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An Assessment of Fuel Treatment Effects on Fire Behavior, Suppression Effectiveness, and Structure Ignition on the Angora Fire

An Assessment of Fuel Treatment Effects on Fire Behavior, Suppression Effectiveness, and Structure Ignition on the Angora Fire

Lake Tahoe Basin Management Unit

Report Submitted to

Ed Hollenshead
Regional Fire Director, Pacific Southwest Region,
Vallejo, California

Authors

Kathy Murphy
Fuels Operations Officer, Pacific Southwest Region,
Vallejo, California

Tim Rich
Fuels Specialist, Pacific Northwest Region,
Portland, Oregon

Tim Sexton
Fire Use Program Manager, National Interagency Fire Center,
Boise, Idaho

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Executive Summary

The Angora Fire started southwest of South Lake Tahoe on the afternoon of June 24th from an unattended campfire. It burned under some of the most severe fire danger conditions experienced in this area during the last 20 years. The fire spread four miles in three hours and burned more than 250 structures on private property. Most of the 3,072 acres within the fire perimeter involved National Forest System lands, however about 300 urban lots administered by the United States Forest Service (USFS), California Tahoe Conservancy (CTC), and Eldorado County, and 231 acres of private property burned.

Ed Hollenshead, USFS Region 5 Fire Director requested a team to assess:

- Effects of fuel treatments on:
  - fire behavior
  - fire suppression
  - structure ignition
  - public safety/egress
- Fire behavior in non-treatment areas and other vegetation management treatments units.

Areas evaluated within and adjacent to the fire perimeter included all of the 480 acres of USFS area fuel treatments, and about half of the approximately 300 urban lots. About 405 acres of USFS area fuel treatments burned with surface fire intensity. More than 80 percent of the urban lots burned as surface fire. Almost all of the non-treatment and other vegetation management areas burned with crown fire intensity.

Key findings:

- Most of the area fuel treatments reduced fire behavior from a crown fire to a surface fire.
- Area fuel treatments adjacent to subdivisions provided important safety zones, increasing suppression effectiveness which saved houses.
- Urban lot treatments reduced ember production, and reduced heat and smoke allowing firefighters to be more effective.
- A large number of houses burned from firebrands generated from other burning houses rather than wildland fuel.
- Fuel treatment units on steep slopes burned at higher intensity than those on flat ground
- Some fuel treatment units burned at high fire intensity because they were adjacent and downwind from untreated units. Crown fire momentum carried high fire intensity partway into these treated areas before the more widely spaced crowns and reduced surface fuel caused the fire to fall to the surface.

Introduction

The Lake Tahoe Basin encompasses about 500 square miles of which more than a third (122,600 acres) is the lake itself. The basin is located 150 miles east-northeast of San Francisco on the Califor-

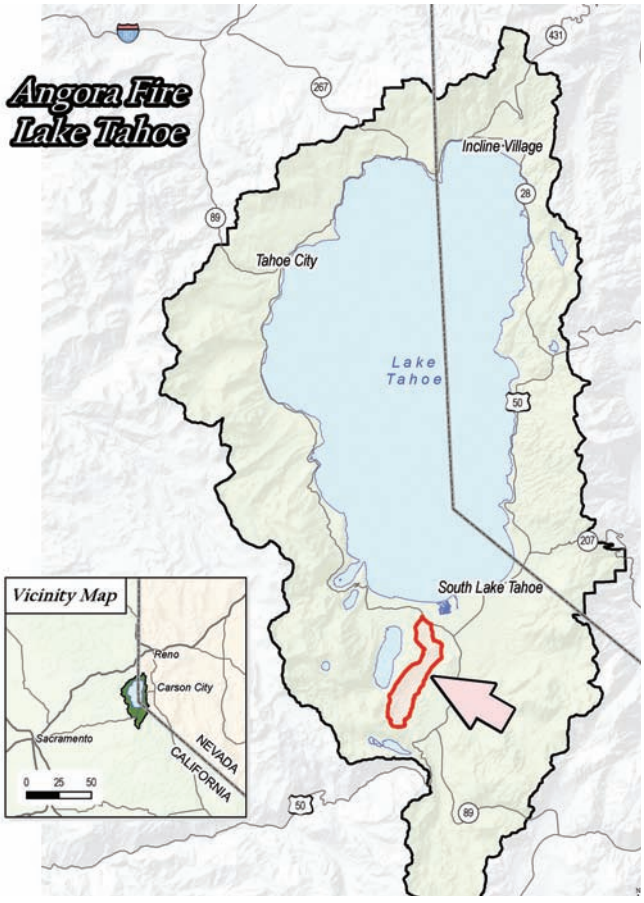


Figure 1. Vicinity Map of Angora Fire

nia-Nevada border. The lake, at 1645 feet deep and maximum elevation of 6,229, is most famous for its crystal clear water. Recreation and scenic beauty attract 3-4 million visitors to the National Forests in the Lake Tahoe Basin each year.

The U.S. Forest Service administers the Lake Tahoe Basin Management Unit (LTBMU) and is the Tahoe Basin's largest land manager, responsible for 78% of basin lands, approximately 165,000 acres. As such, the Forest Service has the largest single role in ecosystem and watershed management and protection.

The LTBMU is a unique intermix of forest and urban communities, presenting a variety of challenges and complexities. The Forest Service works in collaboration with other federal, state and local agencies to reduce hazardous fuel in the Lake Tahoe Basin.

National Forest System Urban Intermix Parcels

The Santini-Burton Act of 1980 (Public Law 96-586) authorized the Forest Service to acquire environmentally sensitive lands within the Lake Tahoe Basin to protect these lands from development. The Act has resulted in federal acquisition of over 3,500 parcels, varying from a fraction of an acre to several hundred acres in size. The primary focus of Forest Service activities on these lots has been fire hazard reduction, hazard tree management, and watershed restoration. Nevada Division of State Lands and the California Tahoe Conservancy manage more than 6,500 additional urban lots within the Lake Tahoe Basin.

Fire History

Tree ring studies in the Lake Tahoe Basin indicate that the natural fire return interval was approximately 5-20 years in the lower elevations. A century of fire exclusion has interrupted the natural fire cycle resulting in dramatic changes in the forest. Tree density has increased, ladder fuel has developed, and surface fuel has accumulated.

In the last twenty years, there has been an annual average of 62 fire starts on National Forest System lands within the Lake Tahoe Basin. Twenty one percent of those have been caused by lightning and 79% by humans.

Prior to the Angora fire, the Gondola fire (673 acres) and the Showers fire (294 acres) were the largest recorded wildland fires in the Lake Tahoe Basin. Both of these fires occurred in 2002. The Angora fire grew to 3,072 acres and most of that growth was during the initial burn period under dry, windy conditions.

Objectives

The objectives for the assessment were to evaluate:

- ◊ Effects of fuel treatments on:
  - fire behavior
  - fire suppression
  - structure ignition
  - public safety/egress
- ◊ Fire behavior in non-treatment areas and other vegetation management treatments units.

Methodology

Facts and circumstances surrounding the Angora fire were determined through on the ground and aerial reconnaissance, interviews with homeowners, firefighters, fire scientists and fire behavior experts. Videos and photos taken prior to, during and after the Angora fire were also reviewed. In addition, data collected by staff of the Lake Tahoe Basin Management Unit and others were used in the review.

Description of Fire Environment

Fuel and topography

Fuel types within and adjacent to the fire perimeter vary by vegetation types. Most of the fire area is characterized by multi-storied mixed conifer stands with moderate and heavy dead woody fuel and mixed brush in the understory. A variety of vegetation and fuel management activities have occurred throughout the area.

Conditions in untreated stands varied but were mostly dense, multi-storied stands with abundant ladder fuel (Figure 2). Live surface fuel consisted mostly of manzanita, bitterbrush, and sage brush. Heavy dead woody fuel loadings were present in the south portion of the Angora Creek Stream Environment Zone (SEZ), and in the areas not actively managed. Fuel was sparser on the southwest perimeter and the southeast slope of Tahoe Mountain, where the terrain is steep and rocky.

Figure 2. Typical conditions in stands which had not received fuel treatments

Figure 3. Fuel treatment area southwest of Cayuga Circle *(see Residential Area Street Map in Appendix A)*.

Where vegetation and fuel management activities have been implemented, stands were less dense, with fewer small trees, and greater numbers of large Jeffrey Pine. Surface fuel in these managed stands consisted of pine needles and brush, with small amounts of large decayed wood (Figure 3).

The topography within the fire perimeter varies from flat on the southeast flank to steep (>40%) on the south and southeast aspects and on the west side of Angora Ridge and Tahoe Mountain.

General Treatment Types	Acres
USFS Fuel Treatments	480
USFS Other Vegetation Treatments	850
USFS Urban Lot Treatments	42
USFS Non Treatment	1,366
State CTC Urban Lot Treatments	24
California State Park Treatment	3
California State Park Non treatment	17
State Ownership, Non Treatment	79
Private and other	211
Total	**3,072**

Table 1. Treatment types and approximate acres within the Angora Fire perimeter. Source data is the LTBMU Geographic Information System Staff

Fire Danger and Fire Weather

The Angora fire started on Sunday, June 24, 2007, burning all of the structures and most of the acres in the first burning period. Fire danger was listed as "Very High." The Meyers Remote Automated Weather Station (RAWS) data showed the Energy Release Component (ERC), a measure of fuel dryness, was above the 90th percentile for the season, and set a record for the day (Appendix C). The large dead fuel moisture was 9%, and live woody fuel moistures were 73%, near record lows for the date. The minimum relative humidity was 8%, a record for the date and the maximum temperature was 80 degrees. Winds were initially southwest, and then changed to more westerly later in the day. Wind speeds were recorded at Meyers RAWS at 12 mph with gusts to 22 mph. Local Fire Danger experts indicated that the Meyers RAWS did not reliably indicate windspeed and direction. Firefighters and other eyewitnesses estimated wind gusts on the fire as high as 40 mph.

Fire Behavior Chronology

The fire started near Seneca Pond at approximately 1400 hours at 6600 feet elevation in a dense stand of fir and pine and quickly transitioned to an active crown fire. Initial fire spread was down Angora Creek to the northeast driven by a strong southwest wind. Spotting distances were estimated at about ¼ mile downwind. At the same time, the fire made strong topographically driven crowning runs up to the top of Angora Ridge on the west flank. The fire spread a total of three miles during a four-hour period, reaching the top of Tahoe Mountain at about 1800 hours. Many spot fires developed on the northeast aspect above South Tahoe High School.

Figure 4. Fire behavior above South Tahoe High School Sunday Night, June 24th-25th

Nighttime cooling and a slackening of windspeed late Sunday evening caused a reduction in fire intensity and rate of spread. However, the fire continued backing downslope toward the high school during the early morning hours of Monday, June 25th. Suppression action contained this portion of the fire to a fireline immediately above the high school.

The first known house ignition occurred in the North Upper Truckee Subdivision just west of the intersection of Lake Tahoe Boulevard and Angora Creek Drive in the SW corner of section 18 and was extinguished by firefighters. The house survived with only minor damage to the deck and garage. This house was easily accessible from Lake Tahoe Boulevard and was adjacent to several safety zones (wet grassy areas in Angora Creek and large paved areas formed by road intersections) allowing effective suppression action. Heavy smoke limited early detection of structural ignitions to the north (Mule Deer Drive area). By the time firefighters discovered houses burning on Mule Deer Drive, several were burning with too much fire to extinguish.

Interviews with firefighters indicate that the structure fires grew rapidly and began producing a great number of large firebrands. Most of these firebrands were transported by winds only a short distance but many landed on or immediately adjacent to downwind houses. Many of the downwind houses caught fire in successive cycles. Some houses were not saved by firefighters due to low visibility due to smoke and inability to detect many of the house ignitions until they were too large to extinguish with handcrews and fire engines.

Figure 5. First house to ignite (saved by suppression action) indicated by blue circle. Wind direction indicated by arrow. Full subdivision map is available in Appendix A.

One house in the Angora Highland Subdivision (about one mile north of Mule Deer Drive) burned. It was located very close to the rim of a steep slope which caused it to receive great amounts of convective heat and direct flame impingement.

Also, this house had a large amount of firewood which ignited, producing additional radiant and convective heat that made approach to the house unsafe for firefighters.

Most of the other houses in this subdivision were showered with firebrands and experienced spot fires on and adjacent to them. Many of these houses would have burned without aggressive firefighting by engines and hotshot crews.

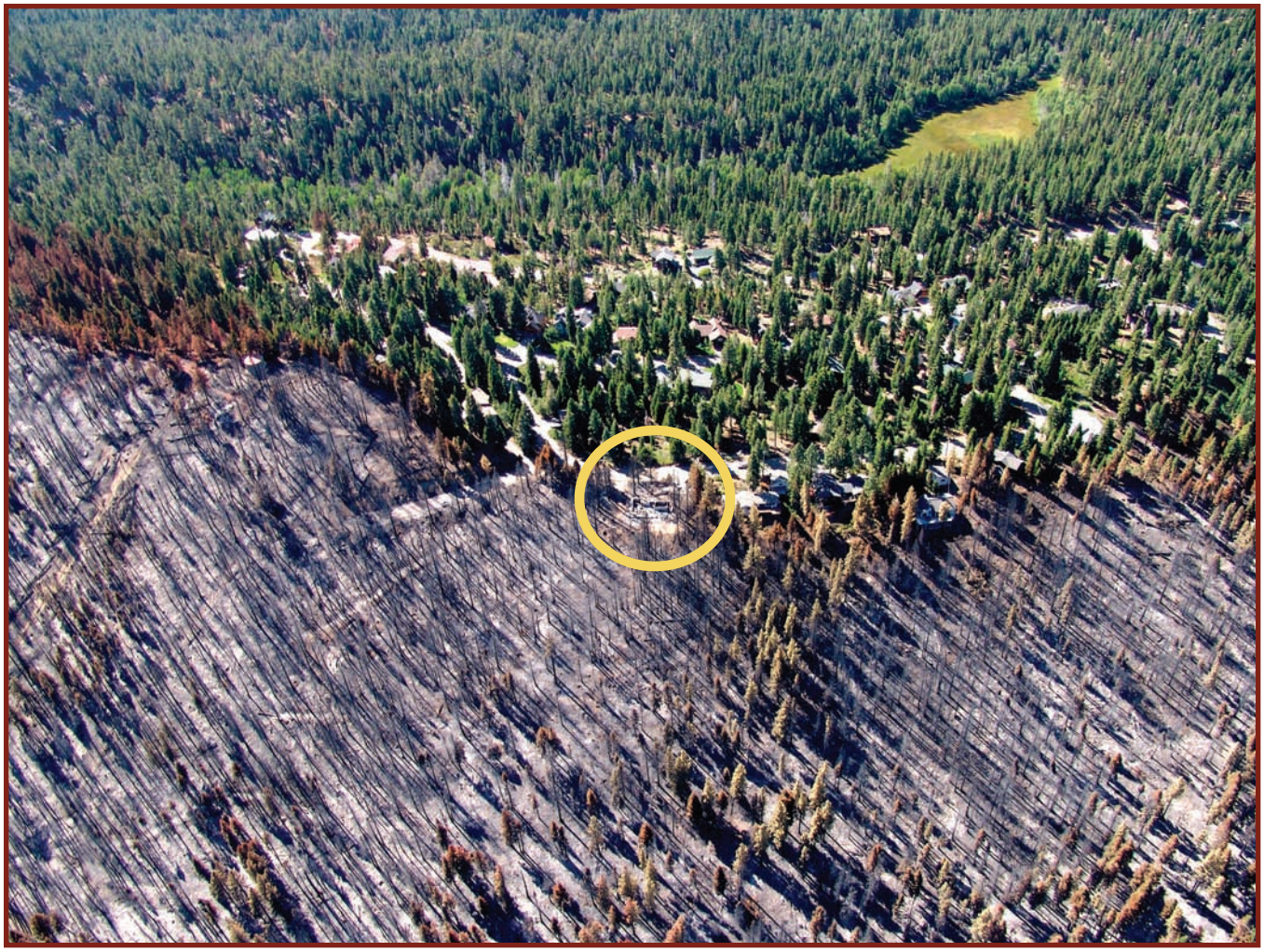


Figure 6. Single house which burned on Heather Circle in the Angora Highlands Subdivision. Note the location of house (yellow circle) on the edge of a steep slope exposed to an upslope crown fire run.

Some houses to the south on Zuni Street, Shoshone Street and Cayuga Circle burned later. The wind shifted to a more westerly direction in the late afternoon pushing the fire more directly toward these houses (see Appendix D).

Fire spread into this residential area with relatively low flame lengths. Almost all of the trees immediately to the west of the residences (in the fuel treatment unit) have unburned crowns indicating low to moderate intensity surface fire behavior. Photographic and video evidence support this conclusion.

Figure 7. Arrow indicates late afternoon wind direction. Note intact crowns of trees ("browned" by the surface fire heat but not burned). Surface fire spread through this Fuel Treatment Unit into the subdivision with low flame lengths (photo evidence and eyewitness estimates indicate flame lengths were less than 4 feet).

Figure 8. Note the unburned tree crowns and very low flame lengths in adjacent vegetation and surface fuel.

After spreading into the residential area the fire ignited combustible material adjacent to houses which then ignited the houses. Interviews with homeowners indicated that many of the houses had attached decks with combustible material stored under the deck. In some cases direct flame impingement from a low intensity surface fire ignited these combustibles, which then ignited the deck and ultimately the house. Visual examinations on the ground and aerial photos reveal that much of the vegetation between houses did not burn or burned with surface fire.

Figure 9. Note the unburned vegetation immediately adjacent to the structure indicating the ignition was from a spot fire.

Interviews with firefighters, other eyewitnesses, and video examination indicate that many houses ignited from burning embers produced by house fires upwind. A cycle of spotting from house to house in this area ended only when the fire ran into a buffer of trees with reduced house density to the northeast of Mt Shasta Circle.

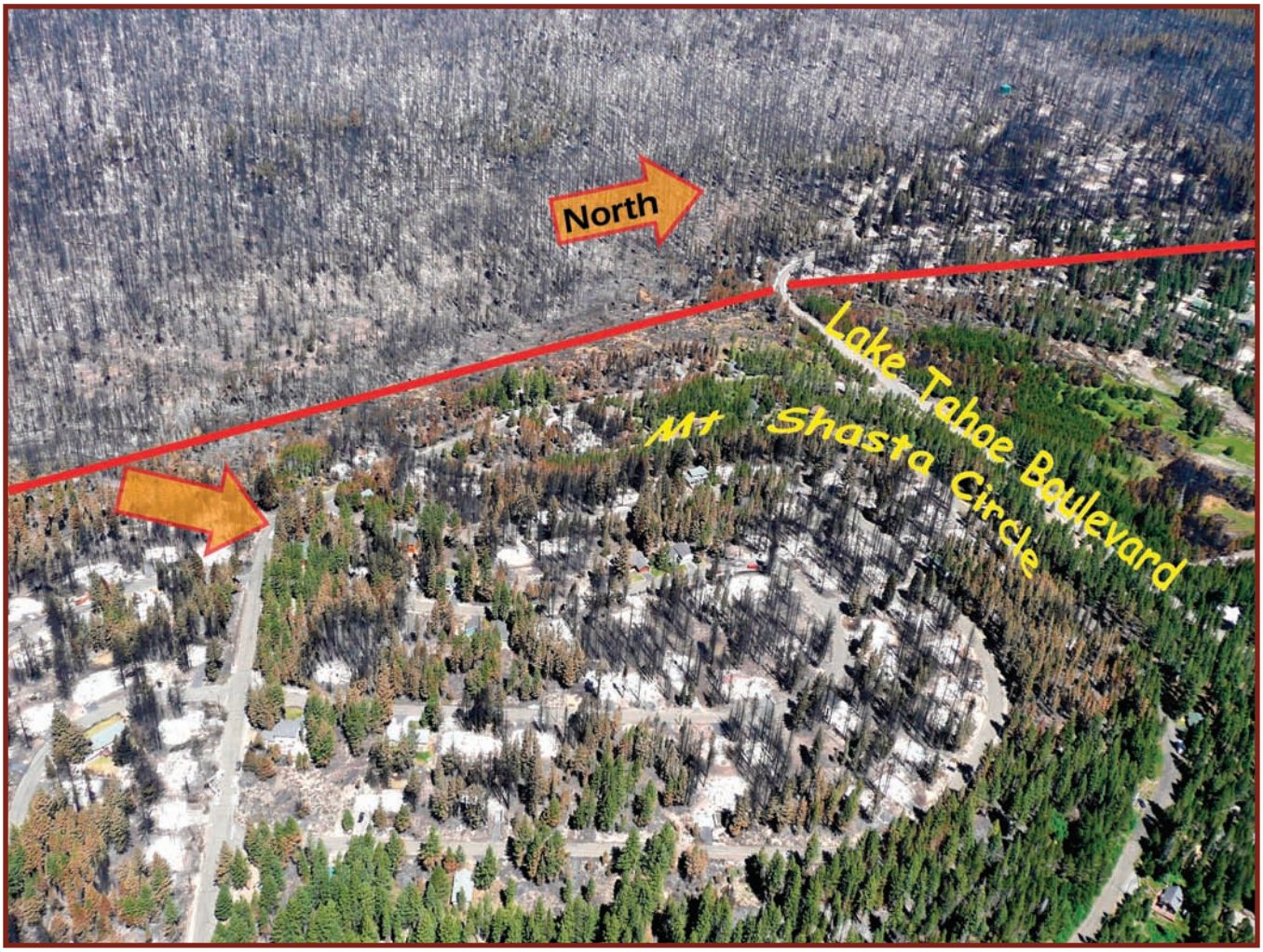


Figure 10. Arrows indicate fire spread. Upper slope fire spread (above the red line) occurred between 1430 and 1630. Lower fire spread (below the red line) occurred between 1700 and 1900 following a wind shift from southerly to westerly (Location of red line and times indicated are approximate). Note the green trees between Mt Shasta Circle and Lake Tahoe Boulevard. Fire spread and intensity was reduced in this area primarily due to USFS and CTC urban lot hazard fuel treatments, reduced concentration of houses and safer access by firefighters.

Fire Effects of Area Fuel Treatments

Description and Prescriptions

Prior to the Angora Fire, approximately 480 acres of fuel treatments were completed on National Forest System lands within the fire perimeter (excluding USFS urban lots). Fuel treatments were purposely located adjacent to residential areas. Other vegetation management activities had taken place in the fire area, but these treatments were not designed to change fire behavior (see maps in Appendix A).

Fuel treatment prescriptions on NFS lands consisted of commercial and/or pre-commercial mechanical thinning, followed by hand thinning, piling, and burning handpiles. Prescription details can be found in Appendix B. Underburning for all of the fuel treatment areas, except the urban lots, was in the planning stages.

Fire Behavior

Fuel treatments are designed to be used together with suppression resources and "fire-safe" principles to effectively reduce risk to homes. The objective of fuel treatments is to change fire behavior from crown fire to a surface fire, reducing spotting distances and convective and radiant heat. Suppression resources are effective only if fire intensity is reduced to moderate or low intensity surface fire. This level of intensity allows firefighters to extinguish spot fires and allow safe "close-in" engagement.

Under the weather conditions present during the Angora Fire, all vegetation would need to have been removed for as much as ½ mile to stop the fire without suppression action. Furthermore, fuel treatments on wildlands are effective only when adjacent homeowners have well-maintained, fire-safe property and when there are sufficient suppression resources present to extinguish spot fires and surface fire spread.

Fire behavior was analyzed for the 16 area treatment units on USFS lands that were wholly or partially within the fire perimeter. About 405 acres of USFS area fuel treatments burned with surface fire intensity and 75 acres burned as crown fire.

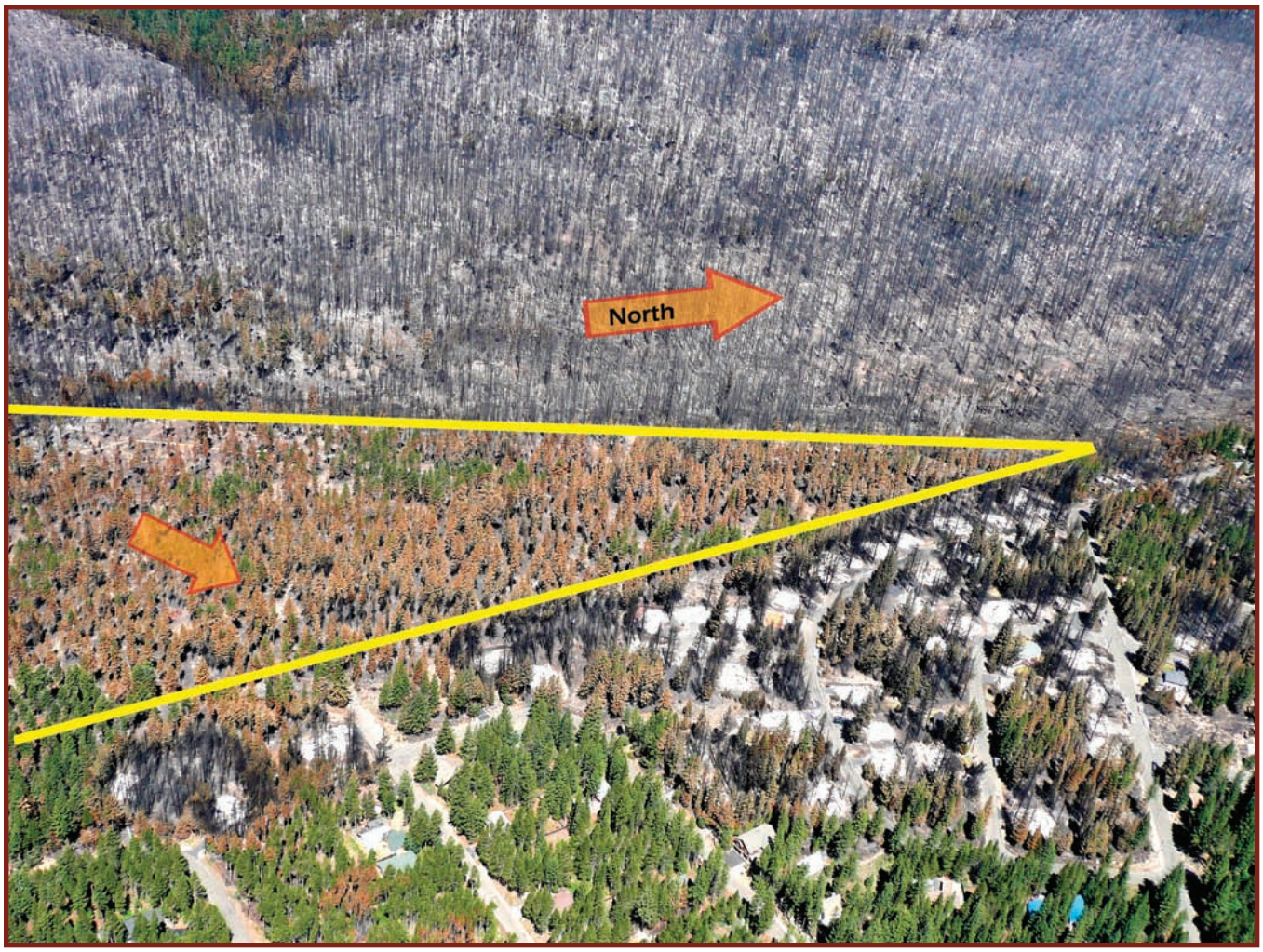


Figure 11. Direction of fire spread is indicated by the red/yellow arrow. Initially, spread direction was to the north. Late afternoon shifting, gusty winds drove the flank of the fire to the northeast. Note the "browned", but intact tree crowns in the fuel treatment area (enclosed in yellow lines) and the completely consumed crowns in the untreated area to the south and west (top of photo). The fire entered the treatment area as a crown fire and immediately transitioned to a surface fire due to the thinning of small trees that would otherwise carry fire into the crowns. When the fire moved into the residential area as a surface fire it increased in intensity due to the increased flammability of the structures and combustible items adjacent to the houses.

Differences in fire behavior within treatment areas were dependent on steepness of slope, position on slope, and the intensity of the main fire when it entered the particular treatment area. A fundamental wildland fire behavior principle states that fire intensity and rate-of-spread increase as slope increases. Fuel treatments need to be more intensive (more surface fuels removed and wider crown spacing) on slopes to achieve the same effect as on flat ground.

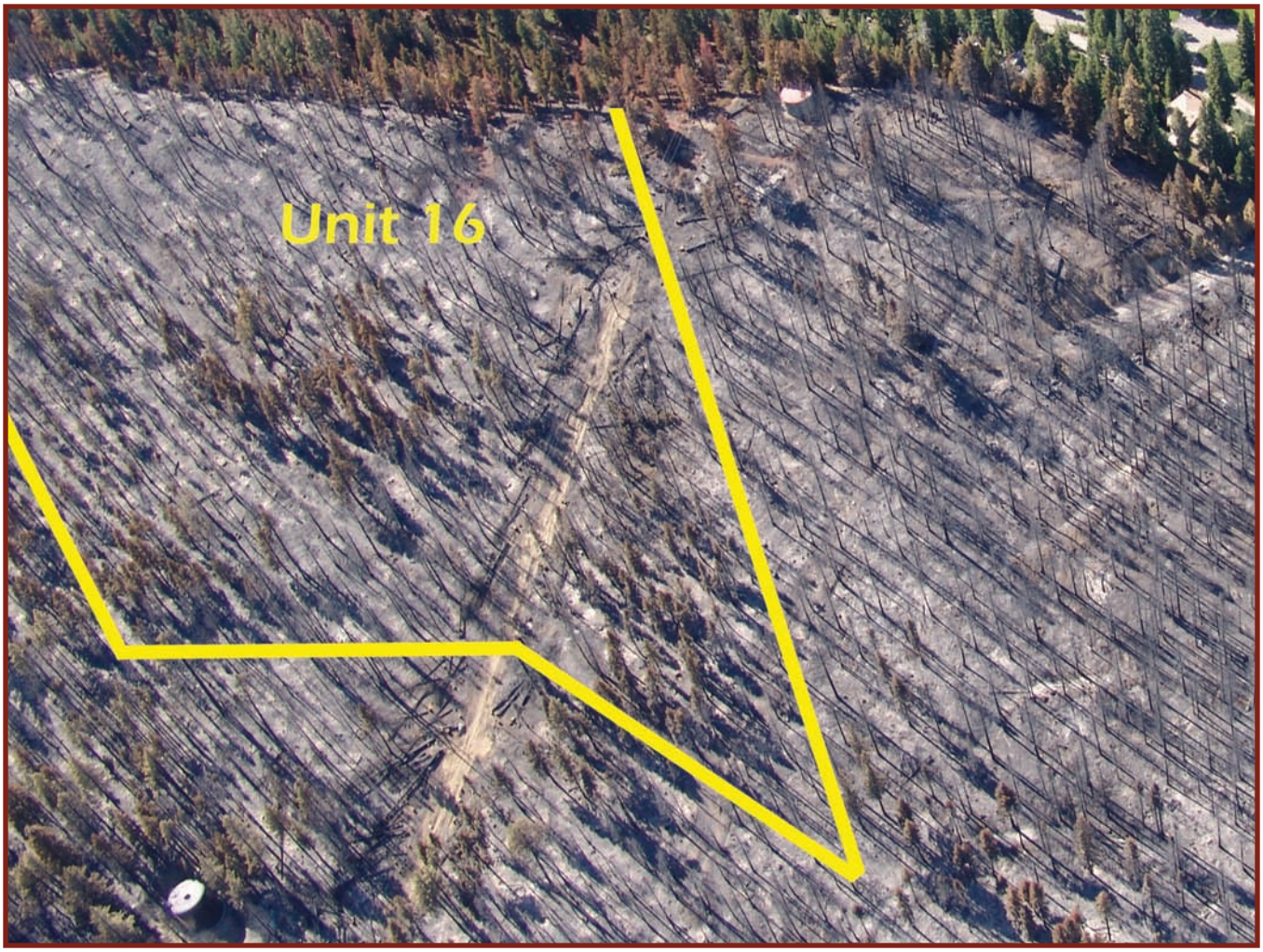


Figure 12. Fuel Treatment Unit 16 which burned at high intensity due to steep slope and the effect of "crown fire momentum".

Unit 16 (see Figure 12) depicts a treatment unit which burned mostly by crown fire due to slope effect and its location in the path of the head fire. All of the fuel treatment units that burned with high intensity (crown fire) were situated directly in the path of the head of the fire on steep slopes. (Fuel Treatment Map located in Appendix A). "Crown fire momentum" will carry high fire intensity into treated areas to a distance associated with the level of radiant and convective heat produced by the crown fire. Eventually, the fire will drop to the surface and burn with lower intensity.

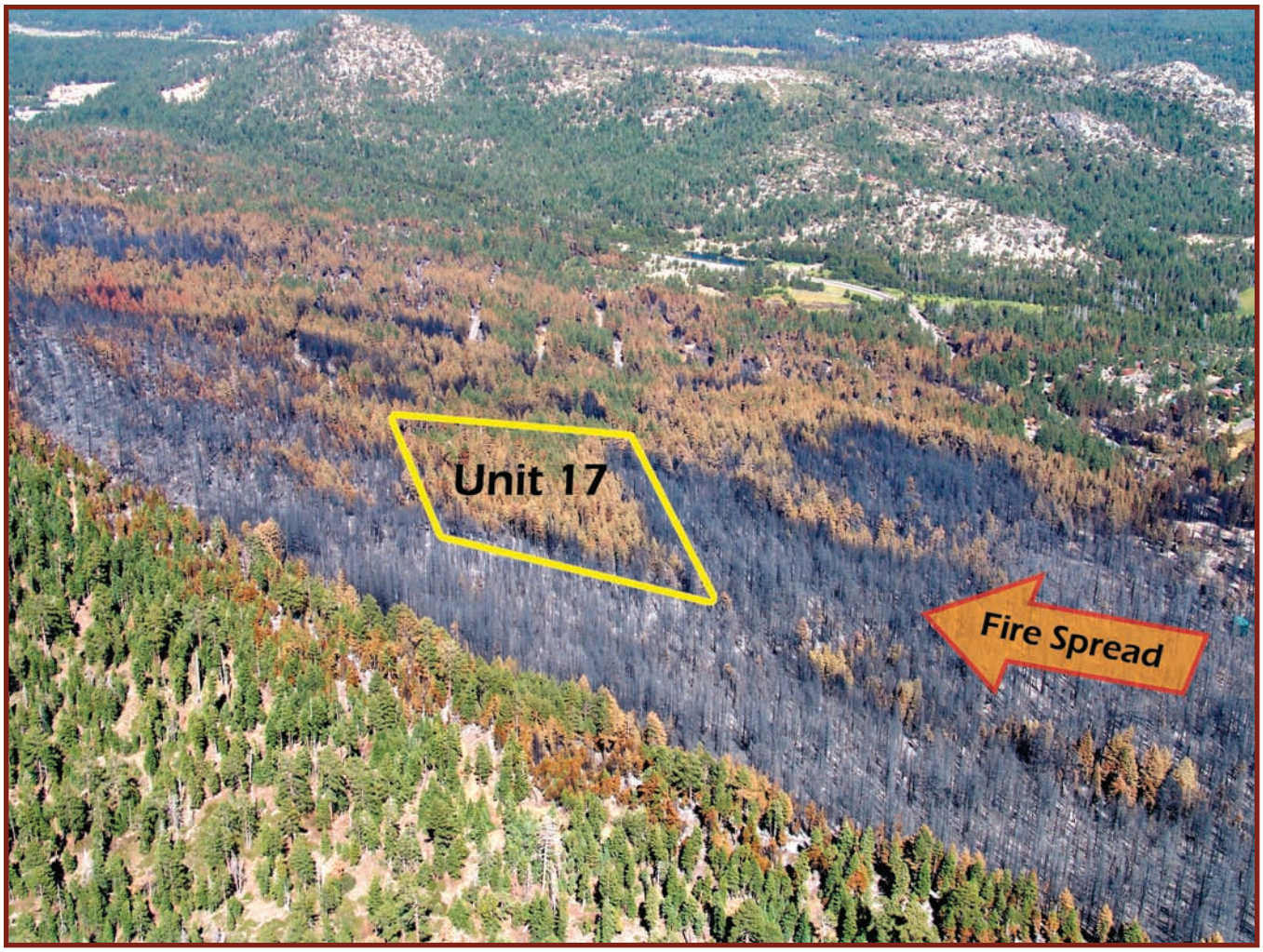


Figure 13. Fuel Treatment Unit 17 (outlined in yellow) is located below and to the east of Angora Highlands. The full force of the crowning headfire ran into this treatment unit, torching trees along the southern edge of the unit. After penetrating the treated area, the crown fire lost momentum and transitioned to a lower intensity surface fire due to greatly reduced amount of surface fuel, limited ladder fuels, and wider crown spacing.

Figure 13 depicts Unit 17 where crown fire momentum carried high intensity fire into a treated unit, but fell to a surface fire partway through the unit. Approximately thirty percent of Unit 8 (steep slope portion) burned as a crown fire. Smaller percentages of Units 21 and 22 burned as crown fire because of steep slope portions and the momentum of crown fire from upwind untreated areas.

The eleven treatment units that burned entirely as surface fire resulted in the desired fire behavior change (from crown fire to surface fire). Units 21 and 29 were located between the main head fire (in the south part of Angora Creek and on the west slope above Angora Creek) and the residential area defined by Cayuga on the south and the Mt Rainier Drive/Lake Tahoe Boulevard intersection on the north. Fuel treatments in these units slowed fire spread and reduced fire intensity. In addition, spot fire production decreased and spotting distances were reduced to less than 50 feet (as reported by eyewitness accounts and videos). The overall effect was a significant reduction in radiant and convective heat and a reduction in the number of houses impacted by firebrands as the fire entered the residential area.

Figure 14. Fuel Treatment Unit 29. Note intact tree crowns indicating a low intensity surface fire.

In general, the effects exhibited by treatments in Units 21 and 29 were evident throughout the fire area. The ultimate fire perimeter, especially on the east flank, was much smaller than it would have been without treatments. Units 18, 19, 21, and 29 reduced the fire to a surface fire, and reduced the number of embers impacting houses. Without the fuel treatment, the ember impact zone would have been several hundred yards further into the subdivisions to the east and northeast. Spotting estimates were determined from firefighter interviews comparing spotting from crown fire runs with spotting from surface fire runs.

Unit 20 (near the Angora Stream Environment Zone as it enters the residential area at Lake Tahoe Boulevard) was unique in that scheduled treatments were partially complete when the Angora Fire burned. This treatment unit had been thinned and the resultant slash was piled between the fall of 2004 and July, 2005. The "green" tree boles, branchwood and needles in the piles were left to dry out prior to burning. Green boles take a minimum of one year, sometimes two years to dry out enough to enable timely and complete consumption of the material during prescribed burning of piles.

Unit 20 received the full force of crown fire momentum when the fire entered it from the upwind untreated stands. Most of this unit burned with crown fire intensity, however, a few trees within the unit did not crown (see Figure 15). Total heat

output from the fire in this unit was similar to that of adjacent untreated stands. All of the fuel in the handpiles would have been located at a greater height (in upper branches and crown foliage) and would have burned just as this fuel burned in adjacent untreated stands. The greater height of the fuel would have allowed embers to be lofted higher and transported downwind to a greater distance. Very little difference in convective or radiant heat output would have occurred because the same amount of fuel would have burned.

The Tahoe Paradise Residential Area (see Residential Area Street Map in Appendix A) was a high priority for LTBMU hazard reduction activities. Hand piles in many fuel treatment units within and adjacent to the Angora Fire (units 7, 8, 11-14, 16-19, and 28) were burned beginning in the fall of 2006 and continuing through April 2007 (see Fuel Treatment Map in Appendix A). More than 850 acres of hand piles were burned within LTBMU last fall, winter, and spring. However, there were not enough available burn opportunities due to a short dry winter and air quality constraints to burn all "cured" handpiles within the Basin. The hand piles in Unit 20 were among those which did not get burned.

Figure 15. *Unit 20 west of Angora Creek Road. This unit contained unburned handpiles which had been generated by a thinning project. While most of this area burned with crown fire intensity it is apparent that some crowns did not burn, likely due to the wider crown spacing created by the thinning project. The wider crown spacing and reduced crown fuel loads (crown residue was lowered to the surface) reduced spotting distances. Spotting distance is related to height of ember loft and transport windspeed. Cutting trees and piling the "crown" residue at the surface had an effect of reducing ember lofting height.*

Suppression effectiveness, structure ignition, and public safety/egress

Many firefighters reported increased ability to take "close-in" suppression actions because of the adjacent treatments which provided "black" safety zones after the fire had passed. Many houses were protected from fire or had spot fires extinguished in areas that would have been unsafe. Units 12, 13, 17, 18, 19, and 29 (see Fuel Treatment Map in Appendix A) all burned as surface fire with less duration than had they been untreated, and therefore provided these important safety zones.

Units 6, 29 and 30 burned with reduced fire intensity that enabled firefighters to build and hold direct fireline. Unit 7 burned mostly with crown fire behavior; however, firefighters reported that they were able to use treated areas within this unit to construct and hold direct fireline.

Eyewitness and video evidence indicates that most houses ignited from ember fall or direct flame impingement by low intensity surface fire. On-site inspections revealed that many trees adjacent to houses had severe scarring on the side facing the house and much less severe scarring on the side facing away from the house. This indicates that the house fire caused the tree to burn and not the reverse.

Public safety, especially during evacuation, was enhanced by several treatment units. Units 8, 12, 13, 14, and 19, adjacent to Lake Tahoe Boulevard and Tahoe Mountain Road all burned as a surface fire, reducing the intensity and amount of smoke than would have occurred had these units been left untreated and burned as a crown fire. Firefighters reported that this provided greater visibility and enhanced an orderly evacuation.

Figure 16. Note the severe scarring (enclosed by yellow circle) on the side of the tree facing the burned structure and intact bark on the side of the tree facing away from the structure.

Fire Effects of Urban Lot Fuel Treatments

Description and prescriptions

Within the fire perimeter and intermixed within neighborhoods, there were over 100 USFS owned urban lots totaling about 200 acres, about 175 lots owned by California Tahoe Conversancy (CTC), and about 28 lots owned by El Dorado County. Fuel treatments occurred on most of the urban lots. El Dorado County has also completed one vegetation treatment for erosion control on USFS lands within the Angora SEZ.

The USFS urban lots within the fire perimeter had been treated between 1995 and 1997 with a similar prescription to the USFS area treatments, but with the addition of hand thinning 30-50% of the brush in a mosaic pattern (Appendix B). The intent of the treatments was to reduce crown fire potential, improve defensible space to adjoining private lands, and to reduce stocking levels to resist insect infestation.

Fire Behavior

Fire behavior was evaluated on 70 of the USFS-administered urban lots within the fire perimeter. Sixty-eight of these lots exhibited surface fire behavior. Eyewitness accounts indicate flame lengths were less than four feet. Of the lots with crown fire behavior, one was not treated; the other was on a steep slope.

Figure 17. Note intact tree crowns indicating that the fire burned at low intensity at the surface in treated urban lots.

Fire behavior was also evaluated on 80 CTC lots. Of these sampled lots, 11 had not been treated. Fifty-two lots exhibited surface fire behavior, 10 exhibited partial torching of the overstory, 14 burned with crown fire behavior, and four lots did not burn. In most cases the urban lots that burned with crowning or torching were immediately downwind from structures that burned intensely.

Within the subdivisions, burning houses created the greatest fire intensities and produced the greatest numbers of large embers. Most urban lot treatments provided fuelbreaks, slowing fire spread. According to interviews with firefighters and on-site inspections, fire intensity was significantly reduced when fire entered urban lots. Had these lots not been treated, they would have provided additional sources of firebrands, and sources of radiant heat to adjacent houses.

Figure 18. Note the intact, unburned vegetation surrounding this structure. It is evident from unburned vegetation and surface litter surrounding the house that it was ignited by a wind-borne ember (spot fire), not by surface fire spread, or radiant heat.

Suppression effectiveness, structure ignition, and public safety/egress

Many firefighters reported that the treated urban lots significantly increased suppression effectiveness because of the relatively low intensity surface fire that enabled direct attack of spot fires, preventing adjacent houses from burning. In instances where a lot was adjacent to a house, firefighters were able to take "close-in" suppression action if an ember landed on the house or caused an adjacent spot fire. Firefighters reported that many structures were saved because of this. They also reported that suppression effectiveness was enhanced by reduced smoke production from the urban lot treatments enabling them to see spot fires when they were small and rapidly suppress them.

Public safety and egress was enhanced by the urban lot treatments for similar reasons as the area treatments. Smoke production was reduced, increasing visibility, and because of reduced fire intensity, firefighters could more effectively protect houses adjacent to urban lots.

There are a variety of reasons that houses burned. Some burned because firebrands landed on receptive locations such as on decks, shake roofs, or woodpiles. Some burned because a continuous fuelbed, such as pine needles, lay adjacent to a burnable part of the house.

Figure 19. Note the small spot fire produced by embers from the burning house.

There are also many reasons houses did not burn. Distance from firebrand sources reduced the number of embers landing on a house. Suppression resources saved many houses from either catching fire, or put them out before they became fully involved. Some houses did not burn because they had less burnable material exposed to firebrands or surface fire. Clearly, fewer houses would have burned had they had more effective defensible space, better access for firefighters, and contained less flammable material.

Fire Effects of Non-treatment Areas

Description

Approximately 1366 acres within the fire perimeter have had little or no management activity in recent history. Most of this area had little commercial timber value. In addition, there was poor access, or adverse terrain for commercial logging or fire hazard reduction activities.

Fire Behavior

Because of steep terrain and heavy fuel, most of the non-treatment areas burned as a crown fire, consuming 95 -100 percent of the tree crowns and surface vegetation. Areas that did not burn in crown fire, particularly on the southwest perimeter, had sparse fuel. Firefighters on-scene and adjacent homeowners reported that the fire raced down the south portion of the Angora Creek SEZ to the north-northeast and burned up to Angora Ridge to the west as an active crown fire. When the fire entered the meadow portion of the lower Angora Creek SEZ (Figure 20 - the area enclosed by yellow lines) it changed to a spotty surface fire. The dense stand portion adjacent and to the west of the green rectangle continued to support crown fire runs upslope to Angora Ridge. These dense stands of trees in the Angora SEZ likely contributed to the rapid spread upslope to Angora Ridge and across the slope to the base of Tahoe Mountain.

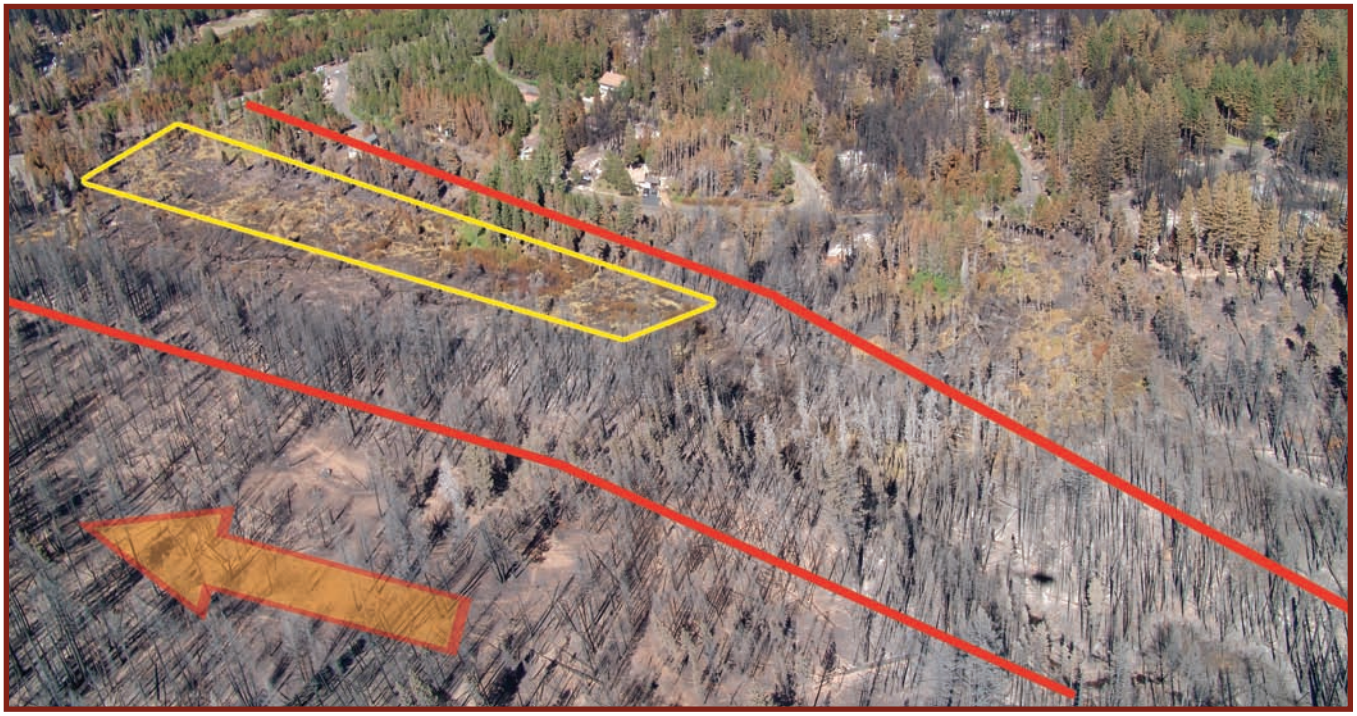


Figure 20. Angora SEZ. Dense, continuous stands of trees contributed to rapid spread rates (to the NNE) down this stream corridor. Arrow points in direction of wind and fastest fire spread (NNE). Note greater density of trees within the SEZ (roughly outlined in red).

The fire perimeter was contained for two days. However, on June 26, strong winds surfaced causing multiple spot fires to the north of the main fire. Most of this area had not received any management activity during the preceding ten years. Approximately 300 acres burned as a high intensity crown fire between Forest Service Road 12N19 and Highway 89 requiring an evacuation of portions of Gardner Mountain Subdivision.

Figure 21. Angora Creek SEZ south of Lake Tahoe Boulevard. Note tree density in back of large log. Most surface fuel and tree crowns were consumed by the high intensity fire.

Suppression effectiveness, structure ignition, and public safety/egress

Suppression resources could not safely engage the fire in most of the untreated areas due to rapid rates of spread and very high intensity. In the southwest portion of the fire, fire crews were able to contain the fire when it reached the rocky ridge top and ran into sparse fuel. The fire was contained in other

untreated areas when it ran into an adjacent fuel treatment area, or encountered a change in aspect or topography. There is a small untreated area just below the Angora Highlands Subdivision (see figure 6). Fire intensity and rate of spread were greatest here. One house burned, but it was situated very close to the edge of the steep slope which exposed it to greater convective heat. Firefighters saved many houses here in spite of the intense fire behavior.

Fire Effects of Other Vegetation Management Areas

Description

About 850 acres within the fire perimeter have had other vegetation management activities in the recent past. Most of these treatments were commercial thinning or salvage logging. Limbs and tops remained on many of the sites. Only roadside logging slash was treated. These mid-1990 activities were not designed or located for fuel reduction objectives.

Fire Behavior

Fire behavior within these areas was very similar to the non-treatment areas. Most of the areas burned with high intensity crown fire.

Suppression effectiveness, structure ignition, and public safety/egress

Suppression effectiveness was also similar to the non-treatment areas. Unit 5, adjacent to the high school, was the only vegetation management unit adjacent to structures. This was a helicopter commercial salvage logging unit completed in 1995. The high school buildings were constructed of fire resistant materials and were easily defended by engines and handcrews. No evidence was found to indicate that vegetation treatments had any bearing on public safety in this area.

Summary

- ◊ Most fuel treatments worked as intended, by reducing fire intensity from a crown fire to surface fire.
- ◊ One partially treated unit (Unit 20 where handpiles had not been burned) showed no significant fire intensity difference from the adjacent untreated stand.
- ◊ One fuel treatment (Unit 16) was only partially effective because it was located on a steep slope which requires greater fuel reduction to achieve the same results as on flat ground.
- ◊ Where urban lots had fuel treatments, they served as fuel breaks, allowing firefighters to safely protect structures.
- ◊ Houses provided a large source of embers for spot fires and additional structure fires.

Acknowledgements

We would like to thank the people who contributed information, photos and provided interviews or other support to the team.

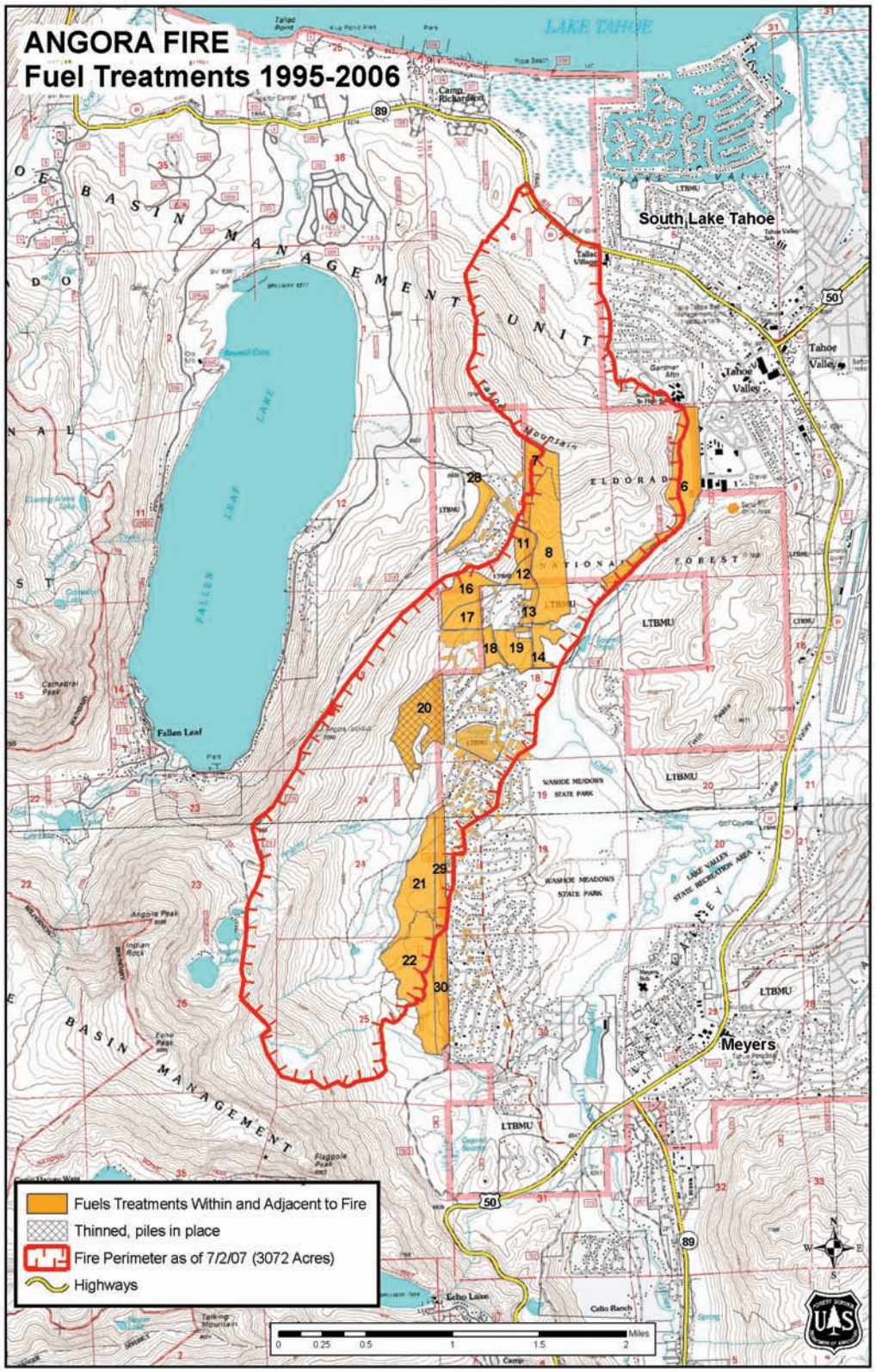
Incident Management Team 1 and others assigned to the Angora fire: Rich Hawkins, Jerry McGowan, Jennifer Boyd, Kelly Martin, Sue Husari, Pete Duncan, Matt Hoggard, Mike Beckett, Robert Holt, Ranger Dorn, Forest Service and other agency initial attack firefighters.

LTBMU employees: Terri Marceron, Eli Ilano, Arla Hains, Dave Marlow, Kit Bailey, Mark Johnson, Steve Burns, John Washington, Beth Brady, Brian Garrett, Scott Parsons, Rita Mustatia, and Kurt Teuber.

Others: Dr. Jack Cohen, Dr. Mark Finney, Scott Dailey, Larry Hood, Rick Robinson, Judy Clott, Ethan Foote and the Damage Assessment Team, Mario Chocooj, and Mark Johnson (homeowner).

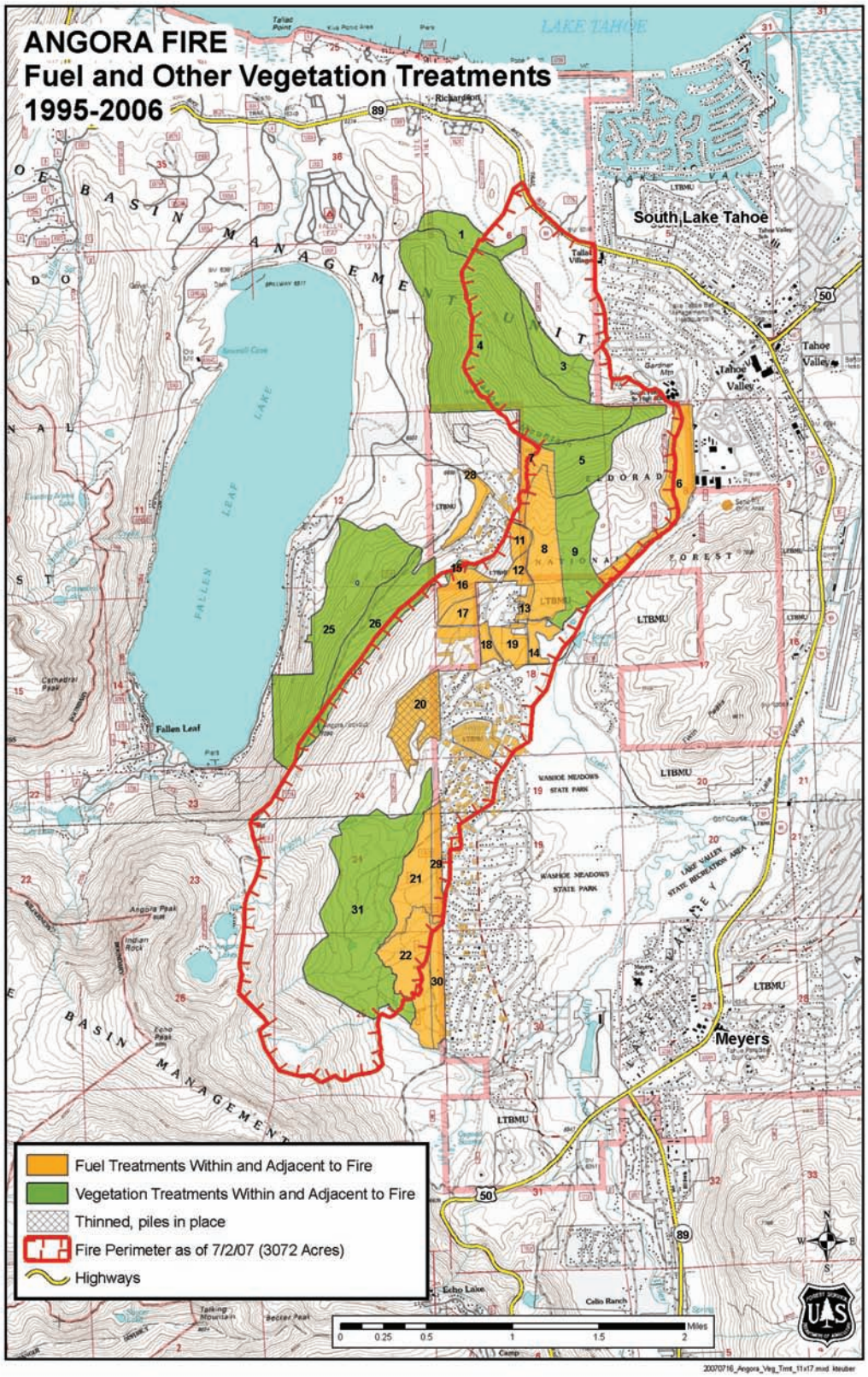
Appendix A

Angora Fire: Fuel Treatments 1995-2006



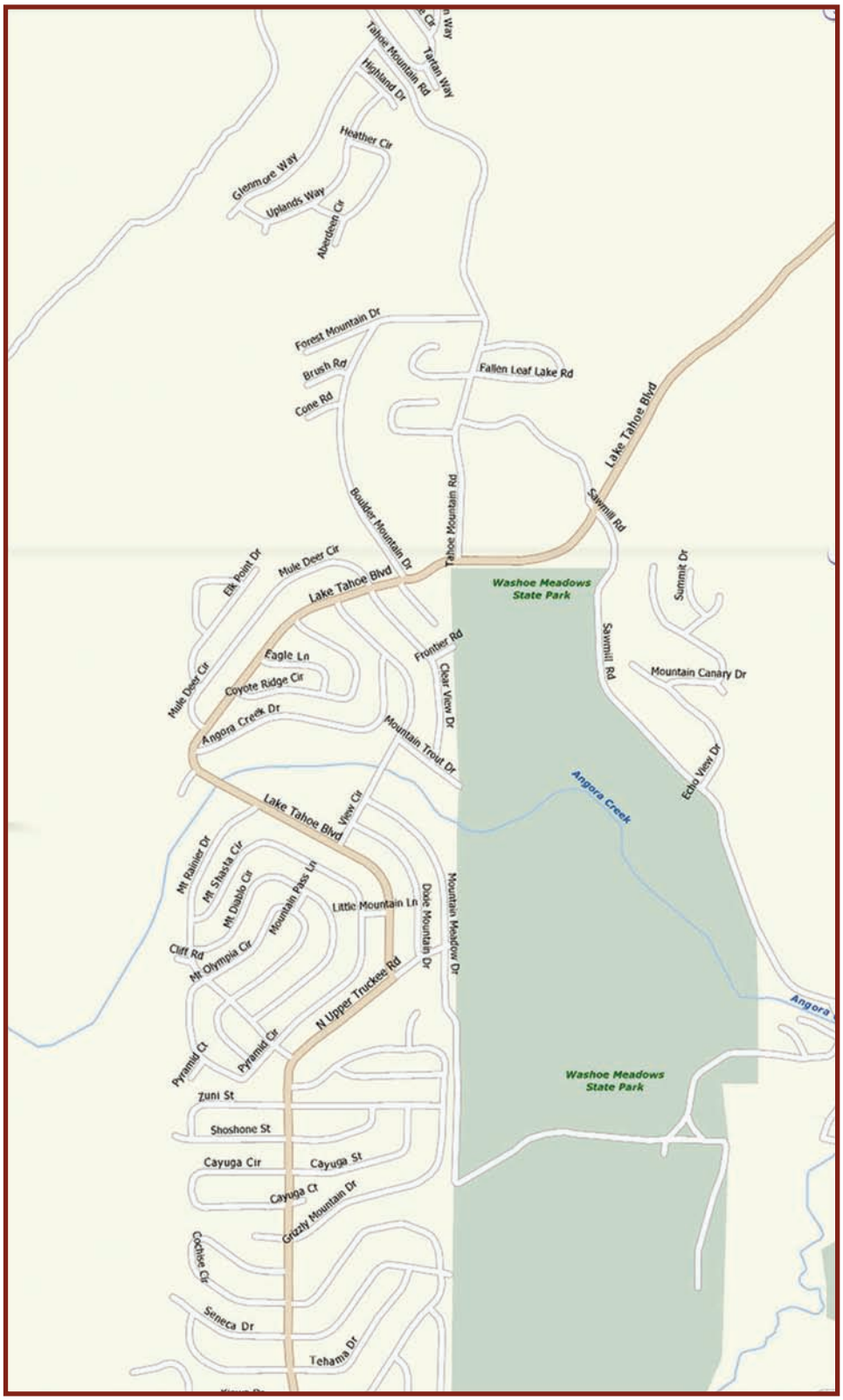
Appendix A (continued)

Angora Fire: Fuel and Other Vegetation Treatments 1995-2006



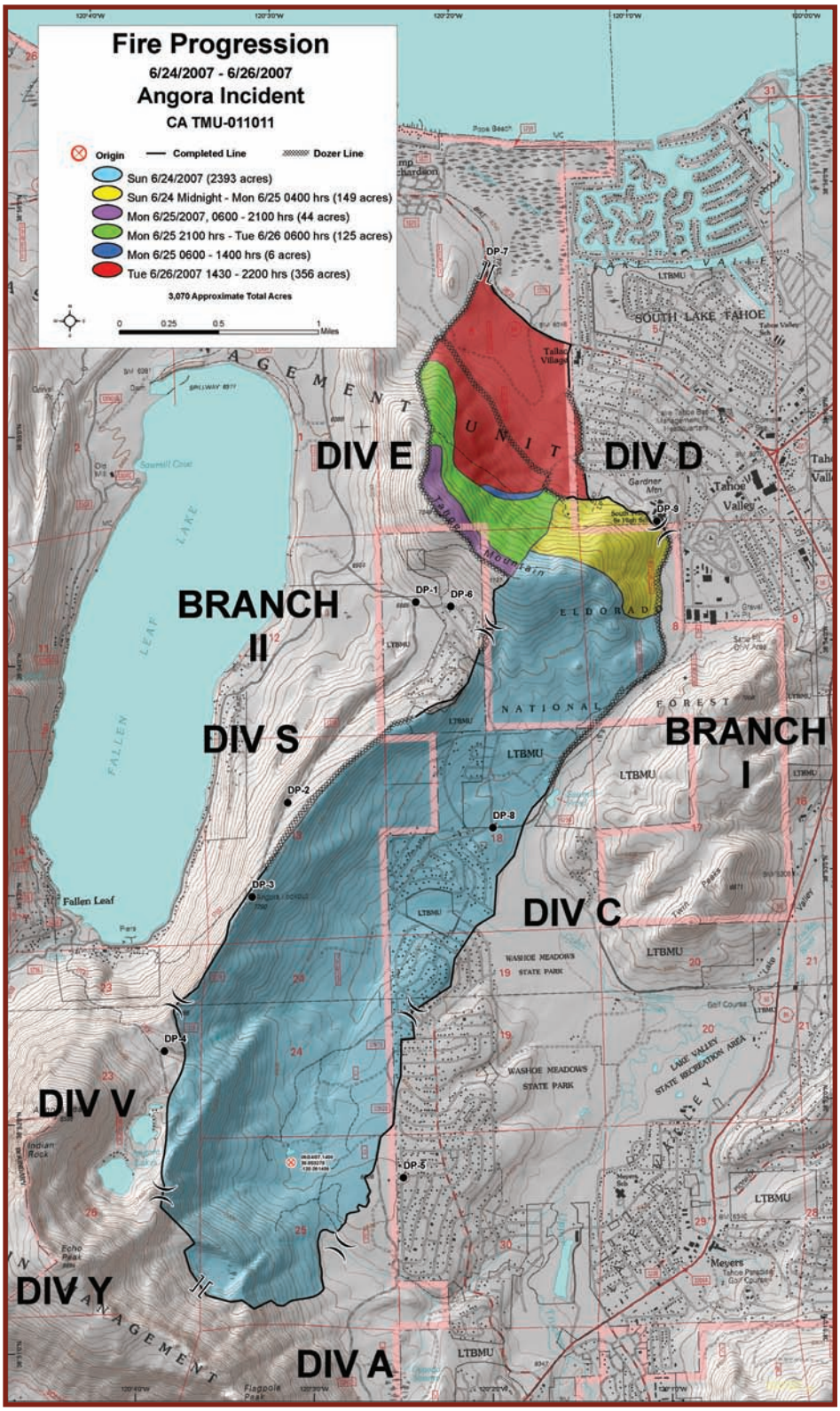
Appendix A (continued)

Tahoe Paradise Residential Area



Appendix A (continued)

Fire Progression Map



Appendix B

Angora Fire Area Pre-Fire Treatment Unit Prescriptions			
Unit	**Acres Treated**	**Year Completed***	**Activity**
6	78	1995	Pre-commercial Thinning / Activity Fuels Pile Burn
7	33	2007	Commercial and Pre-commercial Thinning / Salvage / Activity Fuels Pile Burn
8	91	2007	Commercial and Pre-commercial Thinning / Activity Fuels Pile Burn
11	14	1997	Commercial and Pre-commercial Thinning / Salvage / Activity Fuels Pile Burn
12	12	2006	Commercial and Pre-commercial Thinning / Salvage / Activity Fuels Pile Burn
13	8	2007	Commercial and Pre-commercial Thinning / Salvage / Activity Fuels Pile Burn
14	17	2007	Pre-commercial Thinning / Activity Fuels Pile Burn
16	27	2006	Pre-commercial Thinning / Activity Fuels Pile Burn
17	18	2006	Commercial and Pre-commercial Thinning / Activity Fuels Pile Burn
18	11	2006	Commercial and Pre-commercial Thinning / Salvage / Activity Fuels Pile Burn
19	25	2006	Pre-commercial Thinning / Activity Fuels Pile Burn
20	60	**	Commercial and Pre-commercial Thinning / Salvage / Activity Fuels Pile Burn
21	87	2005	Pre-commercial Thinning / Salvage / Activity Fuels Pile Burn
22	123	2005	Commercial Thinning / Salvage / Activity Fuels Jackpot Burn
28	21	2006	Pre-commercial Thinning / Activity Fuels Pile Burn
29	26	2005	Commercial and Pre-commercial Thinning / Salvage / Activity Fuels Pile Burn
30	35	2005	Commercial and Pre-commercial Thinning / Salvage / Activity Fuels Pile Burn

Table 1. Area fuels treatment prescriptions on National Forest System lands.

* This year represents the year the burning was completed. Thinning was completed in previous years.

** All activities completed except pile burning

Mechanical Thinning Prescription

Unit 6:

◊ Cut all dead trees less than 30" dbh. Pile slash for Forest Service burning.

Units 7, 8, 11, 12, 13, 17, 18, 19, 21, 23, 29, 30:

◊ Cut all dead trees less than 30" dbh.

◊ Retain 5 to 8 snags per acre greater than 30" dbh.

◊ Understory thin trees greater than 10" dbh to achieve a residual stocking level of ~160 square feet per acre.

◊ Remove suppressed and intermediate crown class trees and some codominants to achieve the residual stocking level.

◊ Select white fir, incense-cedar, and lodgepole pine for removal over Jeffrey and sugar pine.

◊ Lop and scatter all slash to a height not to exceed 18". Pile all slash within 100' of roadside corridors for Forest Service burning.

Hand Thinning Prescription

Units 7, 8, 11, 12, 13, 17, 18, 19, 21, 29, 30 (follow-up to mechanical thinning):

Units 14, 16, 20, 22, 28 (hand thinning prescription only):

Selection of Cut Trees:

- ◊ Cut all excess trees greater than 24 inches in height and less than 14” dbh.
- ◊ Cut all dead trees between 2" dbh and 20" dbh.
- ◊ Cut all damaged trees less than 14" dbh unless selected as a leave tree per item #4 below.
- ◊ Do not cut live trees within a Stream Environment Zone (SEZ) area identified with red and black striped flagging.
- ◊ Dead trees less than 20” dbh shall be cut within the SEZ.

Selection of Leave Trees:

- ◊ Leave trees shall generally be those of tallest height, largest crown, straight bole, and greatest vigor that are free of damage due to insects, disease, physical and mechanical causes.
- ◊ Select leave trees using the following priorities:

1. Leave all damaged or undamaged conifer trees, which exceed 14 inches dbh.
2. Leave all hardwood trees.
3. Leave all sugar pine and incense cedar.
4. Select leave trees from healthy undamaged conifers less than 14 inches dbh, as necessary to achieve a spacing of 20 feet between edges of tree boles with the exception of sugar pine.
5. If no healthy undamaged tree exists at the required spacing interval, leave the best tree with minor damage.
6. Select taller trees with good form (e.g. no vertical branching, no two way sweep, and no spiral grain) at the same time maintaining species distribution.
7. Species selections for leave trees shall be in this order:
   a. Sugar pine, incense cedar,
   b. Jeffrey pine/ponderosa pine,
   c. White/red fir,
   d. Lodgepole pine.

Stump Height:

- ◊ All trees greater than 24 inches in height other than leave trees shall be cut.
- ◊ White fir or red fir and all trees under 1 inch stump diameter which are cut will be cut below the lowest live limb unless prevented by a natural obstacle.
- ◊ Stump heights for all cut trees shall not exceed six inches above ground level or four inches above natural obstacles.

Felling:

- ◊ Cut trees shall be felled away from unit boundaries, roads, power lines, and stream environment zones. Any trees falling on such areas shall be removed immediately.
- ◊ All thinning slash shall be placed on or near the ground surface so that it will not lean against or be suspended by an uncut tree.

Bucking:

- ◊ All cut trees and limbs over five feet in length shall be cut into five foot lengths from the butt end for piling.

Piling:

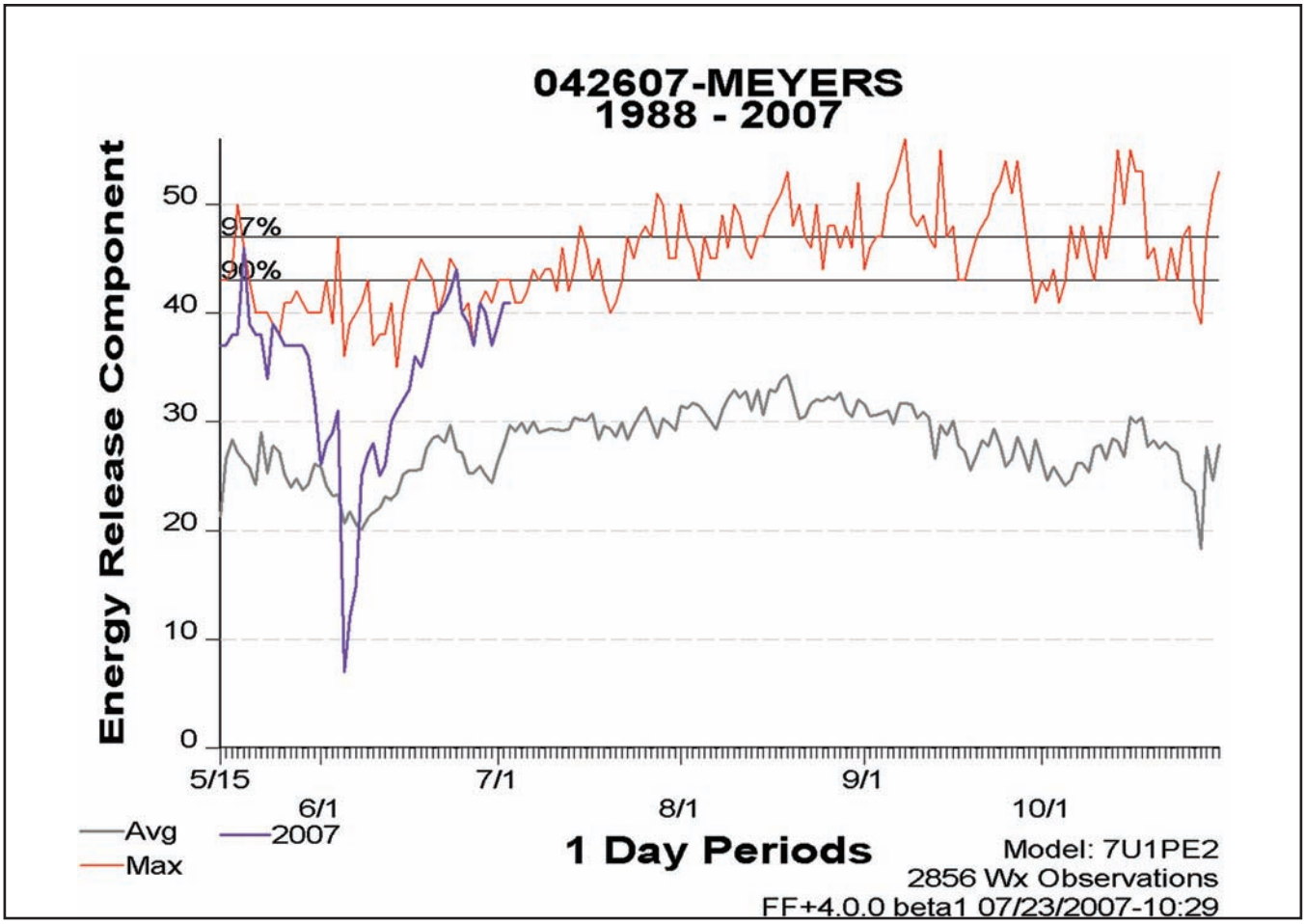
- ◊ Hand pile all slash and existing down bole material smaller than 20 inches in large end diameter and greater than 3 feet in length.
- ◊ Existing logs that have decayed so that 2 to 3 inches of the log has settled into the soil/duff layer (little to no bark left intact) shall not be piled. Piles shall be at least six feet from residual trees.
- ◊ Minimum spacing between piles shall be equivalent to one and one-half (1-1/2) the diameter of the adjacent pile.
- ◊ Slash piles shall be located outside of all designated SEZ boundaries. SEZ boundaries are identified with red and black striped flagging.

Treatment Prescription on Urban Lots

- The thinning prescription goal is focused at improving defensible space to adjoining private lands and reducing stocking levels to resist insect activity and improve forest health.
- The hazard tree goal is to remove identified hazard trees; remove dead trees, thin brush (remove from drip lines of leave trees, thinning in a mosaic pattern leaving 30% - 50% of the brush on site, non riparian species only).
- Thin from below removing suppressed, intermediate and some codominant trees (with the goal of achieving spacing of 10 feet between tree crowns and basal area of 90-120). Remove only dead and dying trees in SEZ's.

Appendix C

Fire Danger Index



2007 ERC values for Meyers Remote Automated Weather Station compared to maximum, minimum and average values from 1988-2007.

Appendix D

Wind

Time	Meyers		D.L. Bliss		Incline Village	
	Gust Speed	Direction (deg)	Gust Speed	Direction (deg)	Gust Speed	Direction (deg)
14:00	21	210	29	171	19	239
15:00	22	185	30	158	20	234
16:00	19	254	23	179	18	227
17:00	20	43	30	174	19	238
18:00	17	315	24	218	22	246
19:00	15	145	22	224	15	268
20:00	12	118	22	233	10	268
21:00	8	177	21	200	9	307
22:00	5	322	19	317	11	305
23:00	7	150	7	227	6	331
24:00	5	183	3	270	5	17

Table 1. Wind observations recorded by three remote automatic weather stations near the Angora fire for the afternoon of June 24th, 2007.