or undersides of decks and balconies, ignite the material, and enter the home through walls or windows.

To harden your home even further, consider protecting it homes with a residential fire sprinkler system. In addition to extinguishing a fire started by an ember that enters your home, it also protects you and your family 24/7, year-round, from any fire that may start in your home, not just wildfire.



Tour a Wildfire Ready Home



Home Site and Yard: Ensure that you have at least a 100-foot radius of defensible space (cleared vegetation) around your home. Note that even more clearance may be needed for homes in severe hazard areas. This means looking past what you own to determine the impact a common slope or neighbor's yard will have on your property during a wildfire.

Cut dry weeds and grass before noon when temperatures are cooler to reduce the chance of sparking a fire.

Landscape with fire-resistant plants with high moisture content and are low-growing.

Keep woodpiles, propane tanks and combustible materials away from your home and other structures, such as garages, barns, and sheds.

Ensure that trees are far away from power lines.

See our website for a list of plants and planting criteria.

Roof: Your roof is the most vulnerable part of your home because it can easily catch fire from wind-blown embers. Homes with wood-shake or shingle roofs are at a higher risk of being destroyed during a wildfire than homes with fire-resistant roofs.

Build your roof or re-roof with fire-resistant materials that include composition, metal or tile. Block any spaces between roof decking and covering to prevent ember intrusion.

Clear pine needles, leaves and other debris from your roof and gutters.

Cut any tree branches within ten feet of your roof.

Vents: Vents on homes are particularly vulnerable to flying embers.

All vent openings should be covered with 1/8-inch or smaller metal mesh. Do not use fiberglass or plastic mesh because they can melt and burn.

Attic vents in eaves or cornices should be baffled or otherwise prevent ember intrusion (mesh is not enough).

Windows: Heat from a wildfire can cause windows to break even before the home ignites. This allows burning embers to enter and start internal fires. Single-paned and large windows are particularly vulnerable.

Install dual-paned with the exterior pane of tempered glass windows to reduce the chance of breakage in a fire.

Limit the size and number of windows in your home that face large areas of vegetation.

Inside: Keep working fire extinguishers on hand.

Install smoke alarms on each level of your home and near bedrooms. Test them monthly and change the batteries twice a year.

Address: Make sure your address is clearly visible from the road.

Walls: Wood products, such as boards, panels, or shingles are common siding materials. However, they are combustible and not good choices for fire-prone areas.

Build or remodel with fire-resistant building materials, such as brick, cement, masonry, or stucco.

Be sure to extend materials from foundation to roof.

Garage: Have a fire extinguisher and tools such as a shovel, rake, bucket, and hoe available for fire emergencies.

Install a solid door with self-closing hinges between living areas and the garage. Install weather stripping around and under the doors to prevent ember intrusion.

Store all combustibles and flammable liquids away from ignition sources.

Chimney: Cover your chimney outlet and stovepipe with a non-flammable screen of 1/4-inch wire mesh or smaller to prevent embers from escaping and igniting a fire.

Make sure that your chimney is at least 10 feet away from any tree branches.

Driveways and Access Roads: Driveways should be designed to allow fire and emergency vehicles and equipment to reach your house.

Access roads should have a minimum 10-foot clearance on either side of the traveled section of the roadway and should allow for two-way traffic.

Ensure that all gates open inward and are wide enough to accommodate emergency equipment.

Trim trees and shrubs overhanging the road to a minimum of 13 1/2 feet to allow emergency vehicles to pass.

Non-Combustible Fencing: Make sure to use non-combustible fencing to protect your home during a wildfire.

Non-Combustible Boxed In Eaves: Box in eaves with non-combustible materials to prevent accumulation of embers.

Raingutters: Screen or enclose raingutters to prevent accumulation of plant debris.

Water Supply: Have multiple garden hoses that are long enough to reach any area of your home and other structures on your property.

If you have a pool or well, consider a pump.

Deck/Patio Cover: Use heavy timber or non-flammable construction material for decks and patio covers.

Enclose the underside of balconies and decks with fire-resistant materials to prevent embers from blowing underneath, lodging and starting a fire.

Keep your deck clear of combustible items, such as baskets, dried flower arrangements and other debris.

The decking surface must be ignition resistant if it's within 10 feet of the home.

Create Your Own Wildfire Action Plan

Your Wildfire Action Plan must be prepared with all members of your household well in advance of a fire.

Use these checklists to help you prepare your Wildfire Action Plan.

Each family's plan will be different, depending on their situation.

Once you finish your plan, rehearse it regularly with your family and keep it in a safe and accessible place for quick implementation.

Get SET - Prepare Your Family

- ☐ **Create a Family Disaster Plan that includes** meeting locations and communication plans, and rehearse it regularly. Include in your plan the evacuation of large animals, such as horses.
- ☐ Have fire extinguishers on hand and train your family how to use them.
- ☐ Ensure that your family knows where your gas, electric and water main shut-off controls are and how to use them.
- ☐ Plan several different escape routes.
- ☐ Designate an emergency meeting location outside of the fire hazard area.
- ☐ Assemble an emergency supply kit as recommended by the American Red Cross.
- ☐ Appoint an out-of-area friend or relative as a point of contact so that you can communicate with family members who have relocated.
- ☐ Maintain a list of emergency contact numbers posted near your phone and in your emergency supply kit.
- ☐ Keep an extra emergency supply kit in your car in case you can't get to your home because of fire.
- ☐ Have a portable radio or scanner so that you can stay updated on the fire.

As the Fire Approaches

- ☐ Alert family and neighbors.
- ☐ Dress in appropriate clothing (i.e., clothing made from natural fibers, such as cotton, and work boots). Have goggles and a dry bandana or particle mask handy.
- ☐ Ensure that you have your brush fire survival kit on hand that includes necessary items, such as a battery-powered radio, spare batteries, emergency contact numbers, and ample drinking water.
- ☐ Stay tuned to your TV or local radio stations for updates, or check the Fire Department website at www.fire.lacounty.gov.
- ☐ Remain close to your house, drink plenty of water and keep an eye on your family and pets if you did not evacuate.

OUTDOOR CHECKLIST

- ☐ Gather up flammable items from the exterior of the house and bring them inside (e.g., patio furniture, children's toys, doormats, etc.) or place them in your pool.
- ☐ Turn off propane tanks.
- ☐ Connect garden hoses to outside taps.
- ☐ Don't leave sprinklers on or water running - they can waste critical water pressure.
- ☐ Leave exterior lights on.
- ☐ Back your car into the garage. Shut doors and roll up windows.
- ☐ Have a ladder available.
- ☐ Patrol your property and extinguish all small fires.
- ☐ Seal attic and ground vents with pre-cut plywood or commercial seals.

INDOOR CHECKLIST

- ☐ Shut all windows and doors, leaving them unlocked.
- ☐ Remove flammable window shades and curtains and close metal shutters.
- ☐ Remove lightweight curtains.
- ☐ Move flammable furniture to the center of the room, away from windows and doors.
- ☐ Shut off gas at the meter. Turn off pilot lights.
- ☐ Leave your lights on so firefighters can see your house under smoky conditions.
- ☐ Shut off the air conditioning.

IF YOU ARE TRAPPED: SURVIVAL TIPS

- ☐ Shelter away from outside walls.
- ☐ Patrol inside your home for spot fires and extinguish them.
- ☐ Wear long sleeves and long pants made of natural fibers such as cotton.
- ☐ Stay hydrated.
- ☐ Ensure you can exit the home if it catches fire (remember if it's hot inside the house it is four to five times hotter outside).
- ☐ After the fire has passed, check your roof and extinguish any fires, sparks or embers.
- ☐ Check inside the attic for hidden embers.
- ☐ Patrol your property and extinguish small fires.
- ☐ If there are fires that you cannot extinguish with a small amount of water or in a short period of time, call 9-1-1.

GO Early

By leaving early, you will give your family the best chance of surviving a wildfire. You also help firefighters by keeping roads clear of congestion, enabling them to move more freely and do their job.

Make a Kit

- Keep a pair of old shoes and a flashlight handy for a night evacuation.
- Keep the six "P's" ready, in case an immediate evacuation is required:
    - People and pets
    - Papers, phone numbers, and important documents
    - Prescriptions, vitamins, and eyeglasses
    - Pictures and irreplaceable memorabilia
    - Personal computers (information on hard drive and disks)
    - "Plastic" (credit cards, ATM cards) and cash

WHEN TO LEAVE

Leave early enough to avoid being caught in fire, smoke, or road congestion. Don't wait to be told by authorities to leave. In an intense wildfire, they may not have time to knock on every door. If you are advised to leave, don't hesitate!

WHERE TO GO

Leave to a predetermined location (it should be a low-risk area, such as a well-prepared neighbor or relative's house, a Red Cross shelter or evacuation center, motel, etc.)

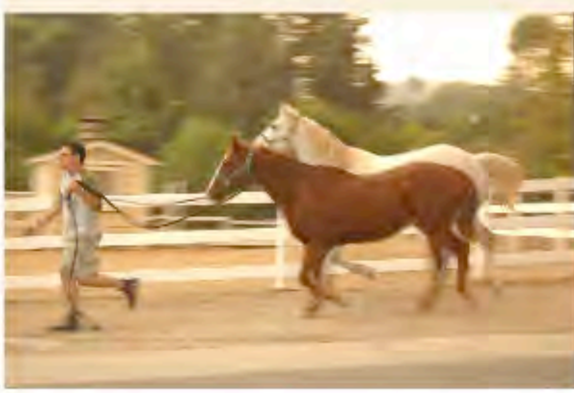
HOW TO GET THERE

Have several travel routes in case one route is blocked by the fire or by emergency vehicles and equipment. Choose an escape route away from the fire.

WHAT TO TAKE

Take your emergency supply kit containing your family and pet's necessary items, such as cash, water, clothing, food, first aid kits, medications, and toys. Also, don't forget valuables, such as your computer, photos, and important documents.

Organize your family members and make arrangements for your pets.



Write up your Wildfire Action Plan and post it in a location where every member of your family can see it. Rehearse it with your family.

My Personal Wildfire Action Plan

During High Fire Danger days in your area, monitor your local media for information on brush fires and be ready to implement your plan. Hot, dry, and windy conditions create the perfect environment for a wildfire.

Important Phone Numbers

Emergency: ____________ ____________ ____________

____________ ____________ ____________

School: ____________ ____________ ____________

____________ ____________ ____________

Family: ____________ ____________ ____________

____________ ____________ ____________

Friends: ____________ ____________ ____________

____________ ____________ ____________

Animal Shelter: ________________________________

____

When to go: ________________________________

____

Where to go: ________________________________

____

How to get there: ________________________________

________________________ Destination: ____________

What to take: ☐ Insurance Papers ☐ Photos ☐ Prescriptions ☐ Important Documents

____

Who to tell (before and after): ________________________________

Los Angeles County Fire Department
If you have an emergency, call **911**
Public Information Office **(323) 881-2411**
Web site: **www.fire.lacounty.gov**