PRE-INCIDENT PLAN MAPPING IN KERN COUNTY'S WILDLAND URBAN INTERFACE

by

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DEDICATION

I dedicate this thesis to my parents Jon and Ann; you really did well. Also, to Julie and Jerry, you guys have always been and continue to be great examples for me; thanks for setting the bar high.

ACKNOWLEDGEMENTS

I would like to express my sincere appreciation to the Kern County Fire Department for their continued support throughout my time spent working with and among them. As a young professional, it was undoubtedly a worthwhile learning experience. Throughout my time with the department I developed invaluable skills that will lead to success in my future endeavors.

I want to thank Chief Ken Stevens for recognizing my potential and allowing me the opportunity to show what I could do, something I will not soon forget. It also gives me great pleasure to convey my sincere gratitude to Kern County Fire Captain Derrick Davis for everything he's done for me personally and professionally. I can honestly say his support and guidance has been second to none, and I honestly don't believe the word gratitude even covers half of my appreciation.

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ABSTRACT

The interface between former wildland and urban sprawl is of major concern in the Western United States throughout wildfire-prone areas. Kern County, California, northwest of Los Angeles, is one such heavily impacted area. Recent major wildfires there have portrayed extreme fire behavior and caused significant property damage underscoring the need for fire prevention efforts before emergency response. This thesis demonstrates the utility of pre-incident planning (PIP) maps for wildfire mitigation built using geographic information system (GIS)-based cartography. PIP maps highlight imperative spatial information for emergency responders during the first, crucial "golden hour" of a wildfire, particularly accurate locations for structures and water sources, along with ratings of roadways for fire engine access. The PIP approach would not be possible without GIS, in fact, owing to the need for an accurate, up-to-date spatial data and voluminous map production. In both concept and execution, PIP maps, have proven valuable far beyond their original intention aiding in at least a dozen major wildfires since 2008, helping to protect over 4000 structures. In addition, PIP maps have shown qualitative benefits, improving firefighter safety, incident organization, and emergency communication. Constructing PIP maps for Kern County cost $115,000; the return on investment is estimated in the millions of dollars.

CHAPTER 1: INTRODUCTION

In the past 40 years, rising spring and summer temperatures, along with shrinking winter snowpack, have increased the risk of wildfires in many parts of the Western United States. Studies suggest that continued climate change may increase the risk of wildfires in the coming decades (Climate Central 2012).

As urban development continues, it is becoming increasingly rare to have a wildfire incident that does not involve people and their homes (Mutch et al. 2011). People are at greater risk due largely to decades of rapid population growth encroaching on areas where natural high intensity wildfires have regularly occurred, long before human occupation (Keeley and Fotheringham 2006). Human presence and population pressure have added combustible materials like homes and gardens, increased wildfire ignitions through anthropogenic causes such as transportation, as well as created dangerous congestion that both accelerates wildfire spread and hampers wildfire-fighting.

Paradoxically, government wildfire suppression policies tend to result in accumulation of forest fuels, including deadfall and litter. Predictions for prolonged droughts and extreme weather events (Weeks 2013) make climate change another major driver of the wildfire danger (Burton 2012). Overall, in the Western United States particularly, wildfires have become larger and more numerous since 1970; a trend estimated to continue through at least mid- 21^{st} century (Bump 2012). Many of these wildfires directly impact human settlements between the wildland areas and urban sprawl, commonly known as the wildland-urban-interface (WUI).

For fire protection agencies, WUI areas are of major concern because of the large and growing populations there. Preparation for wildfire scenarios in WUI areas has increased in recent years including the development of comprehensive pre-incident plans and maps of at-risk areas, e.g. Hofer 2004[1]. However, most plans have traditionally focused on one or a few major at-risk communities while effectively ignoring other equally risky "pockets" of the WUI population.

To fill the pockets in Kern County, a program of pre-incident planning (PIP) maps of WUI areas was initiated by Kern County Fire Department (KCFD) in 2008. Major objectives for the PIP program was to make the WUI maps broadly applicable and easily updateable for all wildland areas where people reside. In 3 ½ years, the entirety of Kern's WUI residential areas were mapped.

This thesis consists of seven chapters detailing the different aspects of PIP mapping of WUI areas and its products commonly referred as PIP maps. Chapter 2 provides perspective through a background on wildfire, the wildland urban interface, and the emergency management cycle, along with traditional application of GIS in wildfire management. Chapter 3 presents the PIP map project done in Kern County, with brief descriptions of the county's wildfire history and KCFD's wildfire management program. Chapter 4 demonstrates the PIP map product and outlines the GIS methods used in its voluminous map production. Chapter 5 documents the overwhelmingly positive results of PIP maps, from both fire-fighter feedback and management cost-benefit perspectives.

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[1] Daniel Hofer. "GIS Applications for Wild-land Urban Interface Fire Planning: A Case Study in Silverado Canyon, Orange County, CA." *California State University, Long Beach.* May 2004.

Chapter 6 argues for wider use of PIP maps, notwithstanding some limitations, and makes suggestions future research and development of the concept. Finally, Chapter 7 summarizes PIP maps as a beneficial and cost-effective application of GIS for dealing with wildfire in the West.

CHAPTER 2: BACKGROUND

Wildfires are a fearsome natural hazard, which have an increasingly complicated relationship with humans. In this chapter the prevalence of wildfire in the WUI is illustrated, and the management of wildfire through mitigation and preparedness practices is explored. Emphasis is placed on studies, applications, and different methods for using GIS as an emergency response tool.

2.1 The Evolution of Wildfires and the Human Presence

Wildfire is a naturally-occurring process in the environment, which has been important in the maintenance of forests, brush lands, and grasslands throughout history. In semi-arid regions, such as the Western United States, wildfire supports, and is critical to, the maintenance of ecosystem structure, function, and health (California Department of Forestry and Fire Protection 2007). Prior to European settlement here, wildfires burned many millions of acres each year, but increasingly society has chosen to deal aggressively with both naturally occurring and anthropogenic (human-caused) wildfires. Where once only natural resources were threatened by wildfire, the threats now extend to life and property.

America's first WUI fire, the Peshtigo Fire, occurred in Wisconsin in 1871, claiming 1200 lives. As a result of this signal event, wildfire began to be viewed as a menace to society: wildfire had to be controlled and suppressed whenever possible (Johnston 2001). In 1891, Congress and President Harrison established "National Forests" which initiated the United States Forest Service (USFS) and the nation's first forest-fire policy. For thirty years and three agency chiefs, early forest policy was to put-out all wildfires as rapidly as possible (Stephens and Ruth 2005). As a result, wildfire suppression became increasingly organized and seemingly very effective at first. Later it was realized that decades of suppression actually resulted in increased forest *fuel loads* and thus significantly increased the likelihood of large, severe wildfires (Board of Forestry and Fire Protection 2011). The residual fuel loads from the 20th century coupled with a growing human presence in forested areas have made for continually complicated wildfire suppression, particularly in the WUI.

2.2 The Birth of the Emergency Management Cycle

The WUI is the dangerous area where human-built structures and infrastructure mix with native vegetation (Platt 2010) or, more succinctly, "where combustible homes meet combustible vegetation" (Federal Emergency Management Agency 2012). The human population that exists in WUI areas is constantly in harm's way as it becoming increasingly rare to have a wildfire that does not involve people and their homes (Mutch et al. 2011). The WUI receives considerable emergency management attention because of recent increases in both the area burned annually by wildfire and the number of structures threatened (and sometimes destroyed) by wildfire.

Population growth in the WUI is one of the chief causes of growing wildfire complexity, perceived severity, and especially increased suppression costs (Johnston 2001). In the Western United States from the 1990s to 2007, over 8.5 million new homes were constructed in the WUI (Bushfire Cooperative Research Centre 2007). Frustratingly, in the WUI, where protection of structures is most challenging, anthropogenic wildfire ignitions are now more common than those from natural causes (Radeloff et al. 2005).

Wildfire is not a matter of *if*, but of *when* and *where*. Modern wildfire protection agencies have gone beyond wildfire suppression policy: now they must consider mitigation before wildfires occur and their own preparedness to handle complex, concurrent wildfires. Figure 1 illustrates mitigation and preparedness, along with response and recovery as key phases of the emergency management cycle[2]. Without all four phases in the cycle, today's wildfire management process would be deemed incomplete and inadequate.

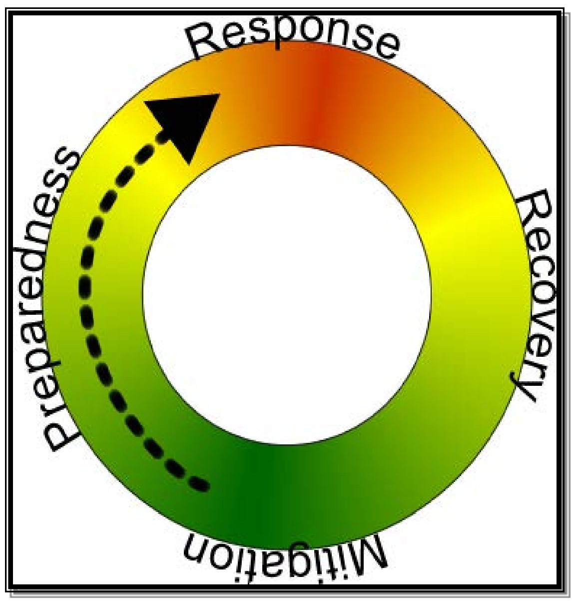

Figure 1: Four Phases in Emergency Management.

Wildfire mitigation is the lessening or prevention of impacts from wildfires before they (inevitably) occur. Wildfire preparedness involves inventorying properties at risk and resources for protecting them along with the development of specific plans of action

[2]"The Four Phases of Emergency Management: Module A (Unit 3)." *Federal Emergency Management Agency.* http://www.training.fema.gov/EMIWeb/downloads/is10_unit3.doc (accessed December 23, 2012)

in emergency. Carrying out these plans of action during the wildfire response phase requires strategic deployment of personnel and apparatus. In the aftermath of the emergency, recovery from wildfire to an area's prior state by rebuilding destroyed property and repairing essential infrastructure is paramount (Federal Emergency Management Agency n.d.). Together, the four phases contribute to wildfire management costs far beyond the publicized figures associated mostly with wildfire suppression on major incidents (Dale 2009). The importance of the four-phase approach is evident in federal policy-making and monetary allocation as well as through numerous studies (California Department of Forestry and Fire Protection 2007; Firewise Communities 2011; Stephens and Ruth 2005).

2.3 The "Golden Hour" of Emergency Response

Planning and preparedness are crucial precursors to an actual wildfire response: the speed at which actions take place in the first few minutes of an emergency call will often determine its outcome. For example, a typical "room and contents" structure-fire becomes dangerous within seven to ten minutes of ignition, and occupants who have not already escaped are not likely to survive. Likewise, accident victims will begin to suffer brain damage if deprived of oxygen for more than six minutes (Esri 2006; University of Maryland Medical Center 2011). The phrase "golden hour" is often used in wildfire situations to describe the opportunities for saving lives (the most important thing in emergency response). First responders must get to the scene, size up the emergency, and deploy: life-saving opportunities exist primarily in the first hour of an emergency and decline rapidly thereafter.

2.4 GIS, a cross-functional resource for Wildfire Management

In the last decade, geographic techniques have increasingly been broadly applied across the field of wildfire research and management. Geographic information systems (GIS) especially have become a major tool for wildfire mitigation and preparedness, response and recovery, as well as in academic and scientific research (Esri 2006; Esteves 2009) to assist emergency response. GIS technology has helped to map wildfire susceptibility (in terms of occurrence and risk) (Romero-Calcerrada et al. 2008), model prescribed burns and wildfire spread (Xu 2006), test different explanatory factors (Martinez et al. 2008), the spatial distribution of WUI infrastructure (Spyratos et al. 2007), look at the effects of fuel modification (Reinhardt et al., 2008), perform evacuation planning (Cova et al. 2005; Dennison et al. 2007), and support decision-making for individual wildfires (Yassemi 2006). Results from these widespread studies have aided in wildfire planning, natural resource management, risk assessment and management, assessment of short- and long-term post wildfire effects across space and time (Koutsias et al. 2004).

In wildfire response situations, the golden hour becomes paramount as the outflows from planning and mitigation are applied in real-time. Incident commanders[3] and wildfire managers must be able to quickly answer questions that mitigation and planning cannot, such as: What is the wildfire's rate of spread? What are the highest priority assets to be protected? What are the risks to firefighters and the community? What resources are needed to suppress the progression of the wildfire? Spatial

[3] The ICS position responsible for overall management of an incident; reports to the Agency Administrator for the agency having incident jurisdiction. http://www.nwcg.gov/pms/pubs/glossary/i.htm

information is essential for responding to these What questions with Where answers. Particularly in the golden hour of a wildfire response, quality spatial information is critical to effectively managing a dynamic incident where large numbers of public safety resources are deployed with various assignments (Esri 2007). GIS techniques have made access to maps and imagery commonplace. However, the maps generally lack important details, particularly in WUI areas, and the imagery may be out of date. The traditional applications of GIS for wildfire management have overwhelmingly focused on planning and mitigation; the technology has yet to be widely employed in the golden hour, because of its complexity.

Currently, the State of California's wildfire agency, CALFIRE, is testing a Web-based, Next-generation Incident Command System (NICS) that utilizes real-time maps to display spatial information such as engine and firefighter locations, evacuation routes, wildfire lines, fuel breaks, and weather conditions (Tolin 2012). Similarly, the USFS is evaluating new technology and developing spatial information delivery on a mobile platform to support wildfire operations (Hill and Zimmerman 2013). Both of these initiatives require real-time data delivery technology such as Inmarsat's Broadband Global Area Network (BGAN) service, which can deliver real-time GIS data sets to firefighters in remote areas[4]. However, much can be done with existing GIS technology.

2.5 Pre-Attack and Pre-Incident Planning

Pre-attack planning is an established form of GIS application in the golden hour of emergency response, to insure appropriate and efficient fire suppression in urban

[4] (Inmarsat BGAN to Bring Real-Time GIS Info to Wildfire Teams, September 2009)

settings (Alex 2013). To date, the majority of pre-attack plans exist for large facilities, buildings, and commercial areas where, like wildfires, scenarios can be chaotic. These plans, typically gathered in "map-books", provide intelligence on floor layouts, construction details, important hazards and safety information, response requirements, tactical recommendations, etc. that may be vital to establish a safe firefighting strategy (Engineering, Planning and Management, Inc. 2012; Technical Response Planning Corporation 2012; Fire Engineering Magazine 2009). Recognized success with pre-attack planning for large facilities has made this practice standard among emergency response agencies to accelerate informed decision-making while operating within critical and dynamic areas (The CAD Zone 2012).

Wildfires in the WUI also take place in critical and dynamic areas and call for numerous resources and coordinated responses from multiple agencies. Remarkably, emergency response agencies have come to expect a pre-attack plan and even map-books while en route and at the scene of structure fires, but not for WUI wildfires. Chris White of Anchor Point Group asks "Why are so many departments content to respond blindly to a wildland-urban interface fire?" He goes on to argue that pre-incident plan can provide the same level of pre-planning and firefighter safety that the fire service has become accustomed to in structural firefighting (White 2004).

Some fire departments are incorporating pre-incident planning into their wildfire management programs, though most are missing a practical application for GIS in the golden hour. Lassen Volcanic National Park developed a complete wildfire management plan covering all aspects of dealing with wildfire in the Park. The plan included important information on incident command, operations, planning, logistics, and communications for a response as well as complementary information on wildfire history, structure inventory, and interagency contact information (National Park Service 2004). Similarly, the Fairmont Fire Protection District in Colorado completed a wildfire management plan for one stretch of WUI, which answered expectable questions about infrastructure, potential wildfire behavior, hazards, and risks (Long 2011). CALFIRE has even required that each of its units and contract counties complete a comprehensive pre-fire plan (CAL FIRE 2012). However, Fairmont's, Lassen's, and other wildfire management plans have failed to effectively provide *all* the critical spatial information needed in the golden hour of a wildfire.

By contrast, in a celebrated case study regarding its Silverado Canyon WUI, Orange County Fire Authority (OCFA) determined that using GIS is almost essential for modern wildfire planning and response (Hofer 2004). OCFA's comprehensive pre-incident plan for Silverado Canyon (a historic wildfire corridor) not only demonstrated the same pre-fire organization, preparedness, and planning as the Fairmont and Lassen N.P but also emphasized the importance of the application of GIS through detailed maps and an organized collection of wildfire-critical spatial data.

CHAPTER 3: PIP MAP PROJECT

Southern California has a sizable population (15+ million) that is regularly and directly threatened by wildfire. Kern County, California is a large county in the extreme northwest “corner” of this region. The county has a population of 840,000 within its 8,161 square miles (slightly smaller than the State of New Jersey). The geography here creates a vast and diverse landscape due to acute elevation (206ft to 8,755ft) and climatic differences. Residential areas include a mix of urban and rural communities that checkerboard between the vast agriculture, oil, and federal lands for which, besides country music, Kern County is best known.Temperatures vary substantially throughout the year but in general the area experiences hot, dry summers and a low annual rainfall averaging less than six inches.

Figure 2: Kern County, CA.

The county's terrain is comprised of valley, mountain, and high desert which yield vegetation such as grasslands, chaparral, oak woodlands, and timber at the highest elevations. The county encompasses portions of the Sierra Nevada, Coastal, and Tehachapi Mountain ranges, the Mojave Desert, and parts of the San Joaquin, Indian Wells, and Antelope Valleys. Topography, hot and dry summers, abundant combustible fuels, and increasingly populated residential areas in Kern's WUI create an annual recipe for wildfires endangering people in this area of the state.

3.1 Kern County and Wildfires

Kern's documented history of wildfire dates back to 1900. Since then, over 800 large wildfires have been recorded, burning nearly 1 million acres. Eight of the largest fifteen wildfires (shown as white in Figure 3) in the county's history have occurred in the past twenty years. Recently, three of these large wildfires have caused "state of emergency" declarations by the Governor of California. The *Bull* and *West* fires in July of 2010 destroyed 14 and 50 structures, respectively, and damaged numerous other buildings and infrastructure. The *Canyon Fire* destroyed another 100 structures in early September of 2011. A week later, a lightning storm ignited another 50+ wildfires that scorched over 75,000 acres and required three separate incident command teams[5].

Kern County Fire Department (KCFD) is one of several agencies tasked with protecting the population, specifically from wildfires, in this large, diverse area. In terms of acreage, KCFD has the second largest *responsibility area* of state lands within

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[5]The Bakersfield Californian. *Lightning sparks more than 50 fires.* September 10, 2011. http://www.bakersfieldcalifornian.com/local/x682453012/Lightning-sparks-more-than-50-fires (accessed June 29, 2012).

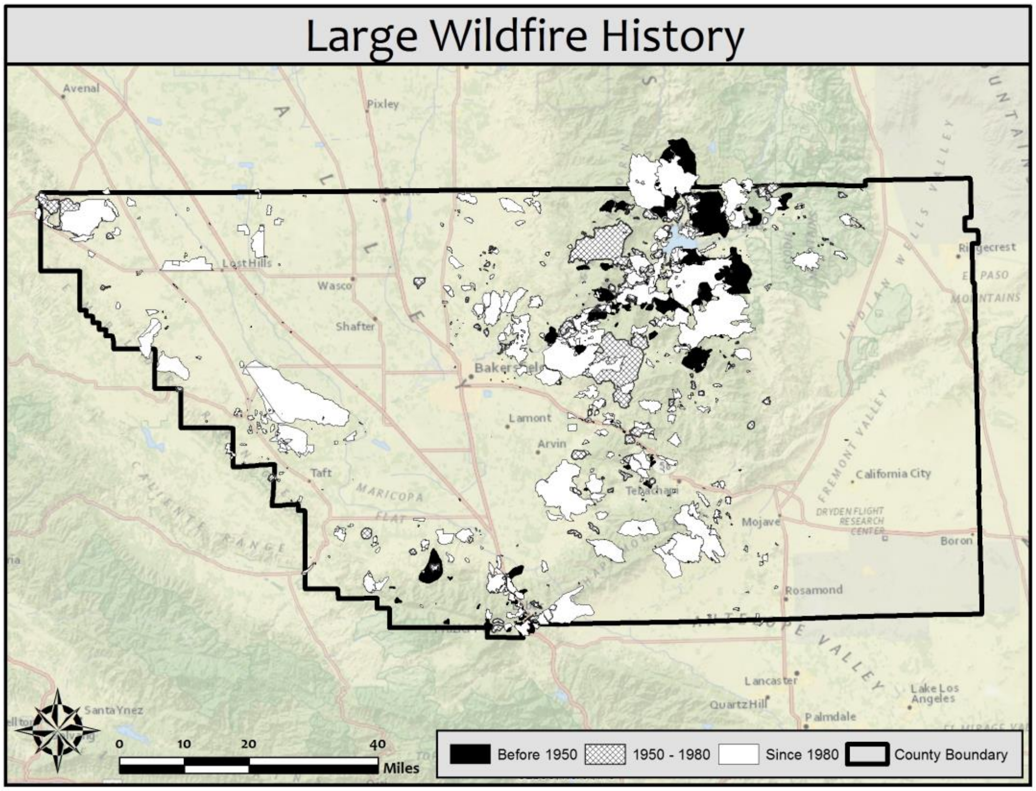


Figure 3: Kern County's Large Wildfire Perimeters since 1900.

California, for which it has an operating budget of $118 million. Additionally, the county leads the way statewide in wildfire activity, dealing with an average of 574 wildfire starts per year. KCFD's 550 uniformed firefighters are organized into seven geographic battalions with 46 fire stations throughout the jurisdiction. KCFD also has mutual aid agreements[6] with 14 fire agencies both within Kern County and in neighboring counties to further strengthen its services for emergency response. Most fire stations are staffed with a Firefighter, an Engineer, and a Fire Captain. Of KCFD's seven response

[6] Kern CountyFire Department. *About Us: Department Profile.* 2011. http://www.kerncountyfire.org/index.php?option=com_content&view=article&id=4&Itemid=15 (accessed 07 09, 2012).

battalions[7], five are comprised of multiple communities, housing tracts, and neighborhoods that fall in the WUI.

Awareness of continual wildfire activity brought about an eighth administrative battalion in KCFD, which manages its “air and wildland” operations. Battalion Eight is dedicated solely to wildfire planning and suppression and is tasked with determining needs before a wildfire starts, attempting to reduce fire-fighting costs and property losses, while increasing firefighter safety. Additionally, Battalion Eight manages the wildfire-specific fire apparatus including air responders (airplanes and helicopters) and ground responders (bulldozers, 4x4 fire engines, extra water-hauling “water tenders”, and hot-shot crews of wildland firefighters) who generally are called upon only for the suppression of wildfire. Battalion Eight has focused much of its efforts in the WUI on planning for wildfire response, enforcement and promotion of defensible space, strategic reduction of fuels, and public education, as well as cooperation of multiple agencies and non-profit organizations.

Beginning in 2000, to bolster its efforts toward the persistent risk of wildfire in Kern’s rural areas, Battalion Eight began regularly using mapping and GIS as an additional strategy. The department currently applies GIS for a wide range of training, planning, recovery actions, and especially for responding to emergencies. GIS technology facilitates faster, safer, and more accurate response to emergencies. GIS has become a vital tool for the fire service (especially KCFD) to more effectively represent location information within the confines of the principles of cartography. GIS has simplified

[7] A geographically partitioned area of common response for emergencies directed by a Battalion Chief who is responsible for the administration and direction of all activities within the area.

dealing with map scale, generalization, symbolizing and classifying features, and overall map design and thus more effective map products for emergency response. GIS has allowed the department to manage spatial data, determine response areas, and provide emergency responders with detailed map books and wall maps so that when a call comes, fire-fighters know where they are going and what is waiting for them there.

Overwhelming constraints exist on a fire-fighting GIS at the time of an event, especially within the golden hour. OCFA's Silverado Canyon case study pointed out the paucity of accurate, up-to-date spatial information for fire-fighter response in WUI areas (especially the structure inventory and road network there) which is also a major problem for KCFD, and many other departments.

Even for major events, wildfire responders' needs from GIS are not well met: getting a GIS facility setup on-scene typically takes a day and mapping often remains seriously in arrears of the event. With smaller minor events, GIS is typically not on-scene at all. This glaring *temporal hole* leaves first responders without access to critical information that helps them engage safely (on accessible roads) and quickly to suppress wildfire (by factoring in terrain/topology and using nearby water), carry out evacuations, effectively communicate, and provide structure protection (using addresses and structure locations), specifically in the golden hour. Wildfire-critical spatial information regarding road networks and engine accessibility (including locked gates), hydrants, water sources, structure locations, addresses, and topography are needed during the golden hour of a wildfire event, regardless of size.

In 2008, only general 1:24000 USGS topographic maps[8] were available to KCFD for use in a typical wildfire event in a rural area. Battalion Eight initiated the PIP map project to provide first responders access to wildfire-critical spatial information for WUI wildfires anywhere in the county. PIP maps use GIS, to organize and curate this wildfire-critical spatial information, which is pre-printed, and stored in special map-boxes throughout the county, available in advance of wildfire events. A sample PIP map, for the community of Golden Hills, near Tehachapi, appears in Figure 5.

3.2 The Pre-Incident Plan (PIP) Map

The cartographic "legwork" that goes into PIP maps reflects the importance placed on each map's quality and usability. To be effective for first responders, an accurately mapped community with quickly recognizable symbology for wildfire-critical

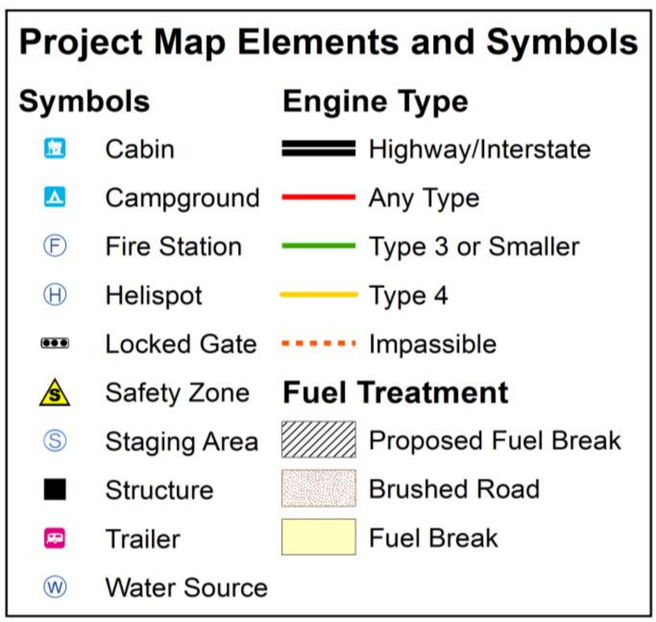


Figure 4: PIP Project Standard Map features and Symbols

[8] 1:24000 quadrangle maps are the best known USGS maps. Each 7.5-minute map shows an area that spans 7.5 minutes of latitude and 7.5 minutes of longitude, and are usually named after the most prominent feature in the quadrangle. 57,000 of them make up the entire United States.

features is essential. Accordingly, each PIP map displays the typical cartographic elements: title, north arrow, legend, scale, symbols, and labels (positioned as needed) together with a custom, but standard, symbology appropriate for firefighting (figure 4).

Each map is assigned a unique name (optionally suffixed in the case of map sets) based on place names or community nickname known locally to firefighters. For maps within a multi-map set, off-sheet connectors on map edges refer to adjacent maps by name or suffix. Many symbols match Incident Command System (ICS) symbols[9] that are standard for maps made on wildfires. For example, wildfire-specific map symbols may highlight safe places for helicopters to land (helispots), areas for incoming responders to wait for their specific task or assignment during an incident (staging areas), or even larger areas where responders can "shelter in place" when a wildfire is encroaching (safety zones).

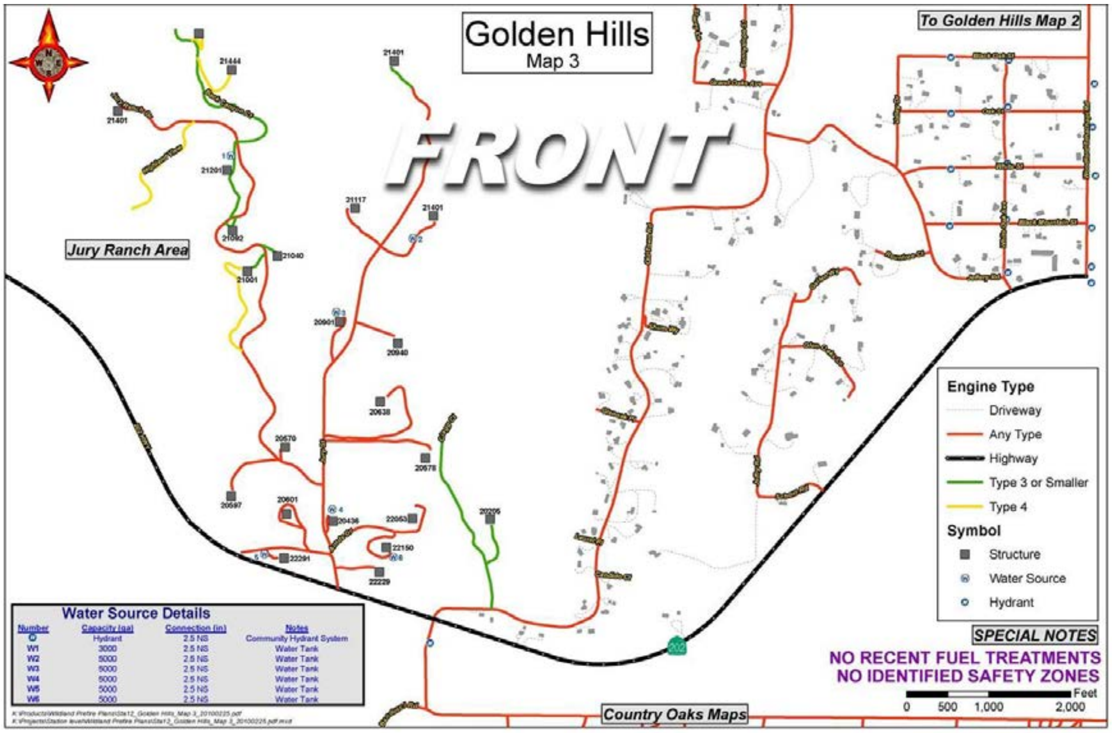
Emphasis is placed on displaying wildfire-critical spatial information: engine access within communities, water sources, and structure locations. The roads are labeled by name and color-coded to show accessibility to fire apparatus. Water sources are presented as a blue 'W' inside a white circle with a blue outline. Each source is labeled with a bold, blue number that refers to a row in the included 'Water Source Details' table on the map's edge. The table row displays four specific details: the water source capacity, source type, the hose connection or water extraction method, and any other comments about the water. Structure locations are simple black squares labeled with addresses,

[9]National Wildfire Coordinating Group. "GIS Standard Operating Procedures on Incidents." National Wildfire Coordinating Group, June 2006.

where possible.   Cabins, campgrounds, fire stations, helicopter landing areas, locked gates, proposed and established fuel treatments, safety zones, staging areas, and trailers are shown where appropriate. Textual information of importance during a wildfire response, such as names of safety zones, recent fuel treatments, and any other special notes about the community (gate codes, bridge capacity, fire-specific water, etc…) is shown in the map marginalia.

Tabloid size (11x17 inches) was chosen as the standard for all PIP map products. (A full size facsimile of the Golden Hills map appears in Appendix A.) Two maps are laminated together, with one side (Figure 5A, watermarked “front”) showing a plain background and the other (Figure 5B, watermarked “Back”) showing a topographic background. The plain background provides both an easily interpreted community layout and a scratch workspace for incident-specific marks, notes, and drawings. The topographic background adds the contour lines and hillshade to better portray the landscape, especially the elevation and slope of an area.

The standard tabloid size makes map layout and scale important issues. In KCFD’s Battalion One, both densely and sparsely populated WUI areas exist, in a variety of spatial patterns. Accordingly, a variety of map scales, in both portrait and tabloid orientations are employed to display wildfire-critical spatial data and their labels effectively. In some cases, multiple maps (map sets) are used for areas too big to fit comfortably on one map. For example, the city of Bear Valley Springs (pop. 3000) requires six maps at several small scales; an adjacent community known as “Hidden Oaks,” only needs one tabloid map at a much larger scale.



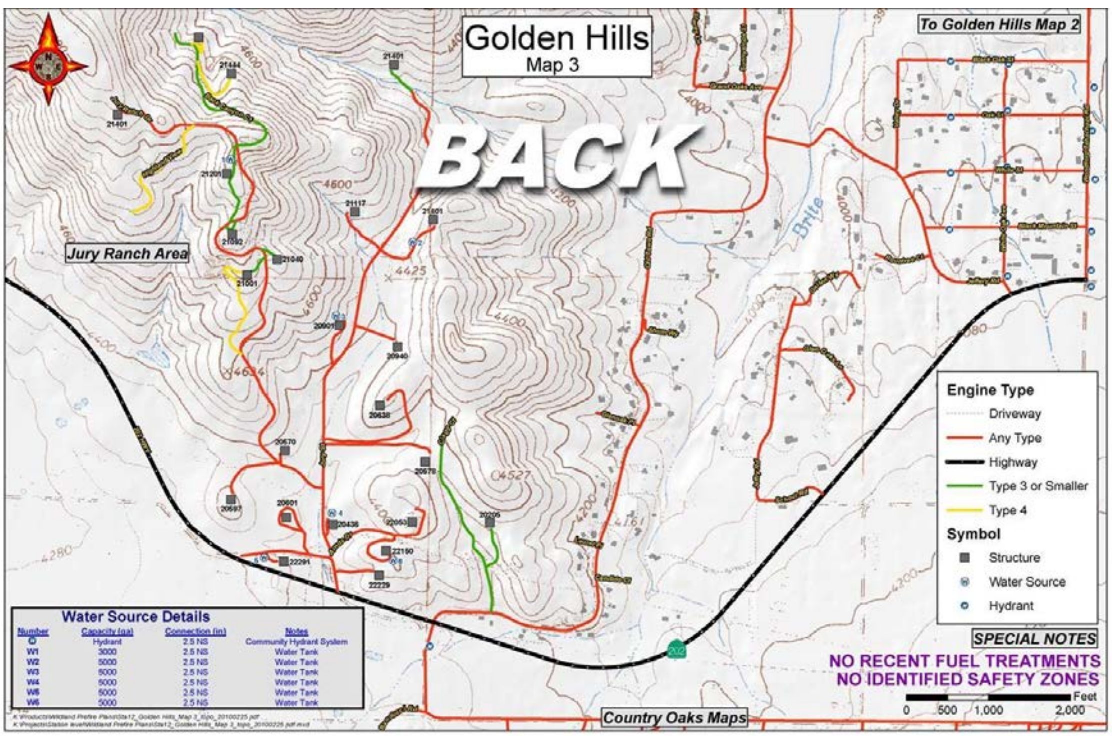


Figure 5: PIP Map Example, Front (A) and Back (B) side

CHAPTER 4: METHODS AND DATA

Kern County's PIP maps cover a WUI area of 1200 mi^2 and 70 WUI communities. To handle such a large project, an organized and iterative methodology was used, relying on a combination of GIS technology and field data collection by firefighters. As KCFD's GIS specialist, I began by creating an empty data structure, then populating it from existing aerial photography and topographic maps through hand-digitizing of selected features, after which field teams confirmed those features while adding important notes and GPS "fixes". The maps were updated, reprinted, and revalidated (where necessary). Thus, PIP maps materialized following multiple rounds of feedback that included continuous data improvement until their eventual approval. The iterative process made the PIP maps credible through the consistent, direct involvement of their most-knowledgeable prospective end-users: local firefighters. This thesis describes the PIP maps generated for KCFD's Battalion One. WUI areas in four other battalions, although not explicitly described, were handled in a similar manner.

4.1 Data Needed For the PIP Maps

The basic GIS data needed for the PIP program were determined by interviews with participating battalion personnel and Battalion Eight. A summary of these data is shown in Table 1. Some of the data were already available through GIS systems at Kern County, or from KCFD itself; the remainder were created through the iterative process outlined above. In general, the raster data identified was already available, but much wildfire-critical vector data was missing: accurate road data for engine access, water sources, and structure locations.

Table 1: Project Data Needs

DATA CREATED OR UTILIZED	
Points	**Lines**
Structure Locations*	Engine Access*
Trailers*	Power Lines
Cabins*	Dirt Roads
Water Sources*	County Roads
Safety Zones*	**Polygons**
Staging Areas*	Fuel Treatment Areas
Campgrounds	Road Brushing Projects
Potential Helispots*	Parcels
Bridges*	Evacuation Routes*
Locked Gates*	**Rasters**
Fire Stations	Aerial Photography
Schools	Topographic Quadrangles
Police Stations	Hillshade
Hydrants	

**Indicates Data Created*

Fortunately both Kern County and KCFD already used Environmental Systems Research Institute's (Esri) ArcMap™ for various purposes, including framework datasets which were primarily maintained in shapefiles (Esri's conventional format for vector spatial data). GPS data was routinely converted to shapefile format, too. For consistency, I organized all the additional data that the project required in shapefiles. Because both point- and line- data were needed, two separate shapefiles for each PIP map. Table 2 shows the attribute fields used for each of the two shapefiles.

Table 2: Shapefile Attributes

DATA ATTRIBUTE FIELDS	
Point Data	**Line Data**
Point Type	Engine Access
Station Area	Road Name
Community Map Name	Community Map Name
Date	County Road Class
Water Source Number	
Address	
Comments	

Relatively simple classification systems were identified for the shapefiles in Table 2, following input from battalion staff. For point-data the 'Point Type' field defines what type of feature is represented spatially. Textual attributes not available elsewhere were also included for labeling purposes: street address for point features where appropriate, for example. Similarly, for line-data, the 'Engine Access' field classifies accessibility for specific types/sizes of fire apparatus, i.e. fire engines.

4.2 Data Creation and Collection

Per Table 1, I had access to an extensive but incomplete collection of public GIS data. For firefighting purposes, neither the road network provided nor the points of interest were sufficiently detailed. Line-data representing roads were first digitized from aerial photography then critical point-data was located along the roads using GPS equipment and documented with extensive notes.

4.2.1 Heads-Up Digitizing

Manual heads-up digitizing was used to develop quality line-data to effectively represent and classify the road network, especially of the poorly mapped rural areas. A combination of aerial photography, existing roads data, parcels, and field notes/maps were used in creating an updated road network for engine access. Much of the updating involved manual drawing of line-data segments in ArcMap, which was a painstakingly long process. In most cases this drawing had to be done for each mapped area before field crews embarked on GPS data collection. After an area's road network was updated, I printed maps and gave them to field teams as a "canvas" to make notes and drawings. These maps guided field teams in checking for accuracy and completeness of the manually-digitized data; when returned I used them update structure locations, labels, addresses, and especially for classifying the area's engine access.

4.2.2 Field Visits

For PIP maps, key wildfire-critical elements in WUI areas are engine access, water sources, structure locations, and topography. These four elements became the focus for both field teams and myself. Gathering GPS points and descriptive notes during field visits often took several days, even weeks for some communities. All field visits involved one or more local-area fire responders trained in GPS data collection, though I was often included as well.

Engine access details are imperative for understanding where each type of fire apparatus can safely respond. Field teams consistently described each community's road network using a KCFD-wide engine-access classification system that took into account emergency response vehicle size, weight, turn radius, overhead clearance, climbing ability, and other limitations. Separately, the roads were also classified as evacuation routes for residents. A four-class system was adopted based on standard wildfire response apparatus shown in Figure 6: so-called type-1 engines, type-3 engines, type-4 patrols, and 4-wheel drive vehicles only. Field teams verified and color-coded the road network: red for universally accessible, green for access to type-3 engines or smaller, yellow for type-4 patrols or 4x4 vehicles, and finally a hashed orange line for roads that were unsafe and impassible for any responding apparatus. Figure 7 shows generic examples of roads within the four-class system.

Figure 6: Wildland Fire Response Apparatus

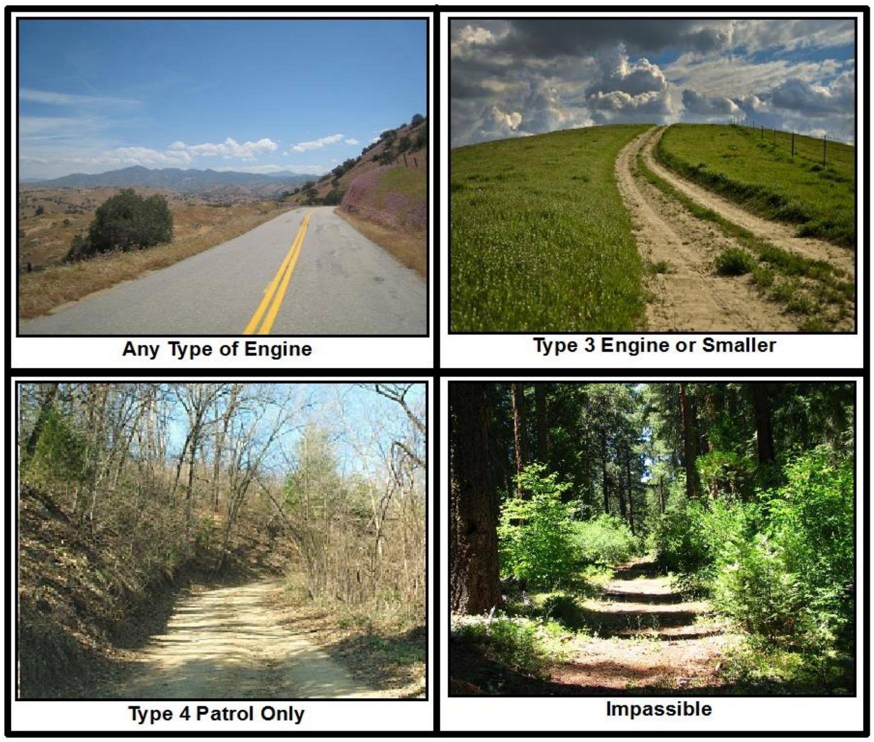


Figure 7: Road Types and Engine Access

Unlike densely-populated urban areas, many of the WUI communities of Kern County do not have established community hydrants or easily accessible water sources. Specifically the water source access, type, and abundance vary significantly. For Battalion One, the communities of Bear Valley Springs, Golden Hills, Hart Flat, part of Alpine Forest, and Stallion Springs have established hydrant systems. But the higher elevation and less accessible areas of Alpine Forest, Mountain Meadows, Old West Ranch, Sand Canyon, Jury Ranch, Hidden Oaks, and Water Canyon only have fire-water tanks, personal water tanks for each home, or a combination. In order to better gauge the water resource and abundance for the communities, field teams established the geographic locations of hundreds of previously un-mapped water sources. Additionally, they provided extensive notes on each water source within or near the communities.

Teams only collected points and information on *accessible* water sources, classified as: helicopter dip sites, draft sites, hydrants or standpipes, and water tanks (Figure 8). The accessibility of a water source was determined by the feasibility of extracting water it by different apparatus in a wildfire situation. In addition to source type, size or amount of water and the type of hose connection, if any, were noted. Although the types of sources differed significantly, the water sources were noted generically in the GIS point data.

Accurate GPS points were also collected for both mapped and previously unmapped structure locations; addresses were verified where possible. Other wildfire-critical elements such as bridges, landing sites for helicopters, locked gates, potential safety zones, and potential staging areas were also collected and GPS'd as needed.

Figure 8: Four Examples of Water Sources

CHAPTER 5: RESULTS

The PIP mapping project lasted three and a half years. In total, WUI areas of five KCFD Battalions, consisting of over 1200 mi^2, were mapped. Within that large area over 6500 road line segments were classified for accessibility, more than 7000 structure locations were identified, over 900 previously unmapped water sources were located, and at least 150 other points of interest were defined. 388 unique 11x17 maps (including 25 map sets) of 70 WUI communities resulted from the collective effort[10].

PIP maps were made available in three forms: 1) digitally, as PDF documents; 2) as paper map products placed in binders by area or battalion; 3) as laminated map sets, pre-deployed to map-boxes in the field. The digital versions were organized on a local server for future reprinting and for binder and map-box replenishment.

Figure 9: A Map Box near the Entrance of a WUI Community

[10] Appendix B highlights Battalion One's PIP Mapped Areas as well as the entire PIP Map inventory.

The paper map binders were distributed to each local responding fire apparatus to be kept on board at all times. The thousands of laminated PIP maps were also organized into map-sets, ring-bound together, placed inside waterproof bags, and strategically placed in a map-box for responders to use during the golden-hour of a wildfire response. The steel map-boxes are painted bright red, conspicuously labeled “Fire Dept”, and are set-out near entrances to mapped communities (as seen in Figure 9) or at KCFD and USFS fire stations.

Since 2008, 12 significant WUI wildfires have threatened 22 communities where PIP maps previously did not exist. Every event in Table 3 has confirmed use of PIP maps, each with overwhelmingly positive results.

Table 3: Significant Wildfires since PIP Project Inception

Name	Dates	Wildfire Suppression Cost	Pre-placed Maps Utilized
Fay	5/5/2010	$1,105,954	Fay Ranch Road
Bull	7/26/2010 - 8/9/2010	$11,274,919	Riverkern
West	7/28/2010 - 8/2/2010	$1,015,050	Old West Ranch
Post	8/24/2010 - 8/29/2010	$816,384	Lebec Oaks, Frazier Park, Ridge Route Drive
Canyon '10	9/12/2010 - 9/20/2010	$9,319,815	Havilah North, Bodfish
Canyon '11	9/4/2011 - 9/10/2011	$5,906,740	Old West Ranch, Wildhorse
Keene Complex	9/10/2011 - 9/16/2011	$1,646,703	Golden Hills
Comanche	9/10/2011 - 9/16/2011	$18,746,982	Stallion Springs, Bear Valley Springs
Breckenridge	9/10/2011 - 9/17/2011	$16,111,107	Breckenridge Subdivision
Gulch	6/19/2012	$314,964	Isabella Highlands, Hungary Gulch, Wagy Flat, Frontage Road
Sand	7/17/2012 - 7/19/2012	$1,016,230	Sand Canyon
Piute Complex	8/4/2012 - 8/11/2012	$19,907,340	Bodfish

As an example, when the Comanche Fire threatened the Stallion Springs and Bear Valley communities on the 11th of September 2011, part of a historic lightning complex that month, dozens of PIP maps were printed to aid in organizing the evacuation of hundreds of residents and thereafter the protection of structures from the approaching wildfire. Similarly, during the Gulch Fire in June of 2012, caused by an explosion, PIP maps for threatened neighborhoods near Wofford Heights, CA were retrieved from a nearby map box and immediately utilized. First responders and cooperating agencies in charge of structure protection and resident evacuation received map sets from a nearby map-box during the first stages of the rapidly spreading wildfire. Fire-fighting personnel repeatedly remarked that PIP maps were critical, direct aid in successfully protecting lives and property during both of these emergency events, as well as the others shown in Table 3.

To further understand the impact of PIP maps since their inception, personal interviews and written surveys were conducted[11]. After-action-reviews (AAR) following several wildfire events highlighted many benefits of having PIP maps summarized below. Feedback from the emailed surveys left an overwhelmingly positive impression of the PIP maps. Fire Captain Davis stated that, “pre-incident planning is vital to the success or failure of the operation,” and that “PIP maps allow wildfire managers and responders to focus more on fighting the wildfire instead of trying to fight and plan the wildfire at the same time.” Battalion Chief Smith added that “with so many variables that make a wildfire dynamic (where a wildfire will start, how it will react to things like weather, topography, and wildfire suppression, etc.)…establishing the ‘constants’ (like road access, water sources, and structures) is important for more effectively handling the situation with any combination of those variables.” Chief Smith described how PIP maps also aid in communication during emergencies. He stated that “prior to this project,

[11] Appendix C shows the e-mailed Survey Questionnaire

detailed information about the WUI was found strictly by memory or word of mouth. In areas where these maps do not exist a lot of time is wasted trying to relay information a multitude of times to multiple authorities. Now, with definitive maps that all responders can reference simultaneously, communication has become more effective and the so-called "fog of war" is reduced." KCFD Deputy Chief Brady cited the drastic improvement PIP maps bring to the situational awareness during emergencies. He says, "many times at wildfires the only means of orientation has … been using a poor quality USGS topographic map or attempting to have someone local try to fill in the blanks before beginning a wildfire assignment. As a tool, PIP maps are great for emergencies where units respond from other parts of the county, multiple different agencies, or from out-of-county and have limited local area knowledge and familiarization."

PIP maps have been heralded for yielding a vast improvement in organization, safety, situational awareness, and decision-making in the hasty environment of a wildfire response. Captain Davis, one of the leaders in wildfire response for KCFD, makes an essential point that summarizes the value to the on-the-ground responder. He states that "this project is 1000% success" from his stand point, having allowed him to rely on PIP maps in different areas where fire-fighting information was otherwise not readily accessible. He recognized that "it was an extremely daunting and time consuming task to develop maps and plans like this in a hasty wildfire environment."

PIP maps have proven worth-while beyond their original intention as they have also aided in pre-planning for wildfire scenarios, performing WUI wildfire training, "resource ordering" during an emergency response, enhancing communications and agency coordination, increasing firefighter safety, organizing structure protection, executing community evacuation, and even completing post-wildfire damage assessment.

Cost and benefit analysis is an important aspect of wildfire response planning, especially in an era of constrained budgets. Taxpayer's money must be spent smartly and effectively. Since the inception of the PIP-mapping project, the four-year operating budget of KCFD has been $508 million (Barnett, pers. comm.). During this period, making the PIP maps cost about $115,000 (less than ¼ of one percent of the budget); the breakdown is shown in Table 4.

Table 4: PIP Project Cost Breakdown

Project Need	Est. Cost
Salary	$93,154
Fuel	$2,625
Map Supplies	$13,610
Food	$600
Map Boxes	$5,000
Total	$114,989

In Kern County, PIP maps have been used exclusively at a dozen major wildfires since 2008 that have threatened communities, including over 4000 structures, and have collectively cost $87.1 million for wildfire suppression. Although it is impossible to determine where, exactly, the expense of PIP mapping was recouped by KCFD, if just one additional home was saved from destruction by wildfire, the investment would have been worthwhile. In addition, the benefits of improved situational awareness, fire-fighter safety, communication and coordination in emergencies are literally priceless. On November 15th, 2012 Kern County Fire Chief Brian Marshall stated that "For every dollar we spend in wildfire prevention and fuel reduction we save over $100 in suppression costs (Gordon 2012)." Although there is no way to precisely quantify the PIP maps' cost savings, they have provided value. The argument for justification then, lay in the testimonials and praise from those who have utilized the products during emergencies.

CHAPTER 6: DISCUSSION

As the lead GIS specialist integrally involved in the long PIP process, it is exciting to see and hear the results of the PIP map use. Countless hours went into collecting/building data, designing maps, printing maps, laminating maps, and creating map books. Those hours were spent without knowing which maps – indeed whether any maps – would be utilized in emergency planning and/or firefighting operations. However, PIP maps *have* been used, widely, and even found applications beyond the initial vision of the project. Some of the data collected or updated has been added to the county-wide GIS database. Other fire department personnel have even inquired about the PIP map project and its products after happening upon them during a wildfire response. Ultimately though, the success of the PIP project must be credited to KCFD management: their financial commitment over many years and their wide adoption of PIP concepts into planning and preparedness, over and above response execution.

Traditions in cartography as well as GIS were challenged in the process of making PIP maps. Maps at a fixed size and not a fixed scale proved difficult at times. Hours of fiddling with the displaying the data and cartographic elements to make a useful product was tedious. Acquiring input from fire-fighters, while resolving differences in opinion among them regarding engine access, structure locations, water sources, and topography took large amounts of time. However, the knowledge and participation of fire-fighters, who would be at the point of execution in emergency, added immense value to the PIP maps; it was a essential form of quality control that significantly matured the quality of PIP maps over the course of project. When the value of the spatial data collected for PIP maps was realized, the portability and utility of that data became as important as the cartographic product itself (the main goal of the project upon inception).

In the 21st century, one might expect paper cartographic products to be passé. The PIP map project proves this is not the case. Although Dargan (2011) highlights GIS technology as game–changing for fire-fighters, GIS has not completely infiltrated the wildfire response scene. GIS applications require sometimes temperamental Web-based delivery, with mobile applications, and modeling and simulation instead of standard paper maps. However, the majority of emergency responders still carry paper map books that detail their response areas precisely because of their immediacy and reliability. Campaign wildfires also depend on paper maps to aid in large and lengthy responses. In much of the rugged, rural, and mountainous West where wildfires frequent, digital tools are impractical. Paper maps are often the preferred and more functional option, operable as they are battery power or complex telecommunication.

6.1 Limitations

The "layout view" of Esri's ArcMap was used exclusively for designing and producing the PIP maps. ArcMap afforded the opportunity to fix the map sizes, use many different scales, create map sets, edit spatial data during design, customize wildfire map elements, add Excel-based tables, and export easily to PDF format. Management of the underlying point and line shapefiles took place in ArcMap's "data view" where hand-digitizing and tabular editing were simple. Raw data collected by KCFD's Garmin GPS units was not immediately compatible (as a shapefile) with ArcMap; however DNR

Garmin[12], another popular, free software program, was used to achieve compatibility. The DNR Garmin process proved problematic at times with user errors such as wrong data formats and misidentified data projections.

Initially, the PIP project focused on making hardcopy PIP map products available for emergencies. The importance of spatial data structure, to manage the data going into the map products, was not immediately recognized. By the time the impact of edits, revisions, and maintenance of both the data and products was realized much of the project was already committed to Esri shapefiles. Some thought was given to creating geodatabases. Ultimately, though, it was re-decided that capturing the data in shapefile, a older and more stable technology, would prove advantageous for future maintenance. Not only are shapefiles more easily understood than geodatabases by the (not so tech-savvy) fire personnel of Battalion Eight, but they also have proven to be more resistant to technological advances. PIP maps are expected to have a 5-10 year shelf-life between updates making technological stability a priority.

6.2 Future Recommendations

Other predictable natural disasters such as earthquakes, floods, hurricanes, and tsunamis might conceivably use GIS-based pre-incident maps also to aid with planning, response, and recovery. Even though wildfire is always unpredictable, and arguably more frequent than other natural disasters, some areas are at higher risk than others. When a flood inundation study (KCFD, 2011) was done for Lake Isabella reservoir, in Northeastern Kern County, PIP-like maps were created (AMEC, 2009) for flood zones

[12] DNR Garmin is an application developed by the Minnesota Department of Natural Resources for transferring data between Garmin GPS handheld receivers and various GIS software packages.

likely to receive evacuation orders and incur property damage. San Luis Obispo County Fire, which also has PIP-like maps for wildfires, has recently applied the concept through a Department of Homeland Security grant to tsunami planning maps for a stretch of coastline, accounting for the expected inundation zone from a tsunami event (Alex 2013).

Recent advancements in mobile applications have brought the mobile device to the forefront of information delivery. Spatially-driven applications are becoming more practical due to continually improving data connectivity, coverage, and speed. In addition, applications now offer options for offline maps utilizing the increases in device storage and greater battery longevity. It would be advantageous to provide the PIP map data directly into a mobile application with an offline background map, where the entirety of the maps' set could be viewed and/or analyzed in other spatial applications than PIP maps. A potential consumer might be the Next-generation Incident Command System project[13] (mentioned previously).

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[13] Rebecca Tolin, *Fighting Fire with Firefox,* San Diego Magazine, http://www.sandiegomagazine.com/San-Diego-Magazine/July-2012/Fighting-Fire-with-Firefox/index.php?cparticle=1&siarticle=0#artanc (accessed August 24, 2012).

CHAPTER 7: CONCLUSIONS

Wildfires and humans have an increasingly complicated relationship. Fire protection agencies have begun to employ GIS technology to aid in wildfire management, however, most applications aim to dispatch emergency responders or study wildfire occurrence and behavior. Real-time GIS solutions are still early in development and are neither widely applied nor very practical. Pre-attack planning maps are an established emergency response aid, which are commonly used in large commercial or industrial facilities. Similar in concept, PIP maps have been developed for pre-attack planning and response in Kern County's extensive, residential WUI.

KCFD's PIP maps differ from other pre-incident planning projects, as noted in Chapter Two. For example, Hofer (2004) went into depth in regards to the Silverado Canyon area of Orange County, CA. While undoubtedly valuable, this one-area, in-depth approach was not applicable in Kern County where wildfire has been historically prevalent throughout its WUI areas. The KCFD PIP map project found success in taking a breadth-over-depth approach by creating a standard map product, applicable county-wide. KCFD placed emphasis on providing essential spatial information for more areas rather than comprehensive planning for fewer areas. The nearly 400 PIP maps incorporate copious amounts of previously unrecorded – now captured, vetted, and easily updated – wildfire-critical spatial information. These PIP maps now wait at the ready as map books and laminated map-sets, in map-boxes, at fire stations, and on most wildfire responding apparatus, to be used for future, inevitable wildfires in the county.

Due to the nature of their geographic location, WUI areas throughout the West will continue to be threatened by wildfires. Preparing GIS-based PIP maps for these areas is arguably the best way to obtain, maintain, and deliver accurate fire-fighting data about them. Access to PIP maps in Kern County's WUI areas has aided KCFD's response to at least a dozen major wildfires since 2008, helping to protect over 4000 structures. Overall, PIP map use has proven a beneficial and cost-effective GIS strategy for wildfires in Kern County's WUI. Unfortunately, most WUI areas don't have anything like PIP maps prepared for the inevitable event of emergency.

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GLOSSARY

After Action Review (AAR) – a learning tool intended for the evaluation of an incident or project in order to improve performance by sustaining strengths and correcting weaknesses.

Battalion – a geographically partitioned area of common response for emergencies directed by a Battalion Chief who is responsible for the administration and direction of all activities within the area.

Battalion Eight – division of fire planners working for KCFD dedicated solely to wildland fire planning. This division places an emphasis on what needs to be done long before a wildfire starts, looking to reduce fire-fighting costs and property losses, increase firefighter safety, and to contribute to ecosystem health.

Battalion One – a Kern County Fire Department organized response area covering southeastern part of Kern County. Battalion one includes the Hwy 58 corridor, Tehachapi Mountains, and portions of the Mojave Desert.

California Department of Forestry and Fire Protection (CDF or CALFIRE) – the State of California's agency responsible for fire protection in State Responsibility Areas of California as well as the administration of the state's private and public forests.

Campaign Wildfire –a wildfire emergency that extends into several days of fire suppression operations or management. Typically campaign wildfires burn the largest number of acres and cost the most to contain.

Defensible Space – the natural and landscaped area around a structure that has been maintained and designed to reduce the risk that fire will spread from the surroundings to the structure while also providing firefighters access and a safer area to defend it from.

DNR Garmin – a software application built by the Minnesota Department of Natural Resources to transfer data between Garmin GPS handheld receivers and various GIS software packages.

Esri ArcMap – a geographic information system (GIS) for working with maps and geographic information. It is used for: creating and using maps; compiling geographic data; analyzing mapped information; sharing and discovering geographic information; using maps and geographic information in a range of applications; and managing geographic information in a database.

Fire Resource Assessment Program (FRAP) – a program from California Department of Forestry and Fire Protection which provides a variety of products: detailed reports on California's forests and rangelands as well as extensive technical and public information for statewide fire threat, fire hazard, watersheds, socioeconomic conditions, environmental indicators, and forest-related climate change.

Fire Suppression – all the work of extinguishing or confining a fire beginning with its discovery.

Fuel load – the mass of combustible materials available for a fire usually expressed as weight of fuel per unit area.

Fuel Treatment – a strategic gap in vegetation or other combustible material that acts as a barrier to slow or stop the progress of a wildfire.

Geodatabase – a database that is optimized to store and query data that is related to objects in space, including points, lines and polygons. The geodatabase supports all the different elements of GIS data used by Esri's ArcMap.

Geographic Information System (GIS) – a system designed to capture, store, manipulate, analyze, manage, and present all types of geographical data.

"Golden hour" – a timeframe of opportunity for saving lives that exists primarily in the first hour following the onset of the emergency; and decline rapidly thereafter.

Global Positioning System (GPS) – a space-based satellite navigation system that provides location and time information in all weather conditions, anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites.

Heads-up Digitizing – a data specialist drawing points, lines, or polygons on a computer screen usually with visual aids such as scanned maps, aerial photography, and other vector or raster data.

Incident Command System (ICS) – system first developed to provide a command structure to manage large wildfires in the United States, now widely used by many emergency management agencies.

Incident Commander (IC) – a single person who commands the incident response and is the decision-making final authority.

Initial Attack – the actions taken by the first resources to arrive at a wildfire to protect lives and property, and prevent further extension of the fire. Initial attack is usually done by trained and experienced crews and takes place immediately after size-up.

Kern County Fire Department (KCFD) – is the agency that provides fire protection and emergency medical services for the county of Kern, California, USA.

Map-box – Steel box cemented into the ground or secured on a building for the strategic placement of readily available laminated PIP maps.

Map Scale – the ratio of a distance on the map to the corresponding distance on the ground. The smaller the map scale, the larger the areas of land shown on the map.

Portable Document Format (PDF) – a file format that provides an electronic image of text or text and graphics that looks like a printed document and can be viewed.

Pre-Attack Planning – a procedure used to insure appropriate and efficient suppression to a given area. The procedure typically gathers intelligence on response requirements, important hazards and safety information, construction details, tactical recommendations, and any other items that may be vital to establish a safe firefighting strategy.

Pre-Incident Plan (PIP) Map – map created for communities for use before, during, of after wildfire occurrence.

Raster – data that is a contiguous array of pixels, each with an assigned value. Raster data is most suitable for data that includes values for every part of space, such as elevation or topography.

Safety Zone – n area cleared of flammable materials used for escape in the event the line is outflanked or in case a spot fire causes fuels outside the control line to render the line unsafe.

Shapefile – a popular geospatial vector data format for geographic information systems software. Shapefiles spatially describe geometries: points, polylines, and polygons.

Size-up – initial assessment of fire including (among other things) fuel load, fire weather, topography, fire behavior, hazards and exposures of valuable properties. Quickly detects need for additional resources and sets operational priorities.

Staging Area – Locations set up at an incident where resources can be placed while awaiting a tactical assignment on a three (3) minute available basis.

Standard Operating Procedure – Specific instructions clearly spelling out what is expected of an individual every time they perform a given task. A standard operating procedure can be used as a performance standard for tasks that are routinely done in the operational environment.

State Responsibility Area (SRA) – the state- and privately-owned/-managed forest, watershed, and rangeland for which the primary financial responsibility of preventing and suppressing wildland fires rests with the state.

United States Geological Survey (USGS) – a scientific agency of the United States government where scientists study the landscape of the United States, its natural resources, and the natural hazards that threaten it. The organization has four major science disciplines, concerning biology, geography, geology, and hydrology.

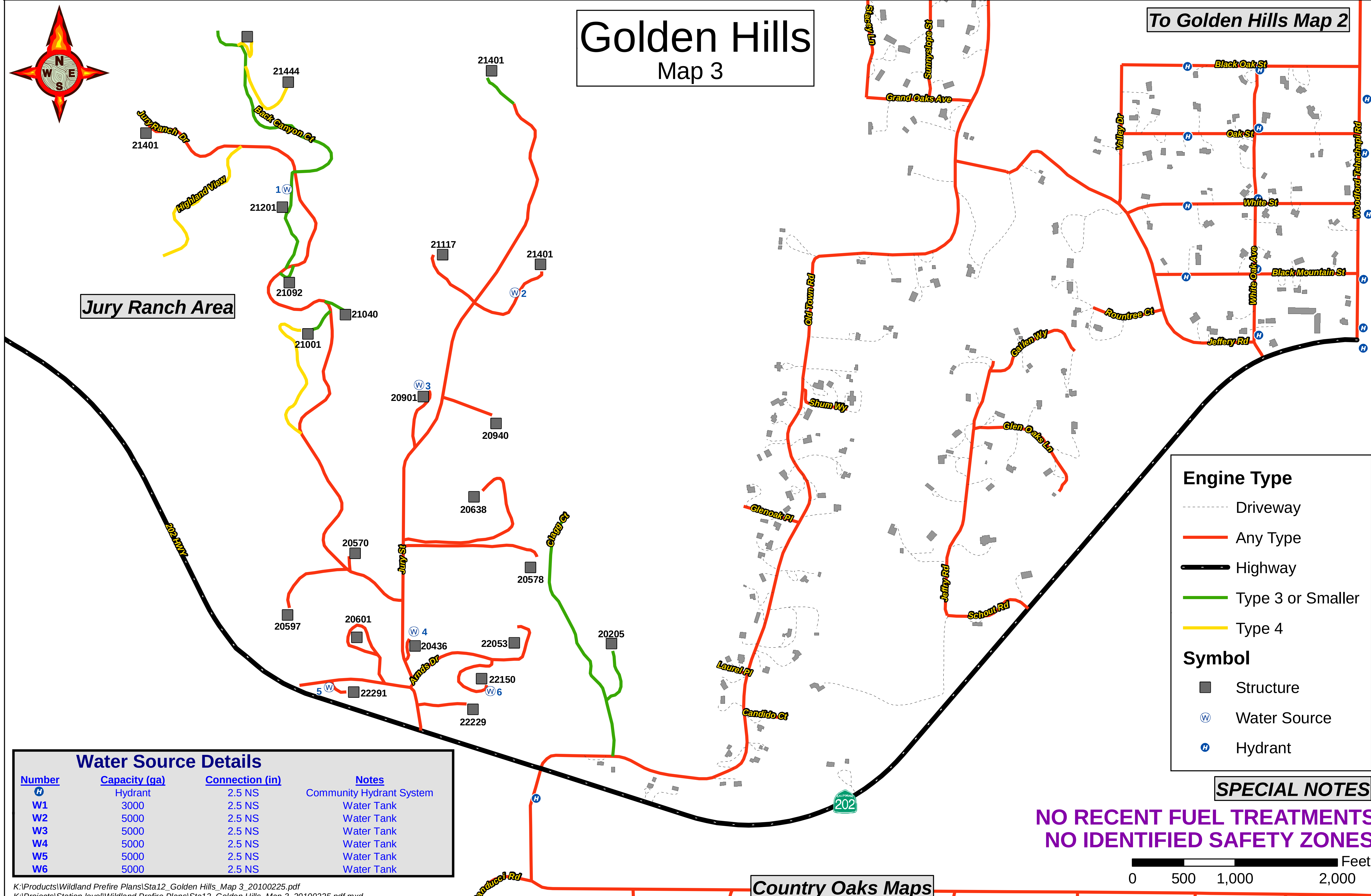
Unit-level Fire Plan – annually completed plans highlighting how each unit is achieving the goals and objectives of the State of California's Strategic Fire Plan.

Wildfire – an unplanned, unwanted wildland fire, including unauthorized human-caused fires, escaped wildland fire use events, escaped prescribed fire projects, lightning strikes, downed power lines, and all other wildland fires where the objective is to put the fire out.

Wildland Urban Interface (WUI) – the Interface zone where man-made structures inter-mingle with wildland areas, creating risk of structural involvement in a wildfire incident and wildfire involvement in structure fires, each of which requires different equipment, training and tactics.

APPENDIX A: Golden Hills: Map 3, Front and Back

Golden Hills
Map 3



Water Source Details

Number	Capacity (ga)	Connection (in)	Notes
H	Hydrant	2.5 NS	Community Hydrant System
W1	3000	2.5 NS	Water Tank
W2	5000	2.5 NS	Water Tank
W3	5000	2.5 NS	Water Tank
W4	5000	2.5 NS	Water Tank
W5	5000	2.5 NS	Water Tank
W6	5000	2.5 NS	Water Tank

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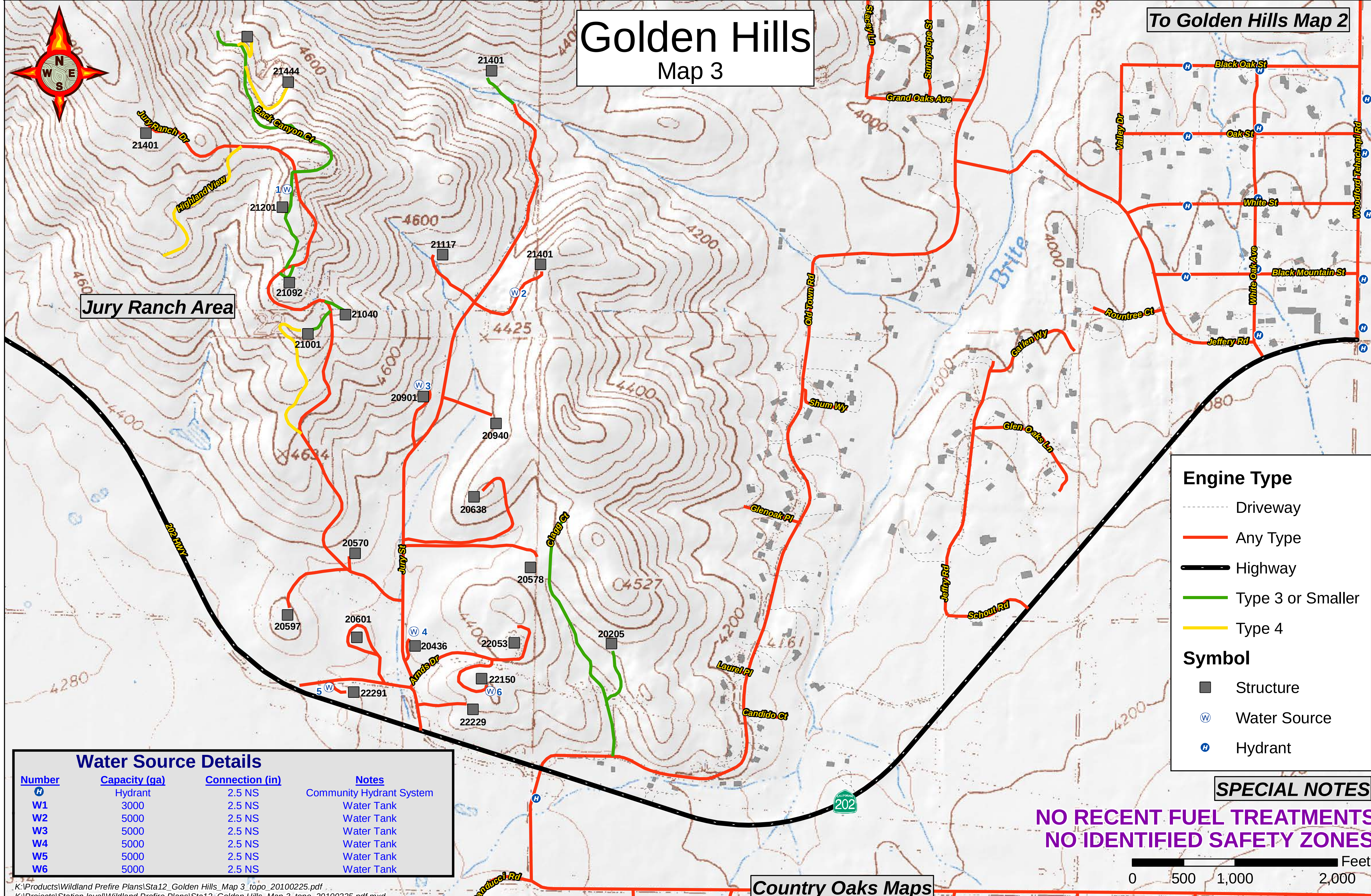

Water Source Details

Number	Capacity (ga)	Connection (in)	Notes
H	Hydrant	2.5 NS	Community Hydrant System
W1	3000	2.5 NS	Water Tank
W2	5000	2.5 NS	Water Tank
W3	5000	2.5 NS	Water Tank
W4	5000	2.5 NS	Water Tank
W5	5000	2.5 NS	Water Tank
W6	5000	2.5 NS	Water Tank

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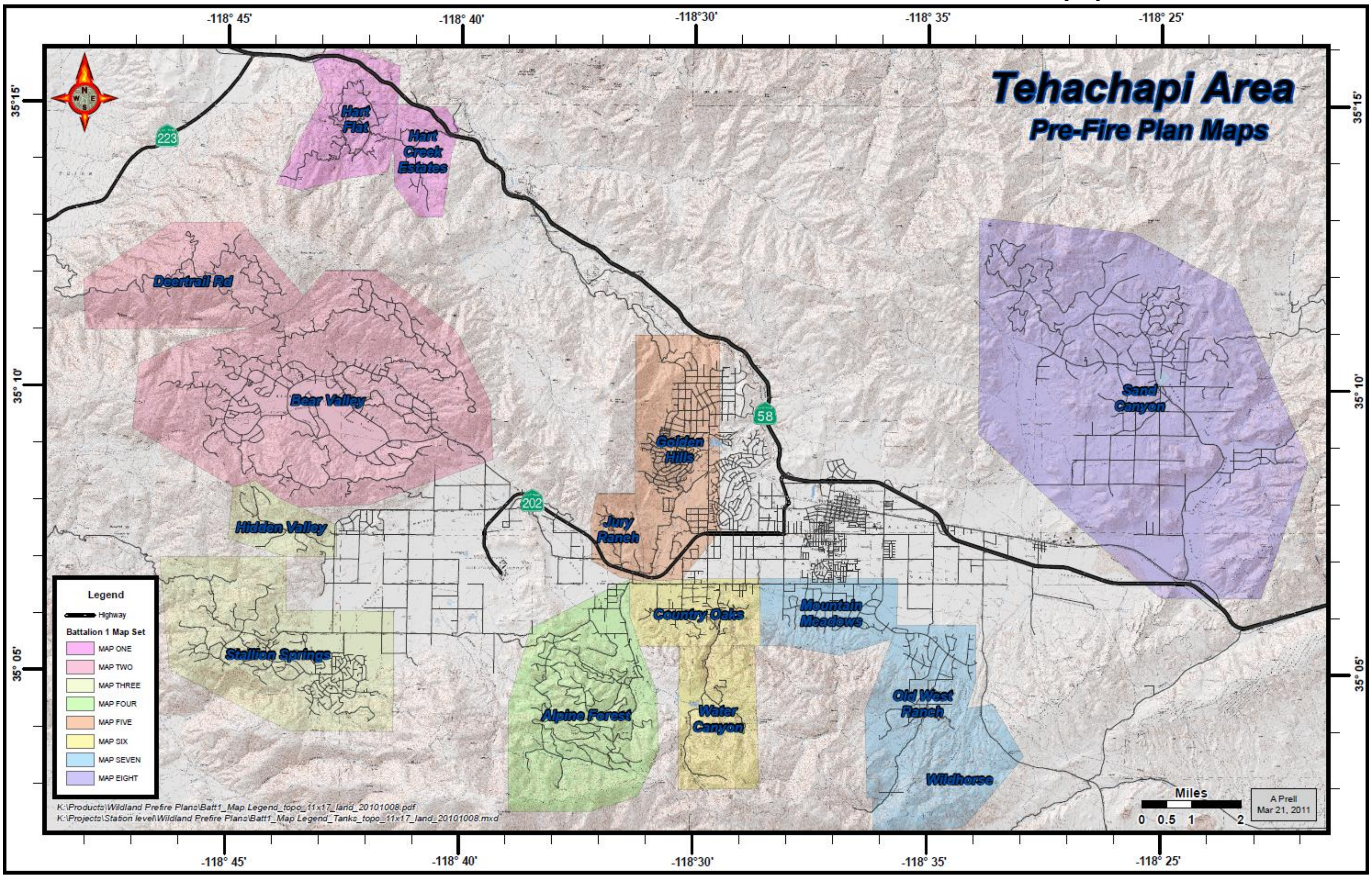
APPENDIX B: PIP Map Inventory

PIP Map Inventory

*PIP Maps for Battalion 1 are highlighted in blue in the table below



Battalion	Map-Set	WUI Community	# of Maps
1	Hart Flat	Hart Creek Estates	4
1	Hart Flat	Hart Flat	8
1	Bear Valley Springs	Deertrail Road	5
1	Bear Valley Springs	Bear Valley	10
1	Stallion Springs	Hidden Oaks	2
1	Stallion Springs	Stallion Springs	4
1	Alpine Forest	Alpine Forest	18
1	Golden Hills	Jury Ranch	2
1	Golden Hills	Golden Hills	7
1	Country Oaks	Country Oaks	7
1	Country Oaks	Water Canyon	2
1	Mountain Meadows	Mountain Meadows	2
1	Old West Ranch	Old West Ranch	2
1	Wildhorse	Wildhorse	2
1	Sand Canyon	Sand Canyon	11
1	Battalion 1	N/A	2
Battalion	**Map-Set**	**WUI Community**	**# of Maps**
3	Battalion 3	Blue Mountain Road	2
3	Battalion 3	Jack Ranch Road	2
3	Battalion 3	Woody and Hwy 155	4
3	Battalion 3	Glennville Area	6
3	Battalion 3	Woody Granite Road	2
3	Battalion 3	Granite Road	4
3	Battalion 3	Pine Mountain Road	2
3	Battalion 3	Poso Flat & Rancheria	2
3	Battalion 3	N/A	2
Battalion	**Map-Set**	**WUI Community**	**# of Maps**
4	Station 42	N/A	18
4	Station 45	Breckenridge	2
Battalion	**Map-Set**	**WUI Community**	**# of Maps**
5	Battalion 5	N/A	1
5	Station 56	Digier Canyon Road	2
5	Station 56	Hayride	2
5	Station 56	Juniper Ridge	2
5	Station 56	Lebec Oaks	2
5	Station 56	Lebec - Ridge Route Drive	2
5	Station 57	Cuddy Valley	10
5	Station 57	Frazier Park	8
5	Station 57	Lake of the Woods	2
5	Station 57	Pinion Pines	2
5	Station 58	Pine Mountain Club	14

Battalion 1: 88 Maps
Battalion 3: 26 Maps
Battalion 4: 20 Maps
Battalion 5: 47 Maps
Battalion 7: 205 Maps

TOTAL: 388 Maps

Battalion	Map-Set	WUI Community	# of Maps
7	Station 71	N/A (other)	1
7	Station 71	Bull Center	3
7	Station 71	Canebrake	3
7	Station 71	Cap Canyon	3
7	Station 71	Cortez Canyon	3
7	Station 71	Fay Ranch	11
7	Station 71	Oliver Tract	3
7	Station 71	Rockin Bear	3
7	Station 71	Squirrel Valley	3
7	Station 71	Walker Pass	3
7	Station 72	N/A	3
7	Lake Isabella	Auxilary Dam & Lakeland Ave	3
7	Lake Isabella	Bodfish Canyon	13
7	Lake Isabella	Bodfish: Columbus	3
7	Lake Isabella	Bodfish: Kilbreth and Reeder	3
7	Dutch Flat	Dutch Flat	3
7	Lake Isabella	Erskine Creek	10
7	Havilah North	Havilah North	3
7	Keysville	Keysville	3
7	Lake Isabella	Rim Road	3
7	Yankee Canyon	Yankee Canyon	3
7	Station 76	N/A	5
7	Big Blue Mine	Big Blue Mine	3
7	Wofford Heights	Bristle Cone Heights	3
7	Kernville	Burlando Road	3
7	Wofford Heights	Calgary Tract	7
7	Cyrus Canyon	Cyrus Canyon	3
7	Kernville	Frontier Trails	3
7	Sawmill Road	Hungry Gulch	3
7	Sawmill Road	Isabella Highlands	3
7	Wofford Heights	Nellie Dent	7
7	Wofford Heights	Old State	3
7	Wofford Heights	Pala Ranches	3
7	Plater Rd	Plater Road	3
7	Riverkern	Riverkern	3
7	Sawmill Road	Sawmill Frontage	3
7	Wofford Heights	Sierra Vista	3
7	Sawmill Frontage	Wagy Flat	3
7	Station 78	N/A	5
7	Back Canyon	Back Canyon	10
7	Caliente Creek	Caliente Creek	6
7	Havilah	Havilah	8
7	Piute Meadows	Piute Meadows	2
7	Piute Springs	Piute Springs	6
7	Walker Basin Subdivision	Red Mountain	2
7	Shadow Mountain	Shadow Mountain	2
7	Walker Basin Subdivision	Thompson Canyon	11
7	Shadow Mountain	Walker Basin Road East	2
7	Shadow Mountain	Walker Basin Road West	2
7	Walker Basin Subdivision	Williams Road	2

For more information contact Kern County Fire Department: (661)391-7000

*List includes all PIP Maps

APPENDIX C: Email Survey Questionnaire

Email Survey Questions

1. **Can you describe why pre-planning for wildfire in the Wildland Urban Interface is an important concept within your role at Kern County Fire.** *(from your perspective as a prospective incident commander, firefighter, SPG leader, etc…)*

2. **In regards to the pre-fire plan maps can you share a story of success with utilizing them as a fire management tool?** *(be as specific as you can…i.e. used on *Bull Fire in July of 2010, for ordering or organization because you knew where the fire was, how many structures were threatened, and where access would call for a specific resources)*

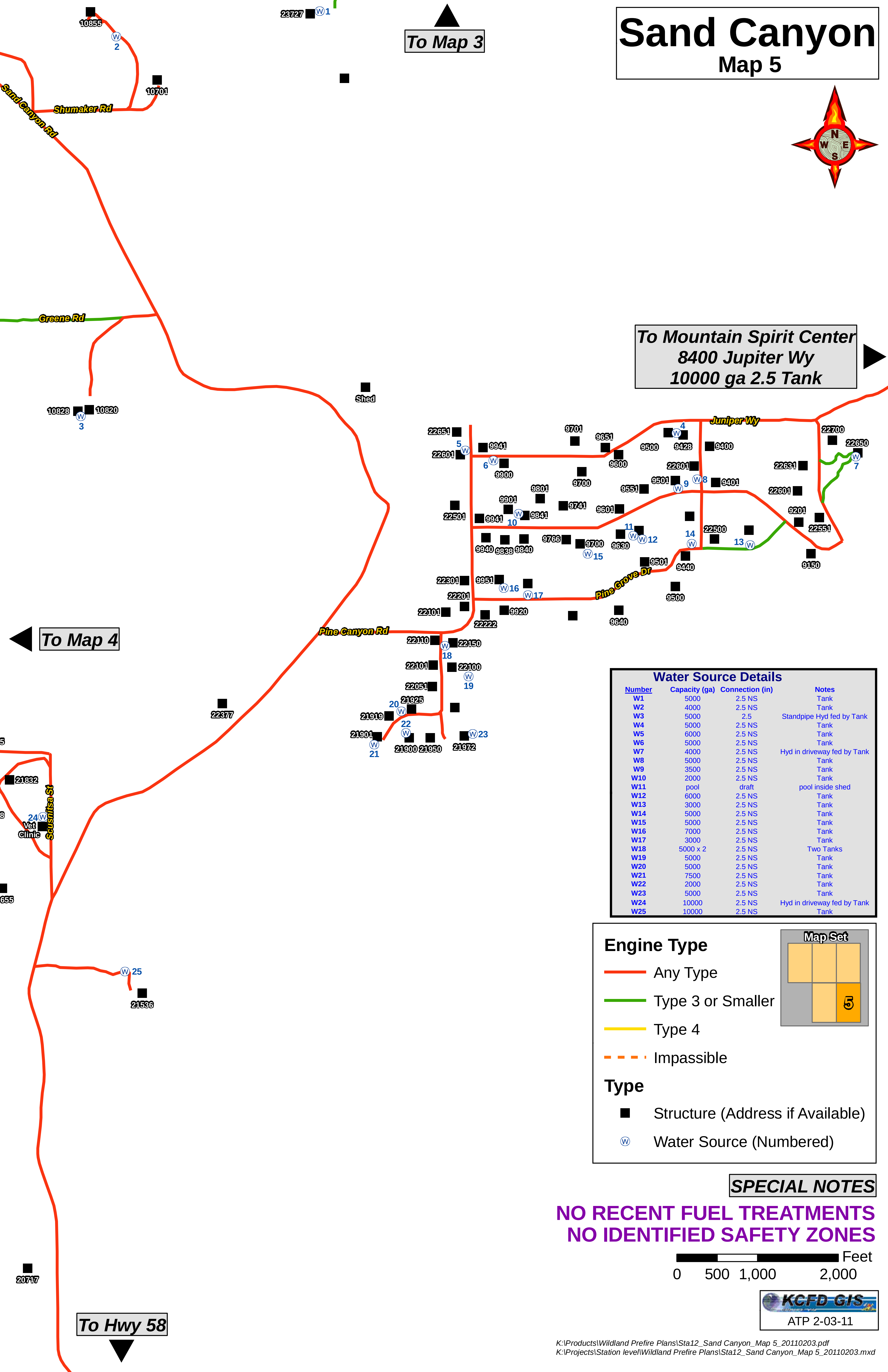
3. **What is biggest difference you've seen between wildfire events that you were involved with before pre-planned intelligence like these maps were available and now, where they are pre-positioned and able to be utilized for emergency response/planning?** *(ex. Radical improvement in situational awareness)*

4. **Can you think of other ways you believe these maps or the data collected/gathered are useful from a fire management perspective?**

5. **Any other comments on the Pre-fire plan mapping project, data, map products, etc…**

APPENDIX D: Sand Canyon: Map 5, Front and Back (Portrait Orientation Example)

Sand Canyon
Map 5



Water Source Details

Number	Capacity (ga)	Connection (in)	Notes
W1	5000	2.5 NS	Tank
W2	4000	2.5 NS	Tank
W3	5000	2.5	Standpipe Hyd fed by Tank
W4	5000	2.5 NS	Tank
W5	6000	2.5 NS	Tank
W6	5000	2.5 NS	Tank
W7	4000	2.5 NS	Hyd in driveway fed by Tank
W8	5000	2.5 NS	Tank
W9	3500	2.5 NS	Tank
W10	2000	2.5 NS	Tank
W11	pool	draft	pool inside shed
W12	6000	2.5 NS	Tank
W13	3000	2.5 NS	Tank
W14	5000	2.5 NS	Tank
W15	5000	2.5 NS	Tank
W16	7000	2.5 NS	Tank
W17	3000	2.5 NS	Tank
W18	5000 x 2	2.5 NS	Two Tanks
W19	5000	2.5 NS	Tank
W20	5000	2.5 NS	Tank
W21	7500	2.5 NS	Tank
W22	2000	2.5 NS	Tank
W23	5000	2.5 NS	Tank
W24	10000	2.5 NS	Hyd in driveway fed by Tank
W25	10000	2.5 NS	Tank

Engine Type

- Any Type
- Type 3 or Smaller
- Type 4
- Impassible

Type

- Structure (Address if Available)
- Water Source (Numbered)

Map Set 5

SPECIAL NOTES

NO RECENT FUEL TREATMENTS
NO IDENTIFIED SAFETY ZONES

Feet: 0, 500, 1,000, 2,000

KCFD GIS
ATP 2-03-11

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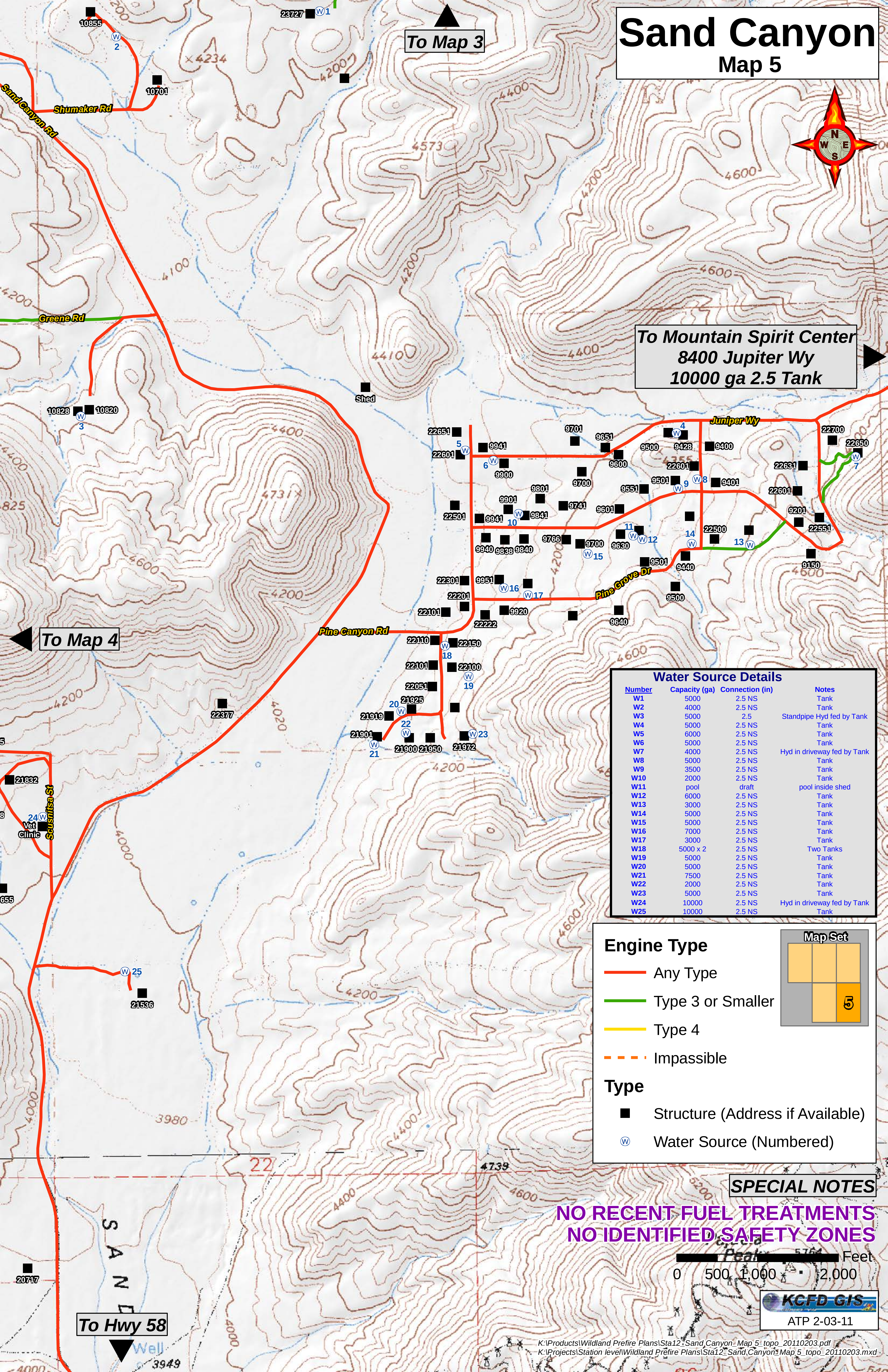
Sand Canyon
Map 5



Water Source Details

Number	Capacity (ga)	Connection (in)	Notes
W1	5000	2.5 NS	Tank
W2	4000	2.5 NS	Tank
W3	5000	2.5	Standpipe Hyd fed by Tank
W4	5000	2.5 NS	Tank
W5	6000	2.5 NS	Tank
W6	5000	2.5 NS	Tank
W7	4000	2.5 NS	Hyd in driveway fed by Tank
W8	5000	2.5 NS	Tank
W9	3500	2.5 NS	Tank
W10	2000	2.5 NS	Tank
W11	pool	draft	pool inside shed
W12	6000	2.5 NS	Tank
W13	3000	2.5 NS	Tank
W14	5000	2.5 NS	Tank
W15	5000	2.5 NS	Tank
W16	7000	2.5 NS	Tank
W17	3000	2.5 NS	Tank
W18	5000 x 2	2.5 NS	Two Tanks
W19	5000	2.5 NS	Tank
W20	5000	2.5 NS	Tank
W21	7500	2.5 NS	Tank
W22	2000	2.5 NS	Tank
W23	5000	2.5 NS	Tank
W24	10000	2.5 NS	Hyd in driveway fed by Tank
W25	10000	2.5 NS	Tank

Engine Type

- Any Type
- Type 3 or Smaller
- Type 4
- Impassible

Type

- Structure (Address if Available)
- Water Source (Numbered)

Map Set

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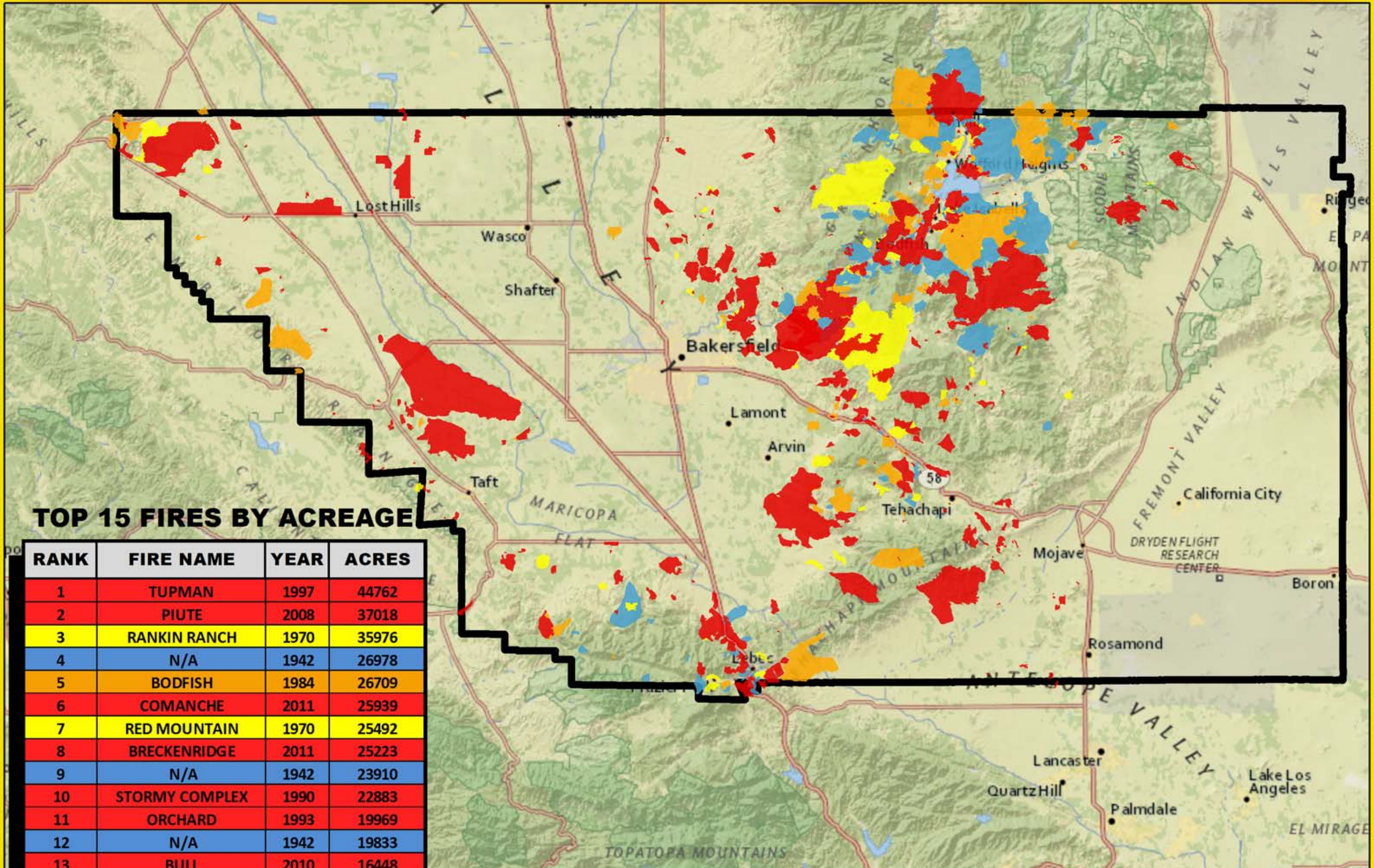
APPENDIX E: Map of Kern County's Wildfire History

LARGE WILDFIRE HISTORY

1900 to 2011

Kern County, CA



TOP 15 FIRES BY ACREAGE

RANK	FIRE NAME	YEAR	ACRES
1	TUPMAN	1997	44762
2	PIUTE	2008	37018
3	RANKIN RANCH	1970	35976
4	N/A	1942	26978
5	BODFISH	1984	26709
6	COMANCHE	2011	25939
7	RED MOUNTAIN	1970	25492
8	BRECKENRIDGE	2011	25223
9	N/A	1942	23910
10	STORMY COMPLEX	1990	22883
11	ORCHARD	1993	19969
12	N/A	1942	19833
13	BULL	2010	16448
14	ORCHARD PEAK	1966	15485
15	CANYON	2011	14585

ATP 20120710
WGS84 DATUM

0 15 30 60 Miles

FIRE PERIMETERS

1950 and before | 1951 - 1970 | 1971 - 1990 | Since 1991

N