# Appendix: Fire Behavior

On July 10, 2001, the weather and fuel moisture conditions in the Chewuch River canyon reached levels that reflected conditions normally present at the peak of the fire season in early August. Winter and spring weather patterns had left fuels abnormally dry and susceptible to the initiation and development of extreme fire behavior. The extreme fire behavior of the Thirtymile Fire could be expected under weather and fuel conditions present on July 10th; however it is unusual for this type of fire behavior to occur in this location in early July.

### *Information Available to Thirtymile Firefighting Personnel*

The National Weather Service issued two Fire Weather Forecasts on July 10th. The morning forecast was transmitted to the Thirtymile Fire personnel but the afternoon forecast was not. The Spot Weather Report for the Libby South Fire, issued 7:36 p.m. July 9th was the only Spot Weather Forecast delivered to firefighters on the Thirtymile Fire (See Appendix: Weather). This forecast predicted a minimum humidity of 10%, maximum temperatures of 98° F and winds from the south 9-13 miles per hour with gusts to 17 in the afternoon.

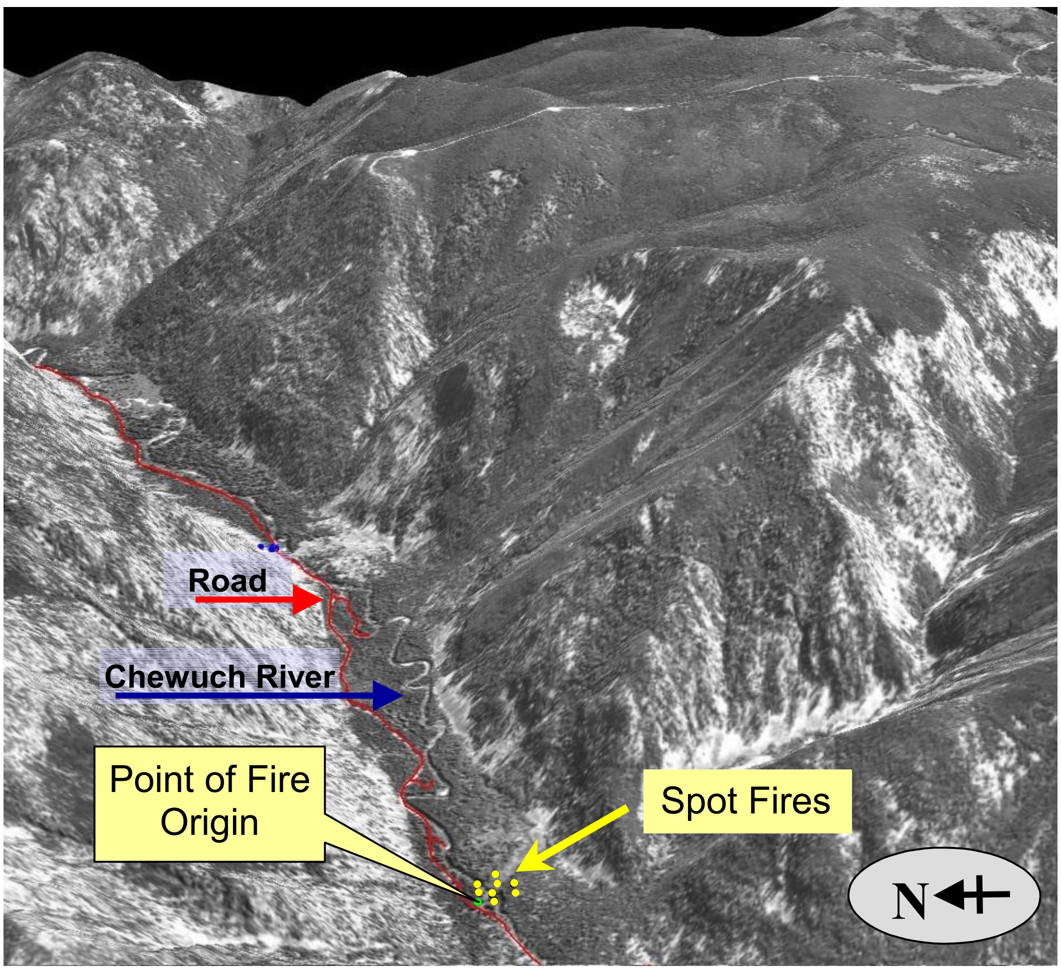
**Fire Behavior Figure 1.** Fireline Handbook Table 13 and the Relation to the Phases of the Thirtymile Fire

| | Relative Humidity | Fuel Moisture 1-Hour | Fuel Moisture 10-hour | Relative ease of chance ignition and spotting, general burning conditions |
|---|---|---|---|---|
| | >60 | >20 | >15 | Very little ignition; some spotting may occur with winds above 9mi/h. |
| Initial Phase | 45 - 60 | 15-19 | 12-15 | Low ignition hazard - campfires become dangerous; glowing bands cause ignition when relative humidity is < 50% |
| | 30 -45 | 11 -14 | 10-12 | Medium ignition hazard - matches become dangerous; "easy" burning conditions. |
| | 26-40 | 8 -10 | 8-9 | High ignition hazard; matches are dangerous; occasional crowning; spotting caused by gusty winds; “moderate” burning conditions. |
| Transition, Entrapment, and Deployment Phases | 15-30 | 5-7 | 5-7 | Quick ignition, rapid buildup, extensive crowning; any increase in winds causes an increased spotting, crowning, loss of control; fire moves up bark of trees igniting aerial fuels; long distance spotting in pine stands; dangerous burning conditions. |
| | < 15 | < 5 | < 5 | All sources of ignition dangerous; aggressive burning, spot fires occur often and spread rapidly; extreme fire behavior probable; critical burning conditions. |

Table 13 in the Fireline Handbook (NWCG Handbook 3 January 1998) displays the expected Fire Severity for combinations of fuel moisture and relative humidity. While more sophisticated models of fire behavior exist, Table 13 would be the most readily available method to predict fire behavior by personnel on the Thirtymile Fire. Fire conditions that could have been expected for the Thirtymile Fire are noted on the left side of the Fire Behavior Figure 1 on the previous page.

### *Initial Phase (from late evening July 9 to 10 a.m. July 10)*

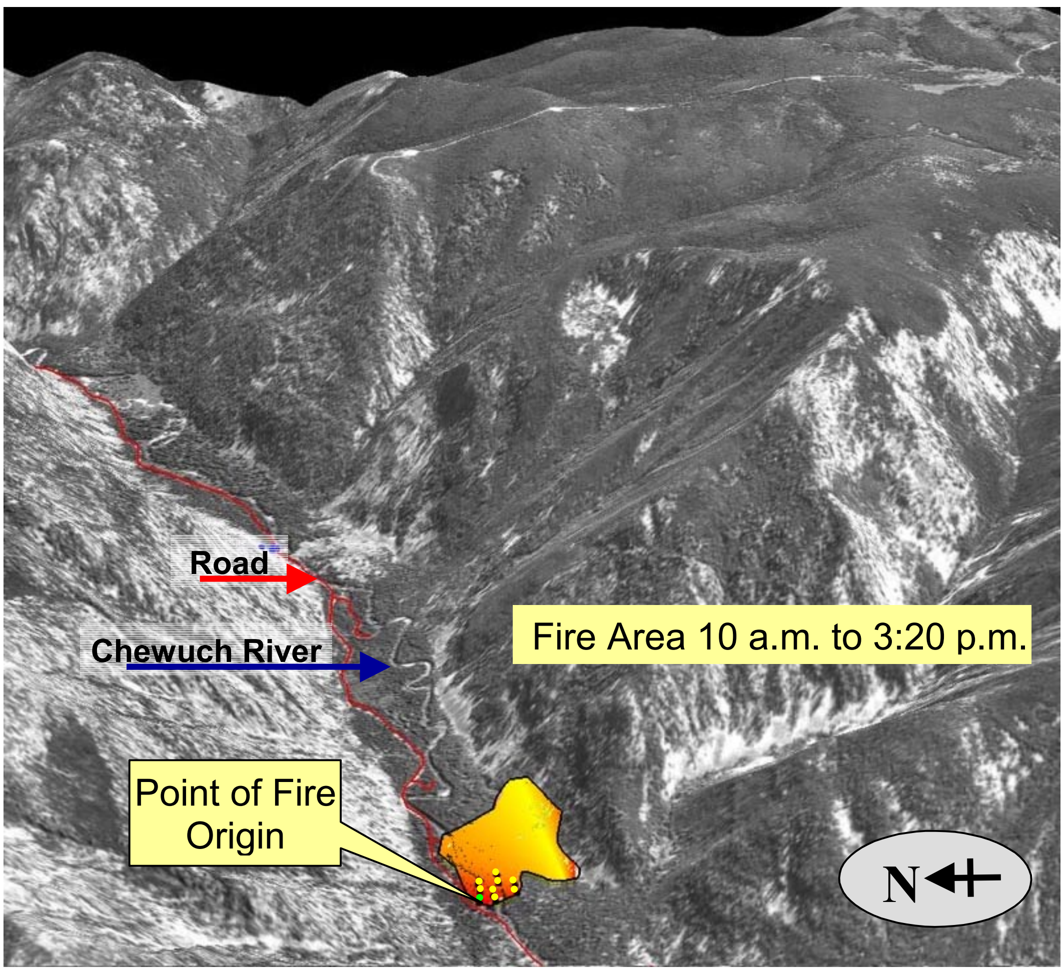
Following ignition, the fire remained active throughout the evening of July 9th and into the early morning of July 10th due to the presence of dry large diameter fuels and poor nighttime relative humidity recovery. Fire behavior at this time was characterized as slow surface spread (calculated rate 1.3 chains per hour). Although predicted flame lengths would be primarily less than 2.3 feet, the presence of downfall and ladder fuels promoted the extension of the fire into tree crowns initiating torching and spotting. At least 6 spot fires on both sides of the river resulted from these conditions.




**Fire Behavior Figure 2.** Initial Phase of the Thirtymile Fire

### *Transition Phase (from 10 a.m. to 3:20 p.m. July 10)*

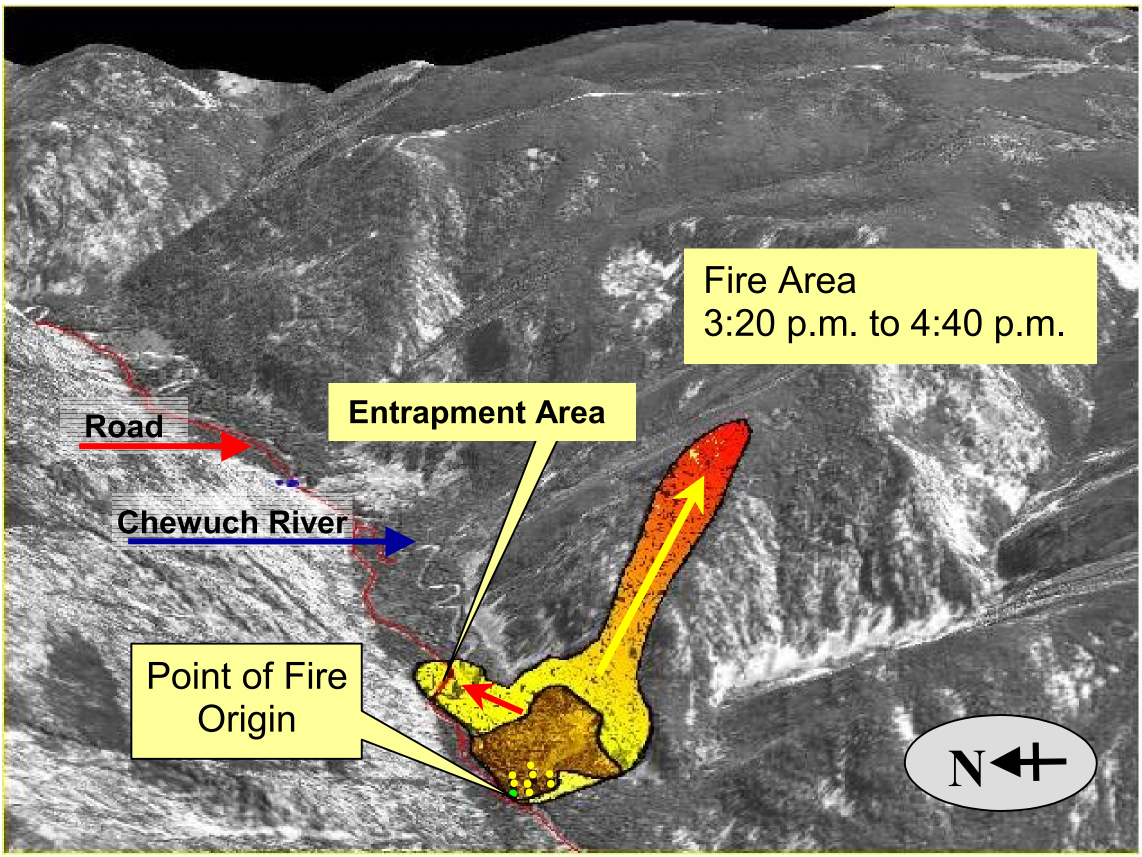
During the transition phase from mid-morning until mid-afternoon on July 10, the relative humidity rapidly decreases to less than 10% and temperature increases to 94° F. Surface fires became more active, with flame lengths approaching 8 feet, increasing the frequency of torching and spotting across containment lines. The fire began to gain a foothold on the east hillside of the canyon, but by 2:50 p.m. it had not yet begun a significant uphill run on this slope. At 3:00 p.m., because of increasing fire activity and spotting, firefighters moved to their identified "safety zone" on the west side of the Chewuch River. The rate of spread of the unconstrained surface fire at this time was calculated to be 10.8 chains/hour.




**Fire Behavior Figure 3.** Thirtymile Fire Spread 10 a.m. to 3:20 p.m. July 10th

### *Entrapment Phase (from 3:20 p.m. to 5:00 p.m. July 10th)*

At 3:20 p.m. the fire began uphill crowning runs from base of east slope. Slopes of nearly 100%, dense forests, and upslope convective winds combine to move this fire uphill at approximately 1.25 miles per hour (100 chains per hour). Spotting was pervasive from all active portions of the fire both in the canyon floor, and up the east slope. The fire established a convection column on the hillside east of the canyon floor. Spot fires became established east of the road 0.4 miles




**Fire Behavior Figure 4.** Thirtymile Fire Spread 3:20 p.m. to 4:40 p.m. July 10th

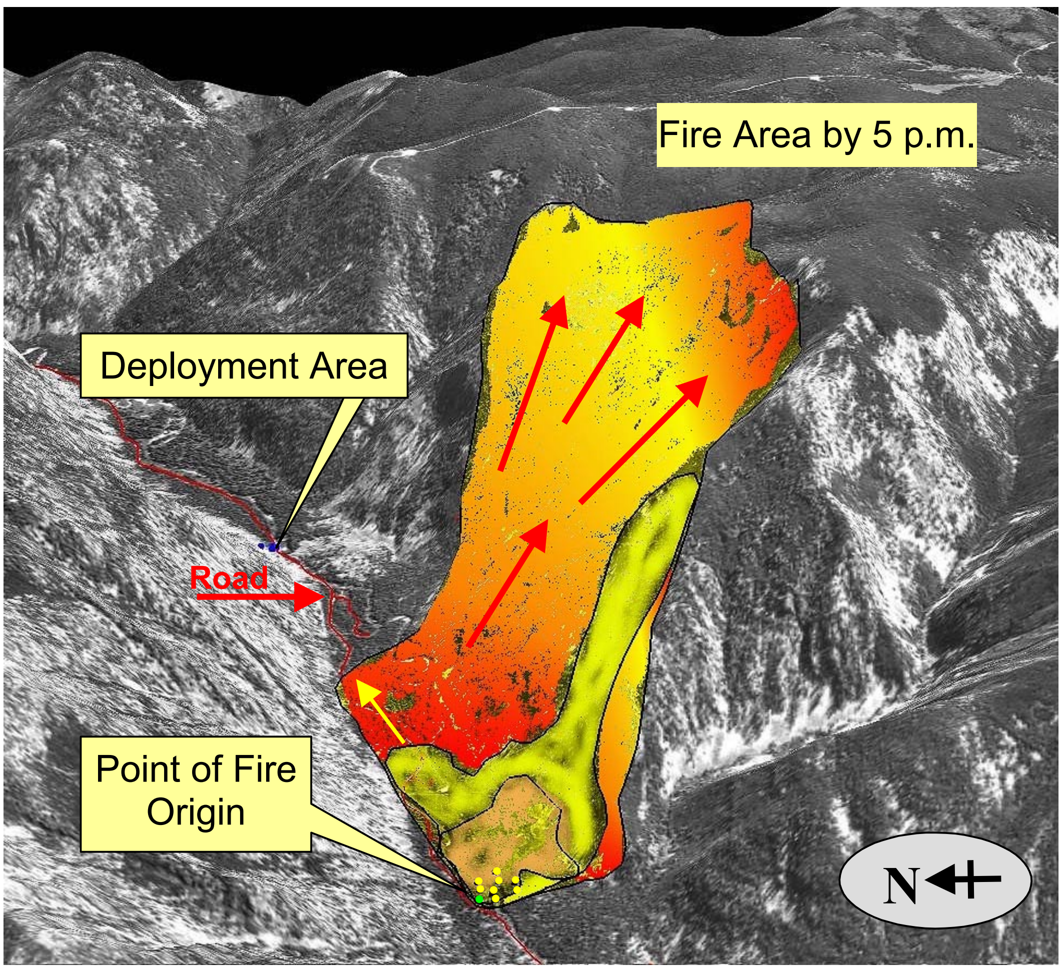
from the main fire area.

Within an hour the fire in the canyon floor began a sustained torching run in tree crowns and at 4:34 p.m. crossed the road at the entrapment point. The up canyon spread of the fire up to this point had been parallel to the road. With a 90-degree turn in the road to the SE, the orientation of fire spread was now directly perpendicular to the road.

A variety of sites and fuel types describe conditions within the Chewuch River canyon. This difference is significant, insofar as it may have influenced tactical decisions as the fire moved between fuel types through July 10. At the point of origin, where the fire was first attacked, spruce and alder dominate the site within a riparian zone. Aspen is also nearby. This is a wetter site relative to the drier surrounding areas where fir, lodgepole, and ponderosa pine occur and where the fire made its largest runs on the afternoon of July $10^{th}$.

Contrasting patterns of fire behavior were observed between the wetter fuel types in the riparian zones and the drier upland fuel types. Initially, the fire spread was principally influenced through torching and spotting in the wetter types, while sustained crowning better defined fire spread in the drier types. The differing patterns of fire behavior were influenced both by the nature of the fuel types, and increasingly drier and warmer conditions encountered as the day progressed. It is remarkable that after the fire, although there are isolated patches of fire-scorched and fire-killed trees in the vicinity of the point of origin, much of the area within the riparian zone where the fire was first attacked remains unburned.

When the fire spread out of the riparian zone, as weather conditions worsened, fire intensities and rates of spread increased considerably. The fuels type and drier conditions were more conducive to rapid spread rates and more severe fire behavior. Notably, entrapment occurred in




**Fire Behavior Figure 5.** Thirtymile Fire Spread by 5:00 p.m. July $10^{th}$

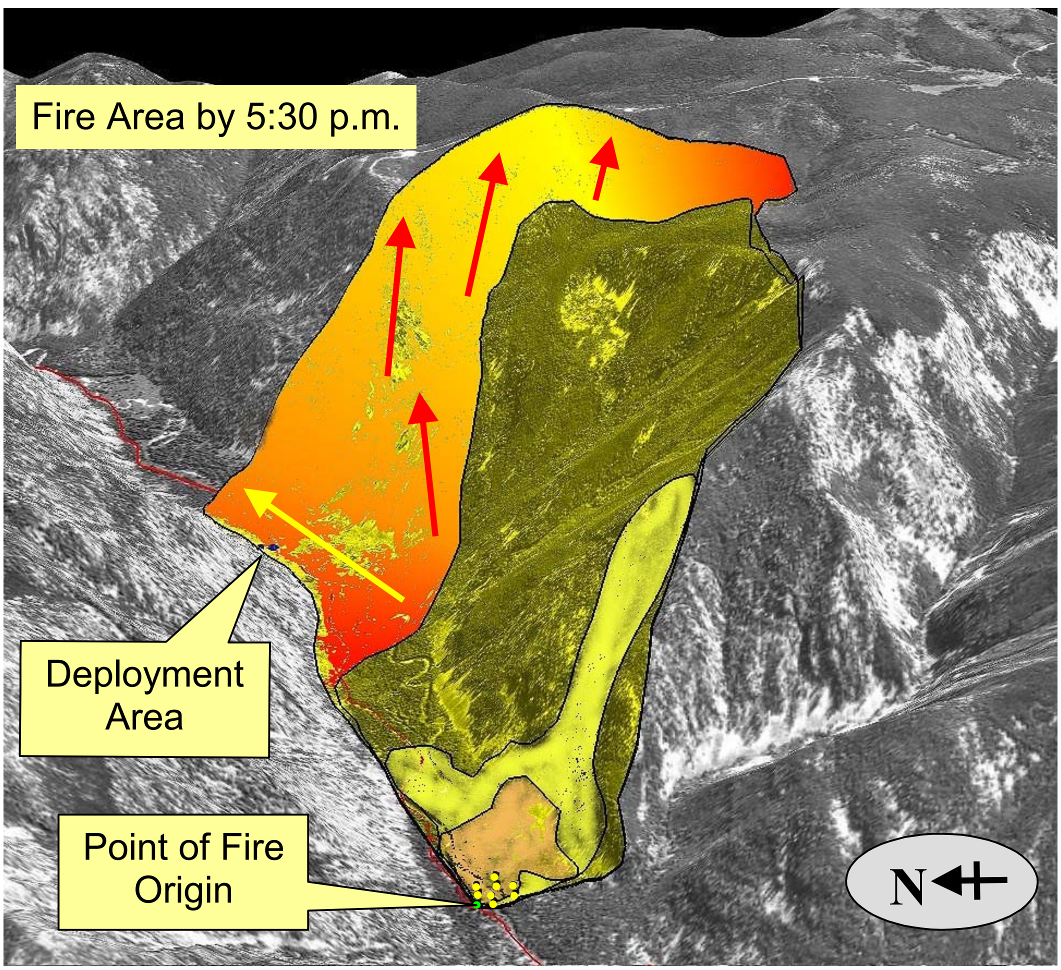
the drier fuels at a bend in the road (perpendicular to the direction of spread), where the only path of down-canyon escape was blocked by the head of the fire moving up-canyon.

This was a result of the tactical decision to suppress spot fires ahead of the main fire along the road, which placed firefighters under increasingly severe weather conditions in a different fuel type that exhibited different, more severe, fire behavior.

By 5:00 p.m. the fire had become well-established on the canyon floor east and west of the Chewuch River and on the canyon slope east of the river.

### *Deployment Phase (from 5:00 p.m. to 8:00 p.m. July 10th)*

At about 5:00 p.m., the fire was firmly established on the hillside east of the Chewuch River. Strong uphill and up canyon fire movement had carried the fire in an easterly direction and crown fire activity was engulfing the hillside east of the deployment location. An active fire front was also located in the canyon bottom in the vicinity of the point of entrapment along a line




**Fire Behavior Figure 6.** Thirtymile Fire Spread by 5:30 p.m. July 10th extending from the base of the northern hillside to the hillside south of the fire.

Strong indrafts and massive spotting associated with the crown fire high on the hillside east of the river intensified the fire activity in the canyon floor. At approximately 5:00 p.m., the fire in the canyon floor transitioned to an active crown fire moving up canyon towards the deployment zone at spread rates estimated to be in excess of 1.6 miles per hour (125 chains per hour).

Two columns had now formed, one on the hillside east of the river and a second column located on the canyon floor. The canyon floor column was initially oriented horizontally directly towards the deployment zone. While the exact interaction of the columns is unknown, it is felt that the column on the hillside south of the river established strong up canyon winds which contributed to the speed and intensity of the canyon floor fire front as it moved up canyon. Immediately preceding fire shelter deployment., embers falling from the fire columns rained down on the deployment site. The flaming front and plume of hot gasses from the canyon floor fire reached the deployment site at 5:24 p.m. The canyon floor fire continued to intensify as it moved past the deployment site to the east and its column began to rise vertically. The column in the canyon floor and the column on the hillside east of the river eventually merged as the fire moved up canyon. The rate of fire movement and intensity of fire activity is characteristic of crown fires observed historically.

During this period of time the fire also began to extend up the northern hillside north of the creek. The scarcity of fuels on this hillside limited the fire behavior, which consisted initially of spotting and isolated torching. Fire behavior became more severe as the forest became denser on top of the ridgeline and north of the deployment site.

Fire continued up canyon at 1.6 miles per hour (125 chains per hour) reaching the trailhead within approximately 1 hour.

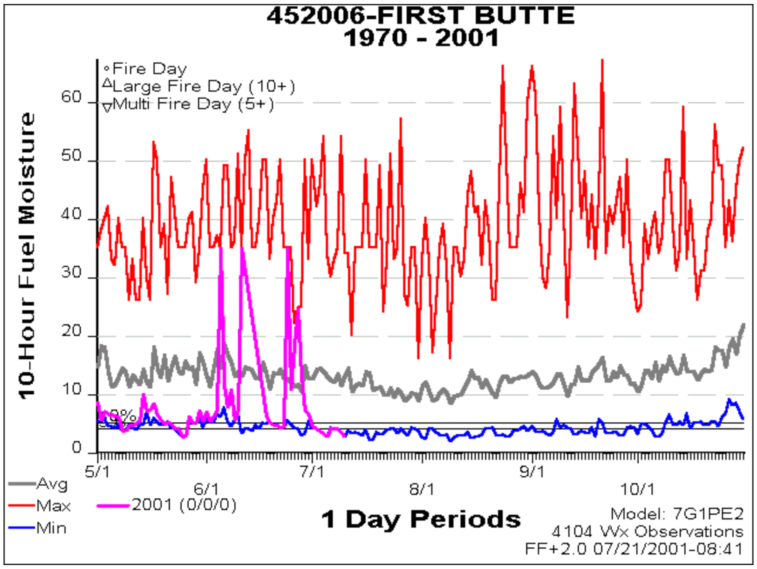
## *Factors Contributing to Fire Behavior on the Thirtymile Incident*

### *Fuel Moistures*

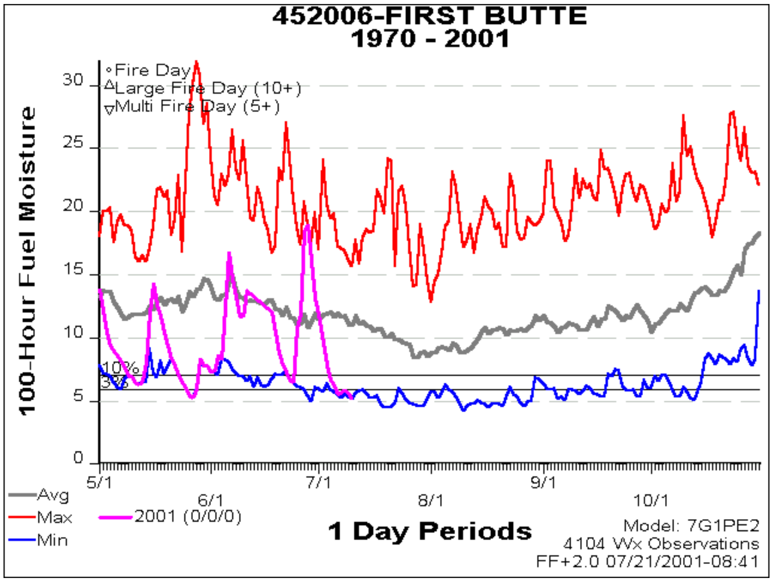
All calculated fuel moistures were at or approaching historically low levels for July 10th. The 10-hour and 100-hour fuel moistures were at 3% and 5% respectively.

Calculated 1000-hour fuel moisture was at 10%. 1000-hour fuel moistures had been persistently

**Fire Behavior Figure 7.** 10-Hour Fuel Moisture

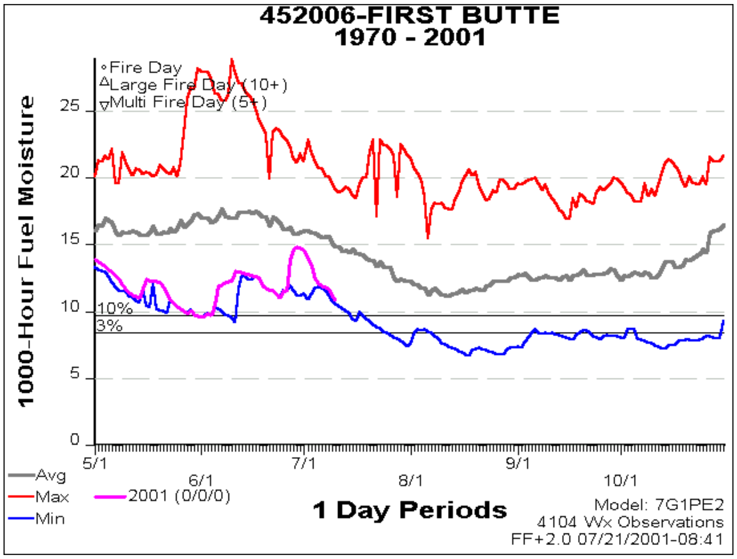



**Fire Behavior Figure 8.** 100-Hour Fuel Moisture



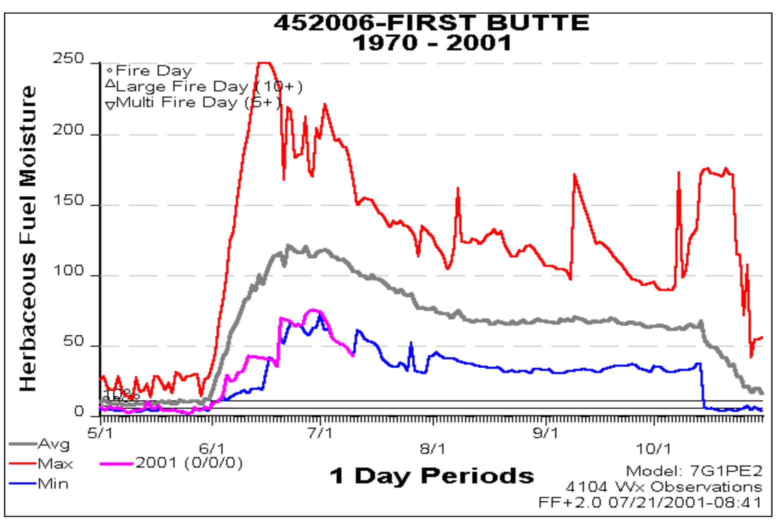
low since the end of April. The fact that the large diameter fuels were extremely dry is evidenced by nearly complete consumption of these fuels in many locations on the Thirtymile Fire.

**Fire Behavior Figure 9.** 1000-Hour Fuel Moisture




Live fuel moistures were calculated at 48%. Although the measurement of live fuel moisture is extremely difficult observations taken from in the vicinity indicate values of less than 100%, which are drier than normal for this time of the year. Foliar moisture content of conifer needles of less than 100% increased the likelihood of surface fire extending into the tree crowns and initiating torching.

**Fire Behavior Figure 10.** Herbaceous Fuel Moisture

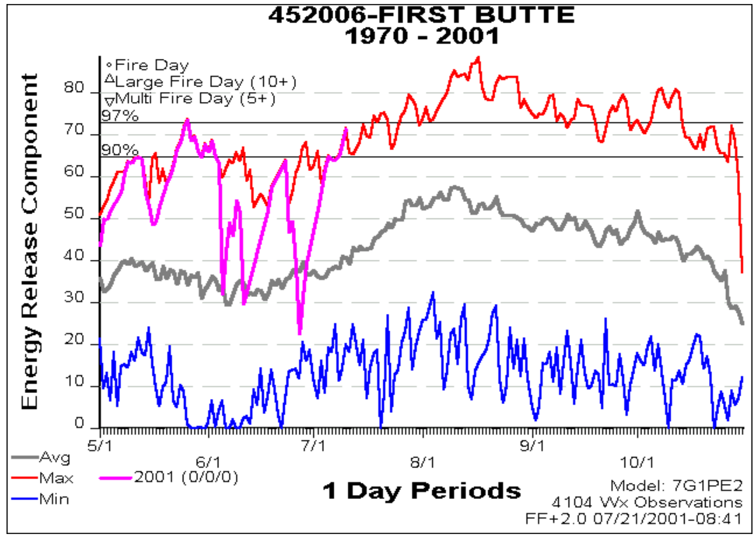


### *Fire Behavior Indices*

The two closest National Fire Danger Rating System Fire Weather Stations, First Butte (elevation 5,509 feet) and NCSB (elevation 1,697 feet), classified the fire danger as "*Very High"* on July 10, 2001.

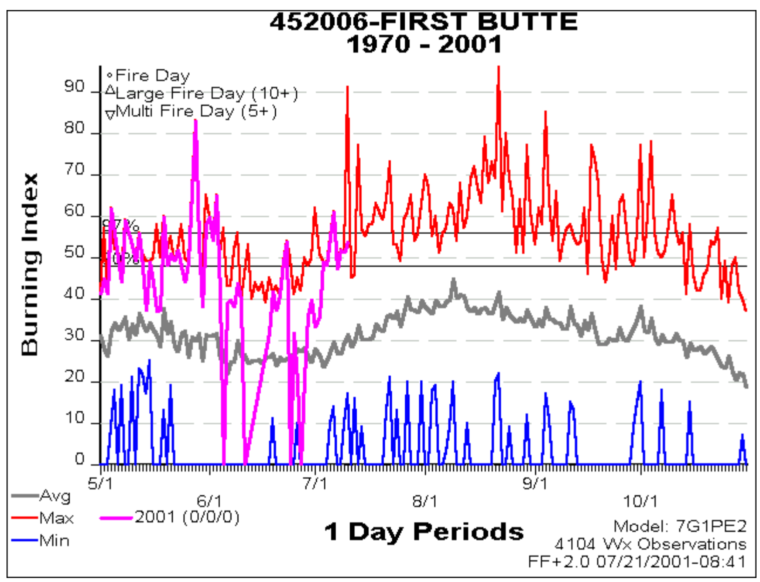
The Energy Release Component (ERC) for First Butte (Fuel model G) is 71 and was close to the 97th percentile (71.75), the historical maximum for that day since records began in 1970. The ERC index describes the potential available energy per unit area in the flaming zone of the fire. Since April 14th the ERC at this station had been consistently approaching maximum levels except for 3 time periods following rainfall.

**Fire Behavior Figure 11.** Energy Release Component




The Burning Index for First Butte (Fuel model G) was at 52 and approaching the 97th percentile. The Burning Index reflects the contribution that fire behavior makes to the amount of effort needed to contain a fire in a specified fuel type.

**Fire Behavior Figure 12.** The Burning Index




### *Weather*

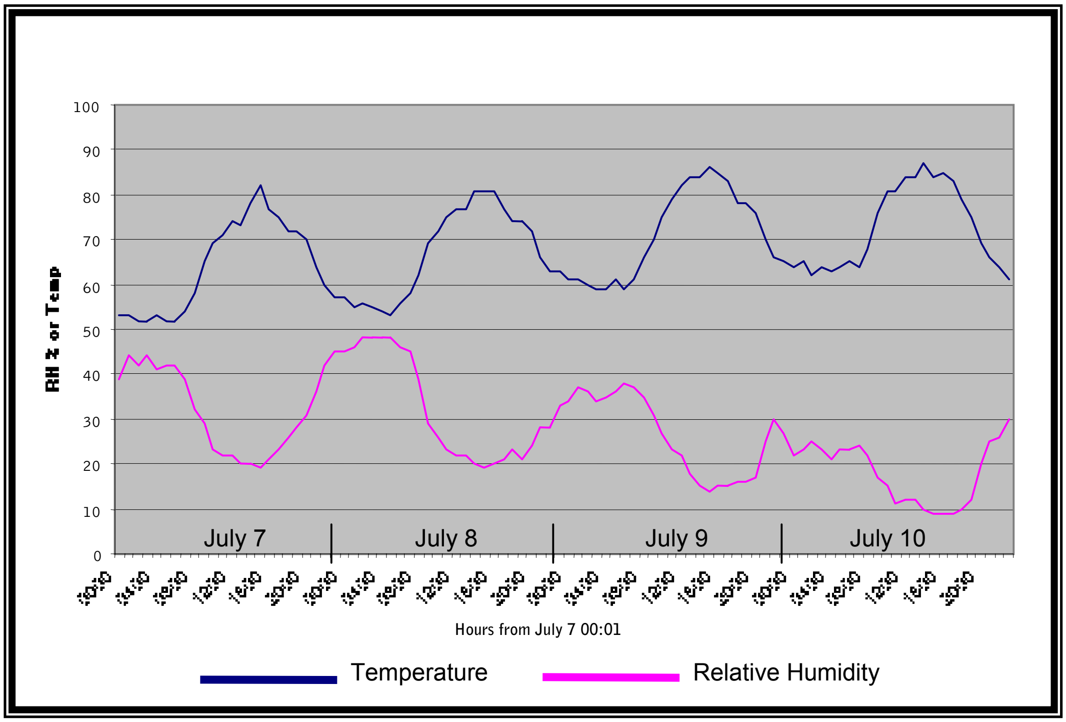
A 5-day period of poor nighttime relative humidity recovery preceding the deployment contributed to spotting and subsequent fire spread during the evening of July 9th. The chart in Figure 13 depicts relative humidity and temperature trends from the First Butte Lookout, located 12 miles south of the 30-mile fire at an elevation of 5,509 feet.

Critically low relative humidity (less than 10%) and high temperatures (daytime maximum of 94ºF) in the Chewuch River Valley on the day of deployment raised the probability of ignition to

100% and increased the potential for extreme fire behavior.

Fire induced winds became significant. The helicopter pilot on west side of the fire observed in drafts of 20 to 30 mph associated with fire activity at this time. Entrapped firefighters remarked

**Fire Behavior Figure 13.** First Butte Lookout
Temperature and Relative Humidity Observations July 7 - July 10, 2001




on high winds and the difficulty of keeping fire shelters in place.

On July 10 atmospheric conditions were conducive to the formation and vertical development of the fire columns. At Spokane, the mid-level Haines Index was a 6, the high level Haines index reached a 4 (predicted 3-4).

### *Fuels on the Canyon Floor*

Abundant large diameter woody debris, much of it in advanced stages of decomposition, was present on the site and highly susceptible to ignition by firebrands. Extensive shrub and conifer reproduction was also present and contributed to the upward extension of surface fire into the tree crowns. Overall, the site could be characterized as Fuel Model 10. Fuel Models 8, 10, and 12 would, however, encompass the variability of fuel conditions present on the canyon floor site.

The forest on the canyon floor consisted of spruce, Douglas fir, lodgepole pine, and cottonwood. Spruce boughs extended within a few feet of the top of the surface fuels and increase the likelihood of surface fire extending into the tree crowns and initiating torching.

### *Fuels on the Hill Slopes*

Forest vegetation was predominantly Douglas fir and lodgepole pine. Timbered areas were densely stocked, with branches extending downward within a few feet of the top of the surface fuels. Fuel Models 8 and 10 would encompass the variable fuel conditions present on this slope.

Vegetation on hillside north of the Chewuch River is sparse and composed of ponderosa pine and Douglas fir. Surface fuel models consist variously of grasses (FM 1 & 2), brush (FM 5 and 6), and woody fuels (FM 10). Numerous rockslides and scree slopes are present, breaking up the horizontal continuity of forest stands and surface fuels. Fuels and vegetation become more continuous near and along the top of the ridgeline.

### *Fuels in the Entrapment Area*

The entrapment area had tightly spaced stand of conifers with extensive shrub and conifer reproduction. This situation contributed to initiation and establishment of torching run, which crossed the road entrapping the firefighters.

### *Fuels in the Deployment Zone*

A lightly vegetated rockslide was located across the Chewuch River. A narrow band of conifers separated the rockslide from the river.

A scree slope and a lightly vegetated hillside were located immediately north of the road to the northwest of the deployment site. A timbered area (fuel model 10) was located immediately to the north and east of the deployment site and extended up canyon for several miles. The general nature of the deployment zone contributed to the survivability by 12 firefighters and 2 civilians. The scarcity of fuels on the hillside above the deployment site and on the non-forested rockslide to the south across the river limited the amount and duration of heat at the deployment site on the road. The narrow band of conifers on the south side of the river may have partially shielded firefighters on the road from the initial blast of heat from the fire.

The fuels in the immediate vicinity of the fatal deployment zone consisted of duff, litter, and rotten wood lying among the boulders and rocks of the scree slope. This material presumably was deposited there from the trees that grew next to this area. Other areas on the rockslide farther away from the trees and fatalities contained less of this duff and litter, although isolated large rotten logs were present, as evidenced by the burn patterns on the rockslide. A timbered area (fuel model 10) was located within 20 feet to the east of this site.

### *Topography*

Topography of the canyon bottom was essentially level enabling initial dispersion of fire in several directions. The fire was positioned at the base of a steep (70% +) slope that enables the rapid, high intensity uphill movement of the fire south of the river. The orientation and narrowness of the river canyon tended to channel and focus up the canyon the diurnal and fire induced winds.