WEATHER AND FIRE BEHAVIOR FACTORS RELATED

TO THE 1990 DUDE FIRE NEAR PAYSON, AZ

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1.0 INTRODUCTION

June of 1990 will long be remembered as one of the hottest months in Arizona history. The temperature rose to 122 F (50C) in Phoenix and to 106 F (4 1 C) in Payson on June 26. These temperatures established a new daily record at Phoenix's Sky Harbor Airport, and equaled the June record temperature in Payson. Along with the record heat, an extended period of drought

Figure 1: The Dude Fire was on the Tonto NF (shaded), near the Mogollon Rim north of Payson, AZ

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persisted. These conditions combined to produce critically high fire danger throughout Arizona, and especially in the Mogollon Rim country and the Tonto National Forest north of Payson, AZ (Figure 1).

The topography of the Mogollon Rim provides a favorable forcing mechanism, which contributes to the development of thunderstorms when the convective environment is favorable. Around midday on June 25, 1990 isolated thunderstorms began forming along the Mogollon Rim, and at approximately 1230 MST lightning sparked a wildland fire. The fire was reported to the U. S. Forest Service in Payson about 1315 MST. Resources were marshaled and an initial attack force mobilized. By noon on the next day (June 26) over 550 fire fighters were engaged in battling the blaze that had grown to about 2000 ac (800 ha). A convection column, aided by thermal energy and moisture from the combustion, began forming over the fire by late morning (1000 MST). This column continued to grow for the next four hours and became a fully mature thunderstorm by 1400 MST.

As the thunderstorm began to decay, a strong downburst occurred. Winds were channeled by the topography, causing dramatic down and across slope fire spread. The rapid fire spread entrapped eleven fire fighters, tragically six of them perished. The fire continued to spread actively for another three days, and was finally controlled at 24,000 ac (920 ha) by July 14.

The factors of dry fuels, complex topography, and strong winds contributed directly to the entrapment and fatalities. These factors are common to other fatality fires including the 1949 Mann Gulch Fire (Rothermel, 1993), the 1953 Rattlesnake Fire (Krumni, 1954), the 1976 Battlement Fire (USDI, 1976), the 1991 Tunnel-Oakland Hills Fire (Goens, 1992), and the

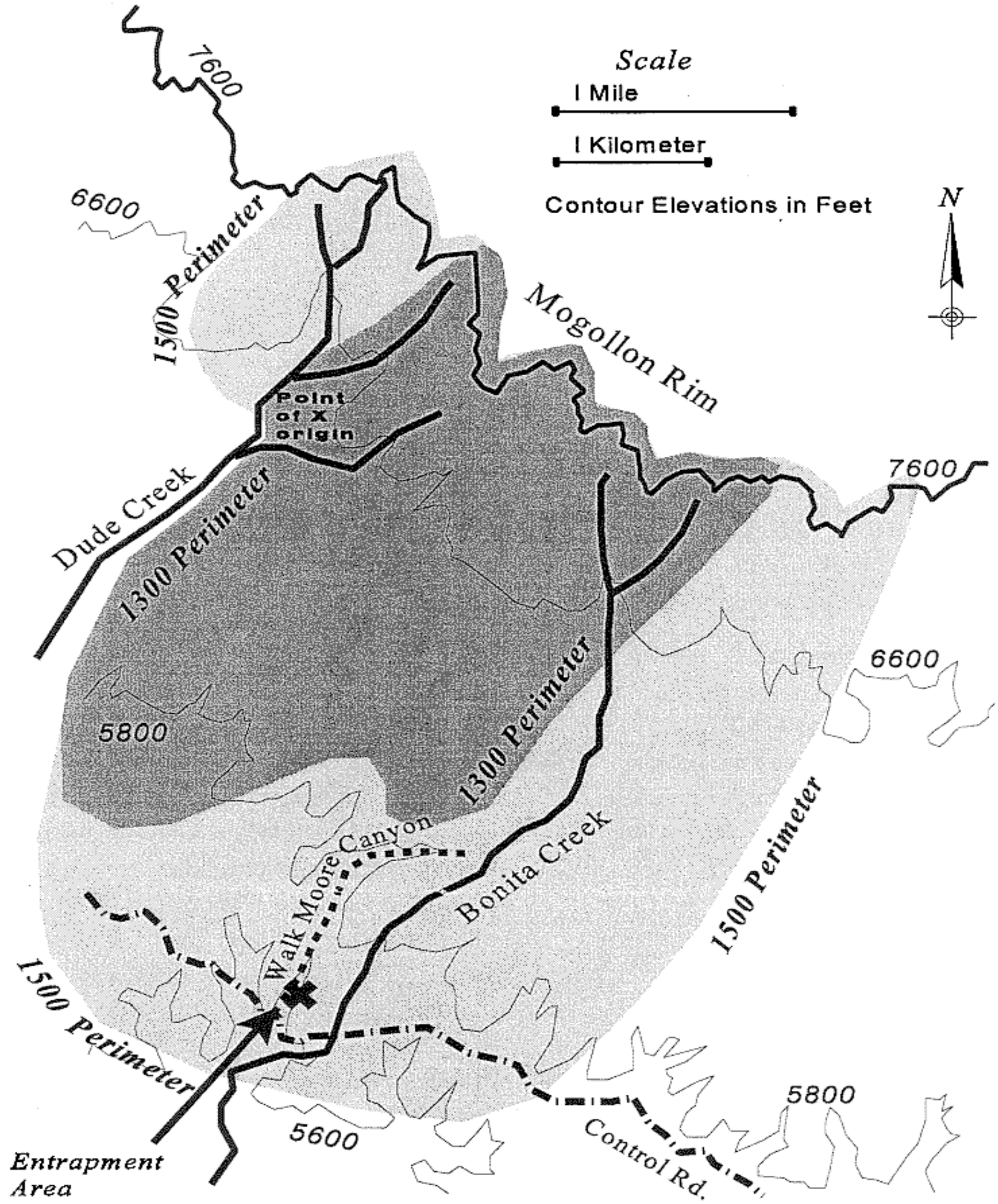


Figure 2: Dude Fire Point of ignition and approximate perimeter location at 1300 and 1500 MST on June 26. The entrapment site in Walk Moore Canyon is noted.

1994 South Canyon Fire (USDI/USDA, 1994).

The authors were members of the original interagency investigation team, and participated in collecting fuels, weather, and fire behavior data, which is included in the official incident report (USDA, 1990). Our purpose in reexamining this incident is to further document the critical conditions that contribute to extreme fire behavior and pose threats to firefighter safety.

2.0 ENVIRONMENTAL FACTORS

2.1 Topography

The fire's point of ignition (POI) was on a steep southwest-facing slope at approximately 6400 ft (1950 in) elevation (see Figure 2). This is a near mid-slope position with the crest of the Mogollon Rim 0.6 mile (1 km) northeast and 1000 ft (330 in) higher. Below the POI the slope is more gradual, falling off to about 5600 ft (1700 m) in 2 miles (3.2 km) to the south. In this area the rim is oriented in a northwest-southeast direction with the terrain decreasing in elevation in a general southwest direction from the rim edge. The entrapment site in Walk Moore Canyon was approximately 2.5 miles (4 km) south of the origin at about 5560 ft (1695 m) elevation. This is a south oriented drainage with sides sloping to 5800 ft (1770 m) on the west and 5900 ft (1800 m) on the east.

2.2 <u>Fuel</u>

Fuels in the fire area were primarily ponderosa pine with an understory of mixed oak, manzanita, needle and leaf litter, and scattered large (greater than 6 inch [15 cm] diameter) dead logs. Much of the understory brush was heavily draped with dead, very dry pine needles. Fuel moisture samples taken in the area on June 26 indicate live fuel moisture in the manzanita and oak was very low (76%). National Fire Danger Rating System (Deeming and others, 1977) derived fuel moisture was 3% for fine dead fuel, and 8% for the larger dead fuels. Low fuel moisture levels indicate a high potential for fire ignition and spread (Rothermel, 1983). These factors compounded the fire hazard and potential. Fuel loads along the jeep trail in the bottom of Walk Moore Canyon were relatively low. Prior to the entrapment crews were clearing brush in that area to create a more defensible line to anchor burnout and control operations.

2.3 <u>Weather</u>

2.3.1 Precursor Conditions

June 1990 was hot and dry across all of Arizona and the desert. Southwest. Below normal precipitation had been observed for the previous six-month period, and June precipitation was only 40% of normal at Payson. General drought conditions had persisted for three years and late June crop moisture indices for the area reflected the persistence of "Severely Dry" conditions.

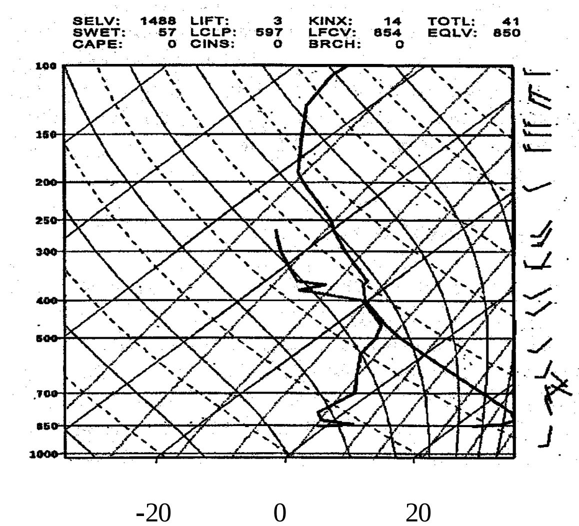
2.3.2 Synoptic Situation

Arizona was under a strong ridge of high pressure. The axis of the 50kpa high pressure was located from the southern New Mexico-Arizona boarder northward through Colorado and Wyoming. Central height values were above 594dm. At the surface, a thermally induced trough of low pressure was in-place over western Arizona. Soundings from Winslow (60 miles [100 km] northeast of the fire site) at 1200 GMT on June 25 and June 26 were similar (Figure 3) and indicated a classic "inverted V' profile which is related to dry microburst thunderstorm environments (Weisman and Klemp, 1986).

2.3.3 MESO/Microscale Situation

Complex mountain topography provides a classic focusing mechanism for convective development (Banta, 1987). Arizona's Mogollon Rim is a perfect example of this with thermal and mechanical dynamics producing well defined up-slope winds during the day under full solar heating. With an abbreviated layer of moisture, as exhibited by the Winslow sounding (similar to Figure 3), the stage was set for isolated thunderstorms with downburst potential. Cumulus clouds began developing over the Rim near the head of Dude Creek during the late morning on June 25 and lightning sparked the fire at about 1230 MST. Outflow winds from the storm spread the fire to about 300 ac (120 ha) in 3 hours. During the night, active burning continued with moderate down slope wind. By sunrise on June 26 the fire was estimated to be 2000 ac (800 ha).

On the morning June 26, the weather pattern had changed little, either synoptically or on the mesoscale.



INW
12 UTC June 26,1990

Figure 3: Radiosonde soundings from Winslow, AZ at 1200 GMT on June 26, 1990 exhibiting a classic inverted "V" profile.

The main difference was that an active fire was now producing additional thermal energy and moisture from the combustion process. Again, the Winslow sounding (Figure 3) indicated a dry-downburst environment. Thunderstorms began forming over the Mogollon Rim and the White Mountains (about 50 miles [85 km] east of the fire area) around 1000 MST. The convection column over the fire began to grow significantly about this time, and fire crews around the fire noted indrafts into the column from all sectors of the fire.

The convective cell's growth over the fire was still continuing around 1300 MST, however fire personnel did report a few sprinkles of light rain around this time. Additional energy was added to the cell around 1400 MST as a weak convective outflow boundary from a decaying thunderstorm complex to the southeast reached the fire area. Aerial observations at this time also reported the convection column had "iced out", indicating cell maturity and the potential for imminent decay. Fire crews in and near Walk Moore Canyon noted the indraft winds had ceased and a complete absence of wind with a "frightening calm" noted around 1400 MST. The cell then collapsed dramatically, producing a downburst with winds estimated from 40-60 mi/h (18-27 mps) by crews on the ground near the entrapment site. The strong winds lasted only 5 to 10 minutes, then decreased by about 50% and persisted for another 30 minutes.

Downburst winds normally fan out in a circular direction from the center of a stationary convective cell in flat terrain (Fujita, 1985). This fire spread in all directions (Figure 2) however, mapping of the actual fire growth indicates predominate spread to the south as the downburst winds were channeled by the topography.

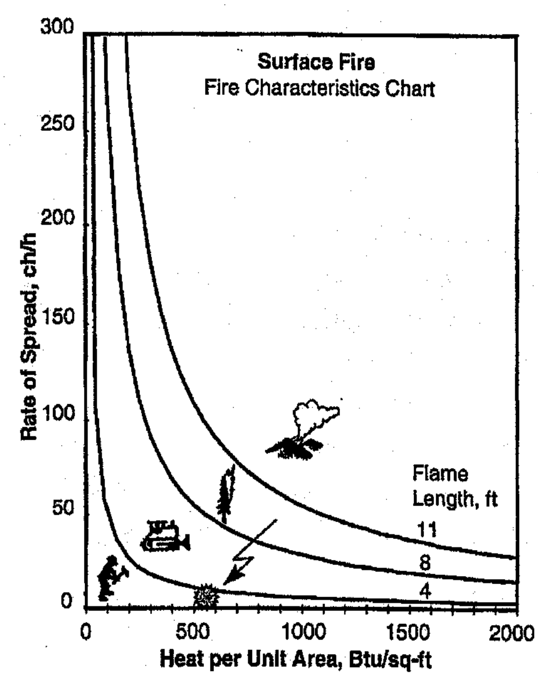
3.0 FIRE BEHAVIOR

For this paper, the fire behavior was calculated using the BEHAVE fire behavior prediction system (Andrews 1986) and crown fire nomograms (Rothermel 1991). BEHAVE was used to calculate the rate of spread (ROS) and flame length (FL) of the fire spreading through the surface fuels (litter and brush), and the crown fire nomograms were used to calculate the behavior of the crown fire spreading through the pine overstory. Calculations were run for the period just before the downburst winds, during the downburst event and for two hours following the observed peak winds. Model results closely agree with the observed fire behavior. Calculating fire behavior after the fact based on estimated, time-averaged wind speeds is, however, very different from making real-time predictions based on projected wind speeds.

The surface fuel was characterized as 80% needle litter (fuel model 9) and 20% understory brush (fuel model 6) (Anderson, 1982). Dead fuels were assigned moisture contents ranging from 2 to 4 percent. Prior to the downburst, midflame wind speed was assumed to be 0 - 4 mph (0 - 1.8 mps). The calculated ROS ranged from 1 to 9 chains per hour (20 to 180 m/hr) with FL less than 4 ft (1.3 m) with occasional flames in the brush to 7 ft (2.4 m). The calculations indicate the fire would be within the limits of control by hand force, which was in fact the case. The calculated fire behavior for the surface fire given the conditions prior to onset of the downburst winds is shown on the fire characteristics chart (Andrews and Rothermel, 1982) in Figure 4a.

In calculating crown fire behavior during and just following the downburst, the 20 ft (6 m) wind speed was assumed to be 40 mph (18 raps) for a half hour followed by 15 mph (6.7 mps) for another 2 hours. Using the "severe drought" crown fire nomogram and 40 mph (18 mps) wind speed, the average ROS is calculated to be 3 mph (5 km/h) with a flame length of

Figure 4a: Fire behavior calculated from models displayed on fire characteristics chart - the surface fire before the downburst



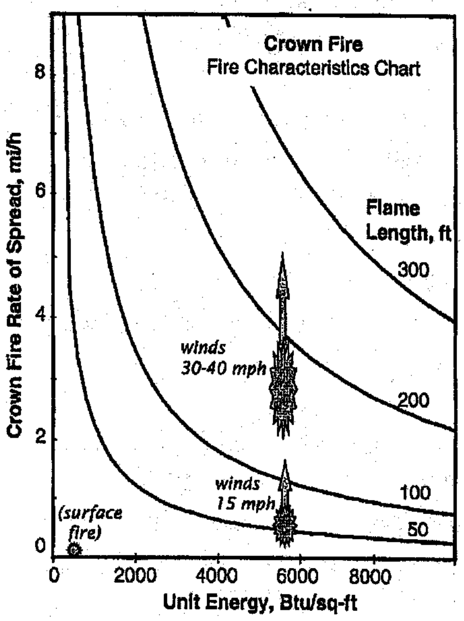


Figure 4b: Fire behavior calculated from models displayed on fire characteristics chart - crown fire driven by the downburst winds.

170 ft. (52 m). For 15 mph (6.7 mps), the average ROS is 0.7 mph (1.2 km/hr) with 60 ft (18 m) FL. Those results are shown on the fire characteristics chart in Figure 4b along with the calculated range and maximum expected ROS. The calculated surface fire behavior is also shown on this chart for comparison and to emphasize the dramatic change in fire behavior that occurs with strong winds. Spread distances using the calculated average rates of spread compare closely with the observed fire spread distances.

4.0 SUMMARY

The behavior of the Dude Fire from its initiation on June 25 through its rapid spread on June 26 was not unusual considering fuel and weather conditions. The high probability of summer thunderstorms in the complex terrain of the western United States is well understood, even in fairly dry atmospheric regimes. The Haines Index (Haines, 1988; Werth and Ochoa, 1993) for both days indicate the extreme potential for rapid-fire growth and spread, and atmospheric profiles indicated the potential for dry microbursts. Fire Weather Forecasts for the area advertised some potential for thunderstorm activity both days. Predicting the exact location of thunderstorm formation is beyond the state of the science, however topographically, favored locations are usually easy to identify. Once the fire started and had spread to nearly 2000 ac (800 ha), it was reasonable to expect a well-developed convection column due to the favorable atmospheric dynamics and the additional impetus of the fire.

Forecasting downburst winds is highly complicated, even more so in complex terrain. Complex terrain tends to channel the wind, often blocking or enhancing speed and direction (Whiteman, 1990). Because downburst winds tend to be cool and dense, the enhancement and channeling down slope that occurred in this case was not unusual. The occurrence of the short duration gust front, followed by 20 to 30 minutes of sustained strong wind, is again within the realm of reasonable experience.

The extended period of high temperatures and dry weather preceding the fire had preconditioned fuels. Live fuels had low moisture content and fine dead fuels were tinder dry. Drought conditions exacerbated the situation, with large dead fuels so dry that they became a major contributing factor to the fire's intensity. The downburst winds caused the fire to change from a fire backing through the understory to a fire that spread rapidly through the overstory.

This paper was undertaken: to further document the conditions that led to the entrapment and fatalities on the Dude Fire. Hopefully, it can also be used to heighten the awareness of the common denominators of tragedy fires (NWCG, 1996). It may also be used as a case study by those who are working to provide methods for better prediction of downbursts on fires.

5.0 ACKNOWLEDGMEENT

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