United States
Department
of Agriculture

Forest Service

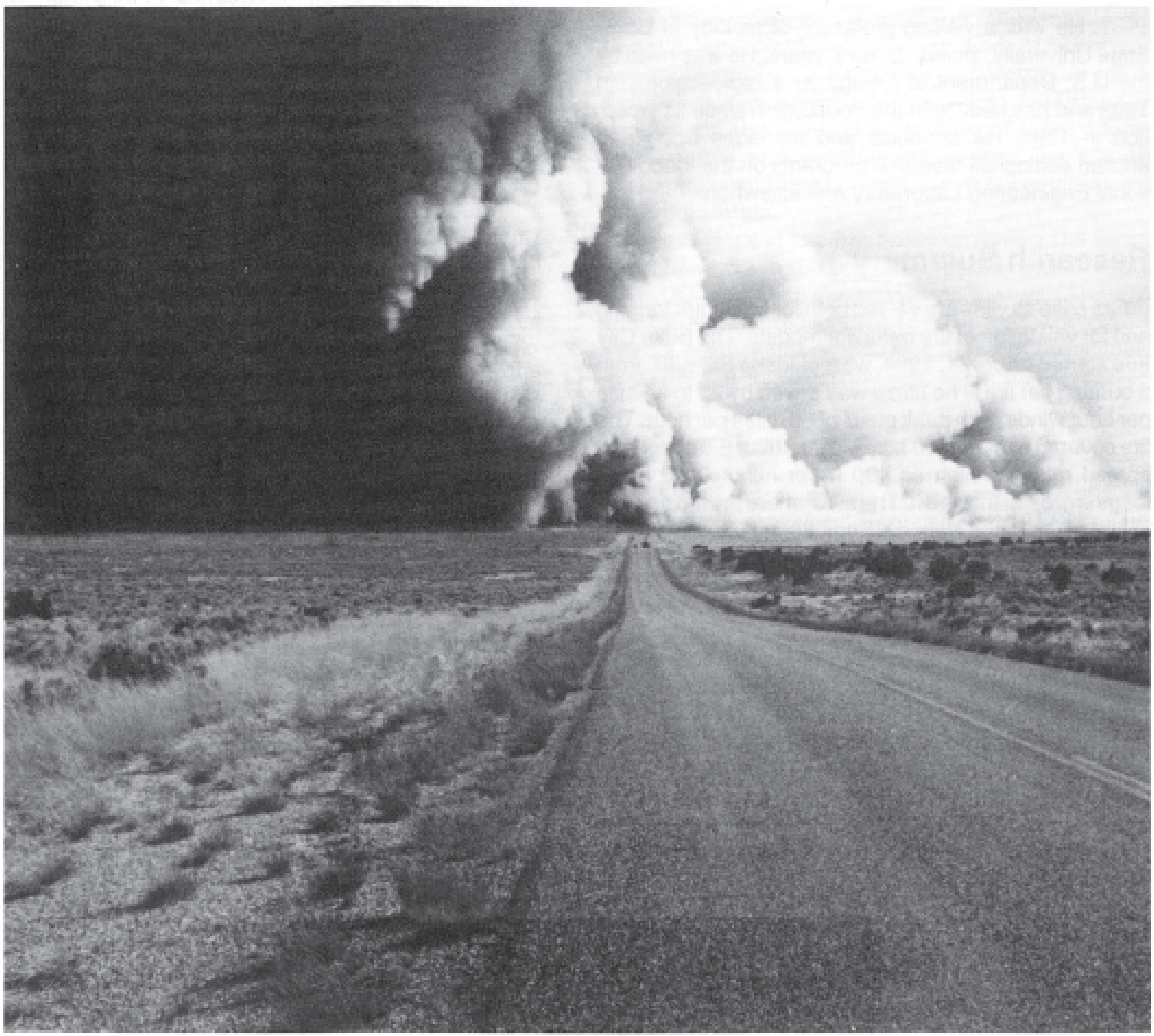
**Intermountain
Research Station**

General Technical
Report INT-GTR-351

May 1997

Wildfire Case Study: Butte City Fire, Southeastern Idaho, July 1, 1994

**Bret W. Butler
Timothy D. Reynolds**



The Authors

Bret W. Butler is a Mechanical Engineer, assigned to the Fire Behavior Research Work Unit at the Intermountain Research Station's Fire Sciences Laboratory in Missoula, MT. He earned a Ph.D. degree from Brigham Young University, Provo, UT, in 1992 where he studied the heat transfer processes occurring in turbulent diffusion flames. Since joining the Forest Service in August 1992, he has been involved in research exploring the fundamental processes governing wildland fire spread and behavior.

Timothy D. Reynolds is a Research Ecologist for the Environmental Science and Research Foundation in Idaho Falls, ID. He received a Ph.D. degree in zoology from Idaho State University in 1978. His dissertation addressed the effects of different land use practices on native vertebrate populations on the Idaho National Engineering Laboratory. He conducted postdoctoral research on pronghorn antelope at that laboratory until 1981. He was a visiting professor of biology at Boise State University, Boise, ID, for 2 years. He was hired by the U.S. Department of Energy as a radioecologist in 1983 and has been with the Foundation since its inception in 1994. He conducts and manages basic and applied ecological research programs on the Idaho National Engineering Laboratory and elsewhere.

Research Summary

Fire case studies are valued both for firefighter training and for validation of fire behavior models. The Butte City Fire started on July 1, 1994, west of Idaho Falls, ID, from a burning flat tire. The blaze was driven by 25 to 35 mile per hour winds, with peak gusts of 60 miles per hour. The fire covered over 20,500 acres in less than 6.5 hours with spread rates as high as 490 ft per minute and flame lengths greater than 40 ft. The area where the fire ocurred is part of the Idaho National Engineering Laboratory and is characterized as high desert rangeland with sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) as the principal shrub species. Wind and air temperature information was gathered at 5 minute intervals from eight remote, automatic meteorological stations positioned on and around the laboratory site. Wind-driven soil erosion rates of 75 tons per acre were measured during the weeks following the fire.

Acknowledgments

Special thanks to Mr. Randy Okopny of the Idaho National Engineering Laboratory Fire Department for assistance in gathering witness statements and fire chronology information. The Idaho Falls office of the National Oceanic and Atmospheric Administration Air Resources Laboratory provided meteorological data. Fuels and topography information were provided by the Environmental Science and Research Foundation and the Idaho National Engineering Laboratory Fire Department. The Idaho National Engineering Laboratory Fire Department and the Idaho Falls District of the U.S. Department of the Interior's Bureau of Land Management provided fire behavior information, local fire characteristics, and fire chronology.

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Cover photo: The Butte City Fire as seen from Highway 22 on the western edge of the Idaho National Engineering Laboratory. The photograph was taken by an unnamed firefighter.

Intermountain Research Station
324 25th Street
Ogden, UT 84401

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Introduction

Many researchers present repeated arguments in favor of documented fire case studies (Alexander 1987; Chandler 1976; Thomas 1994). We present this case study of the Butte City Fire that occurred July 1, 1994, about 60 miles west of Idaho Falls, ID, on the U.S. Department of Energy's Idaho National Engineering Laboratory (INEL). Most of the burned area was managed for grazing by the U.S. Department of the Interior's Bureau of Land Management. This fire should not be confused with the Butte Fire that occurred on the Salmon National Forest during August 1985 (Mutch and Rothermel 1986). We present information on fuels, weather and topography related to the fire, and a comparison between predicted and observed fire spread rates.

On July 1, 1994, at 3:38 p.m. mountain daylight time (MDT), a fire started on a flat tire on a horse trailer pulled behind a vehicle traveling on State Highway 20. The driver stopped the vehicle, removed the tire and let it roll off the road down an embankment into some grass and sagebrush. This ignited a fire on the INEL. At 3:44 p.m., the INEL Fire Department helicopter was dispatched to the scene. The helicopter pilot reported the fire to be approximately 1 acre.

The area's terrain is flat, high elevation desert with sagebrush and native bunchgrasses on basalt. Weather, when the fire began, consisted of winds from the south-southwest at nearly 23 miles per hour measured 50 ft above ground level, air temperature of 89 °F and relative humidity of 10 percent. The strong winds pushed the fire rapidly to the northeast. Flame lengths, estimated to be 5 to 7 ft when firefighters arrived on the scene, soon increased, with some reports of 30 to 40 ft flame lengths.

Fire behavior was characterized by a rapid acceleration from ignition to a high intensity fast-moving fire. An average spread rate for the burn's duration was 162 ft per minute, with short term spread rates as high as 490 ft per minute. Suppression efforts consisted of flanking actions. The initial run lasted approximately 6.5 hours, during which the fire covered more than 12 miles and burned over 20,500 acres.

Although small in terms of total area burned, this fire is unusual among wildfires in that detailed fuels and weather information is available. Besides having a research mission related to nuclear development and associated processes, the INEL is a National Environmental Research Park and serves as an outdoor ecological research laboratory. This designation has focused efforts characterizing plant and animal populations around the site, which has led to the development of a detailed vegetation class map. Additionally, the National Oceanic and Atmospheric Administration's Air Resources Laboratory in Idaho Falls closely monitors meteorological conditions in and around the INEL site. Because of these efforts, detailed fuel and weather information not usually available on wildfires is accessible. We present some of this information.

A chronology of the fire behavior during the initial run follows. Then the predicted spread rates from the BEHAVE fire behavior prediction system (Andrews 1986) are compared against observed rates of spread. Finally, postfire effects, such as soil erosion and changes in vegetation class distribution, are briefly discussed.

The Fire Environment

The INEL encompasses 890 square miles of sagebrush-steppe rangeland managed by the U.S. Department of Energy for the purpose of conducting nuclear energy related research and development. The National Oceanic and Atmospheric Administration's Air Resources Laboratory has deployed a sophisticated network of 31 meteorological monitoring stations in and around the INEL to track and predict air movement patterns. Information from these stations is gathered 24 hours a day and is recorded at 5 minute intervals. Because the INEL is also a National Environmental Research Park, detailed studies of the biota are conducted on the laboratory site and surrounding lands (Reynolds and Morris 1995). As part of these efforts, detailed plant inventories have been completed.

Initially, when the fire was detected, firefighters were concerned about INEL work sites (fig. 1). Several

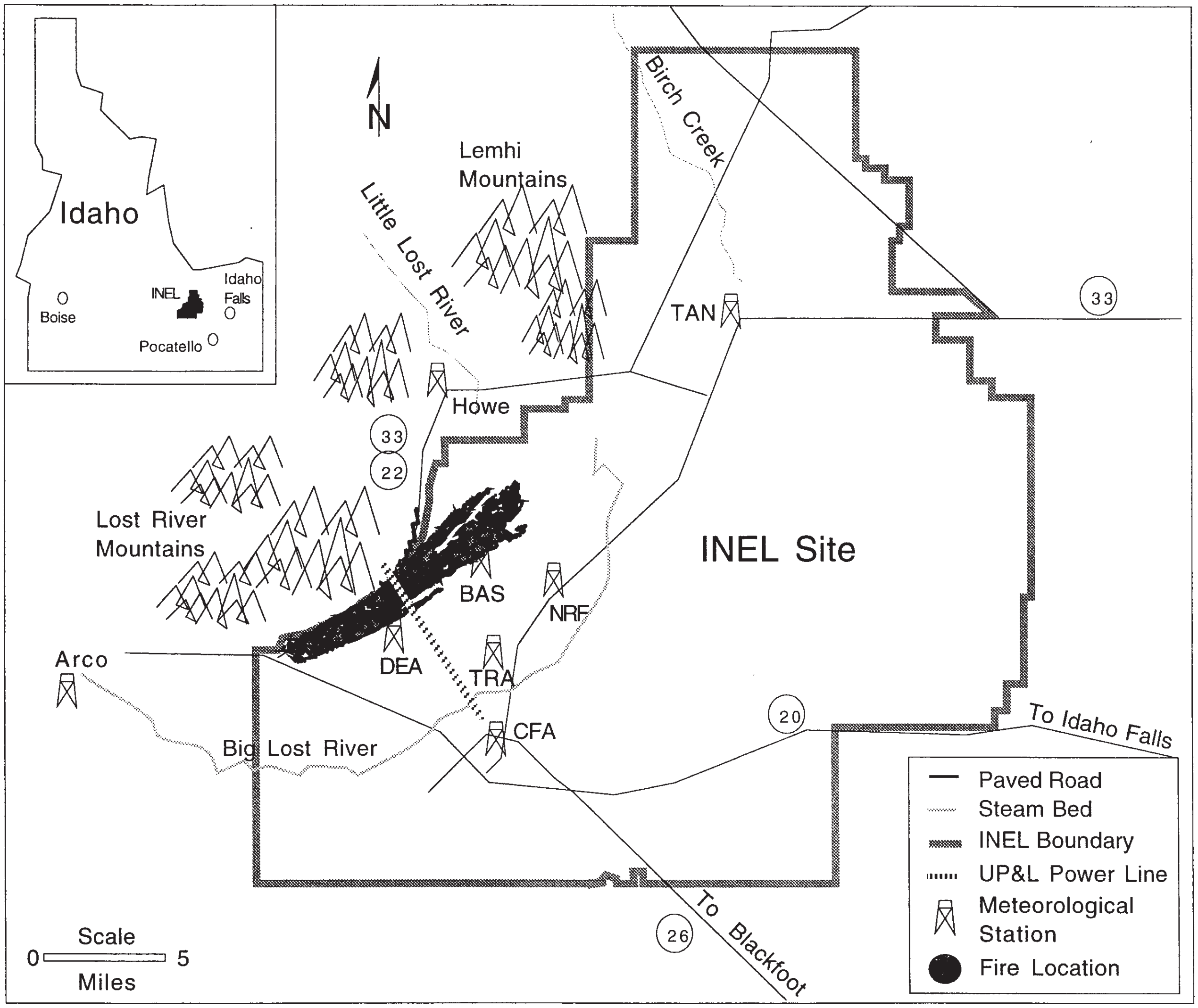

Figure 1—Diagram of INEL site and location relative to the State of Idaho. Eight of the meteorological stations are shown (scale is approximate). Arco and Howe stations' names come from the towns where they are located. Six acronyms stand for: DEA-Dead Man Canyon; BAS-Base of Howe Peak; TAN-Test Area North; CFA-Central Facilities Area; NRF-Naval Reactor Facility; TRA-Test Reactor Area.

facility complexes (including the Central Facilities Area, the Test Reactor Area, and the Naval Reactors Facility) that housed personnel, equipment, and in some cases, toxic substances were at potential risk. Firebreaks existed around the periphery of the facilities; however, the risk of spotting across these breaks was a concern. Additionally, the community of Howe and highways to the west and north of the site were at risk.

Fuels

Although 20 vegetation types have been described on the INEL (McBride and others 1978), the site is dominated by sagebrush and other shrubs (Anderson and others 1996). A detailed map of the vegetation classes and their distribution over the fire area is included in appendix A. Figure 2 shows typical fuels for this site. Mature sagebrush-steppe (*Artemisia tridentata* ssp. *wyomingensis*), on and off lava, occurs on over 90 percent of the burn site. Rabbitbrush (*Chrysothamnus* sp.) and various bunchgrasses constitute much of the remainder of the vegetative community.

Total fuel loading has historically averaged 1,300 to 1,400 lb per acre. However, due to a low snow pack the previous winter (1993 to 1994), the dead fine fuels (such as grasses) from the previous year remained

Figure 2—Typical fuels for the Butte City Fire. The yardstick on the right is included as a reference for fuel depth.

standing. By June 1994, the new growth had combined with the previous year's standing growth to result in a total fuel load of approximately 2,000 lb per acre (Glenn 1995).

Fuel Moisture

At the time of the fire, calculations based on "on site" dry bulb temperatures and relative humidities were used to estimate 1 hour timelag (0 to 0.25 inch diameter) and 10 hour timelag (0.25 to 1 inch diameter) dead fuel moisture contents of 1 and 2 percent, respectively (NWCG 1992). These "on site" estimates were used for all fire behavior predictions.

The live fuel moisture content of sagebrush is sampled every 2 weeks by the Bureau of Land Management's Idaho Falls District as part of the Great Basin Live Fuel Moisture Project (1994). Figure 3 shows live fuel (sagebrush) moisture contents recorded just south of the burn site at Table Legs Butte. During mid-June, live fuel moisture content was 146 percent. By July 1, 1994, it had decreased to 69 percent, the lowest measured level for early July since the sampling project began 5 years earlier. The 5 year average indicates that such low levels are not typically reached until much later in the season (mid to late September).

Weather

The National Weather Service (1994) reported total precipitation in eastern Idaho during the 1993 to 1994 winter to be 50 to 75 percent of normal. Spring temperatures were 4 to 6 °F above normal, and spring precipitation was approximately 50 percent of normal. By June 25, 1994, the Palmer Drought Severity Index (Palmer 1965) was minus 5.8, indicating extreme drought conditions. The Keetch-Byram Drought Index (Keetch and Byram 1968), as reported by the National Weather Service (1994), also indicated that the region was experiencing extreme drought.

One unique aspect of the INEL site relative to other wildfire locations is the presence of 31 remote meteorological stations (eight are shown in fig. 1). Each station provides the following measurements every 5 minutes: average windspeed, wind direction, maximum gust, and air temperature 50 ft above ground; and air temperature, relative humidity, and insolation 6.5 ft above ground. Although not all sensors were reporting at the time of the fire, windspeed and direction were reported by all stations in the fire's vicinity.

The meteorological stations in this area commonly register complex flow. While the terrain that was directly in the fire's path is relatively flat, there are

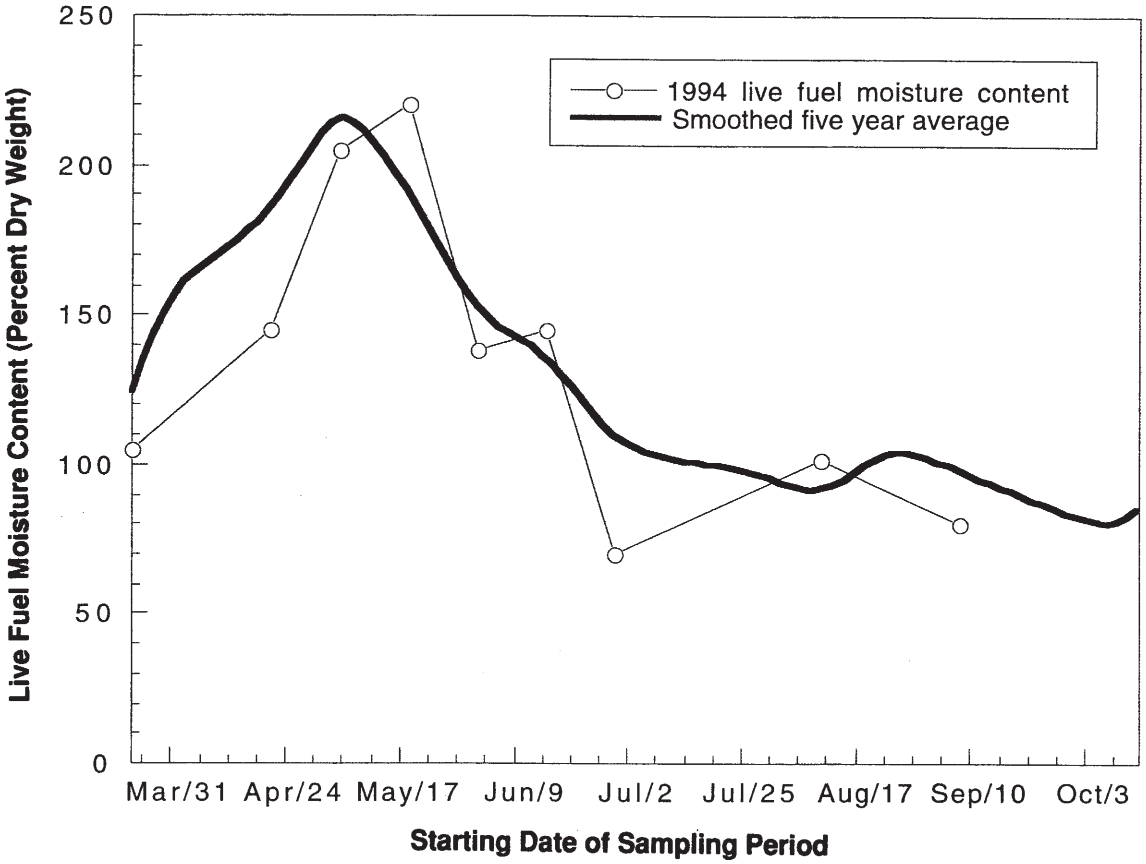

Figure 3—Live fuel moisture content during the 1994 fire season for Table Legs Butte, ID, compared to 5 year smoothed average (Great Basin Live Fuel Moisture Project 1994).

mountains along the INEL's west border. The southwesterly wind coming onto the site is accelerated and becomes more southerly as it follows the edge of the mountains. This effect was one factor that resulted in a reduced fire threat to some of the INEL facilities.

Two meteorological stations were actually overburned by the fire (DEA and BAS; see figure 1 for explanation of acronyms). Initially, we hoped that we could estimate the fire spread rate by comparing the temperature readings from these towers. But after reviewing the fire perimeter information, it appeared that the DEA station was overburned by the fire's flank. The BAS station, on the other hand, was overburned by the fire front; it provided local windspeed measurements at the fire's front.

The DEA, BAS, NRF, and TRA stations were nearest to the fire (fig. 4). Wind and temperature data from these stations are shown in figure 5a-d and in appendix B, which includes additional data from other stations around the fire site.

Winds at ignition were southwesterly at 20 to 27 miles per hour (fig. 5a). The winds gradually increased to 25 to 32 miles per hour over the next 2 hours and then remained nearly constant until about 7:00 p.m. when they decreased sharply to 5 to 10 miles per hour. Air temperatures were 89 °F when the fire started. Temperatures held steady over the next 3 hours then gradually decreased to approximately 60 °F over the last hours of the active burning period.

Fire Narrative

Fire locations were estimated from shift and dispatcher reports taken during the fire and from interviews with INEL and Bureau of Land Management personnel working on the fire. Figure 4 shows the estimated locations of the fire front. Smoke was first reported at 3:44 p.m.; the INEL helicopter was immediately dispatched to the fire. The helicopter pilots estimated the fire at 1 acre with flame lengths of 4 to 6 ft. Bureau of Land Management and INEL fire units were dispatched to the scene. The National Oceanic and Atmospheric Administration meteorological station closest to the ignition site reported average

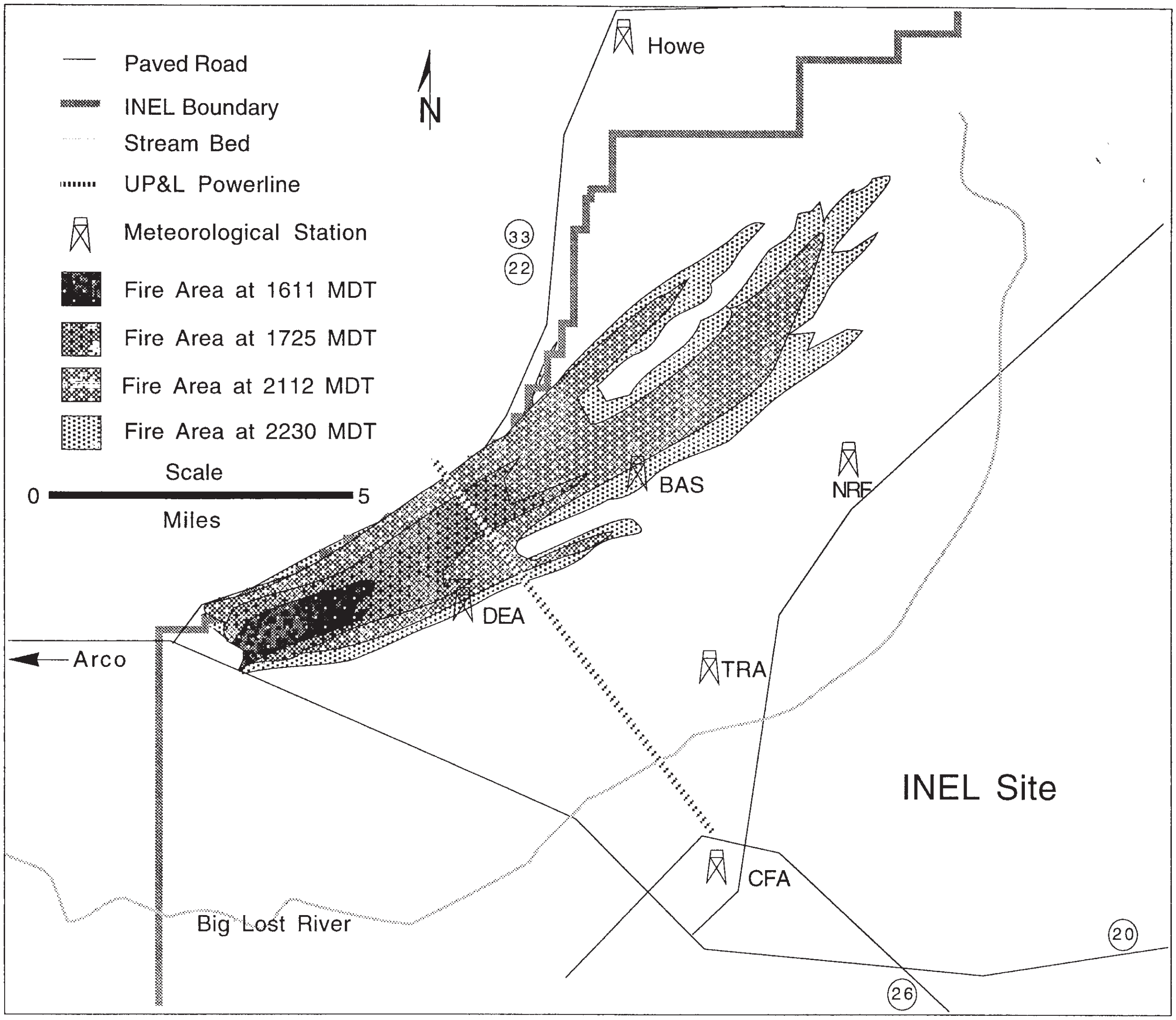

Figure 4—Map of southwestern quarter of INEL site showing estimated fire perimeter locations (scale is approximate). Fire perimeters correspond to rows in table 2.

windspeeds of approximately 25 miles per hour with gusts to 35 miles per hour from the south by southwest (fig. 5a). Within 4 minutes the fire had grown to over 100 acres.

At 4:11 p.m., statements from the INEL Fire Department dispatcher place the fire front 2 to 3 miles northeast of the ignition point. An air tanker was requested. Meanwhile the wind had increased to over 30 miles per hour At 4:34 p.m., the air tanker arrived and dropped retardant on the northeast edge of the fire. One INEL firefighter reported: "The two drops...slowed the fire down so we could mop it up. As I was leaving the fire, some of the areas had rekindled." Other firefighters on the INEL Fire Department brush units in the immediate vicinity of the drop reported that although the fire may have been slowed by the retardant, it quickly recovered and continued burning with 6 ft or higher flame lengths.

One hour later (5:25 p.m.), the flames along the west flank were reported to be 15 to 30 ft tall and 200 to 300 ft deep. Winds were 22 to 28 miles per hour with gusts to 60 miles per hour (fig. 5a,b). The helicopter pilots reported that the fire front had burned over the Utah Power Company powerline (fig. 1). The sharp jumps in windspeed, wind gusts, and air temperatures at the BAS meteorological station clearly indicate the arrival of the fire front (fig. 5b). Five minute average windspeeds were measured at 25 to 30 miles per hour.

The combination of wind and buoyant forces induced intense turbulence at the fire front; this turbulence contributed to increased fire intensity and spread. Immediately after the fire front passed, average

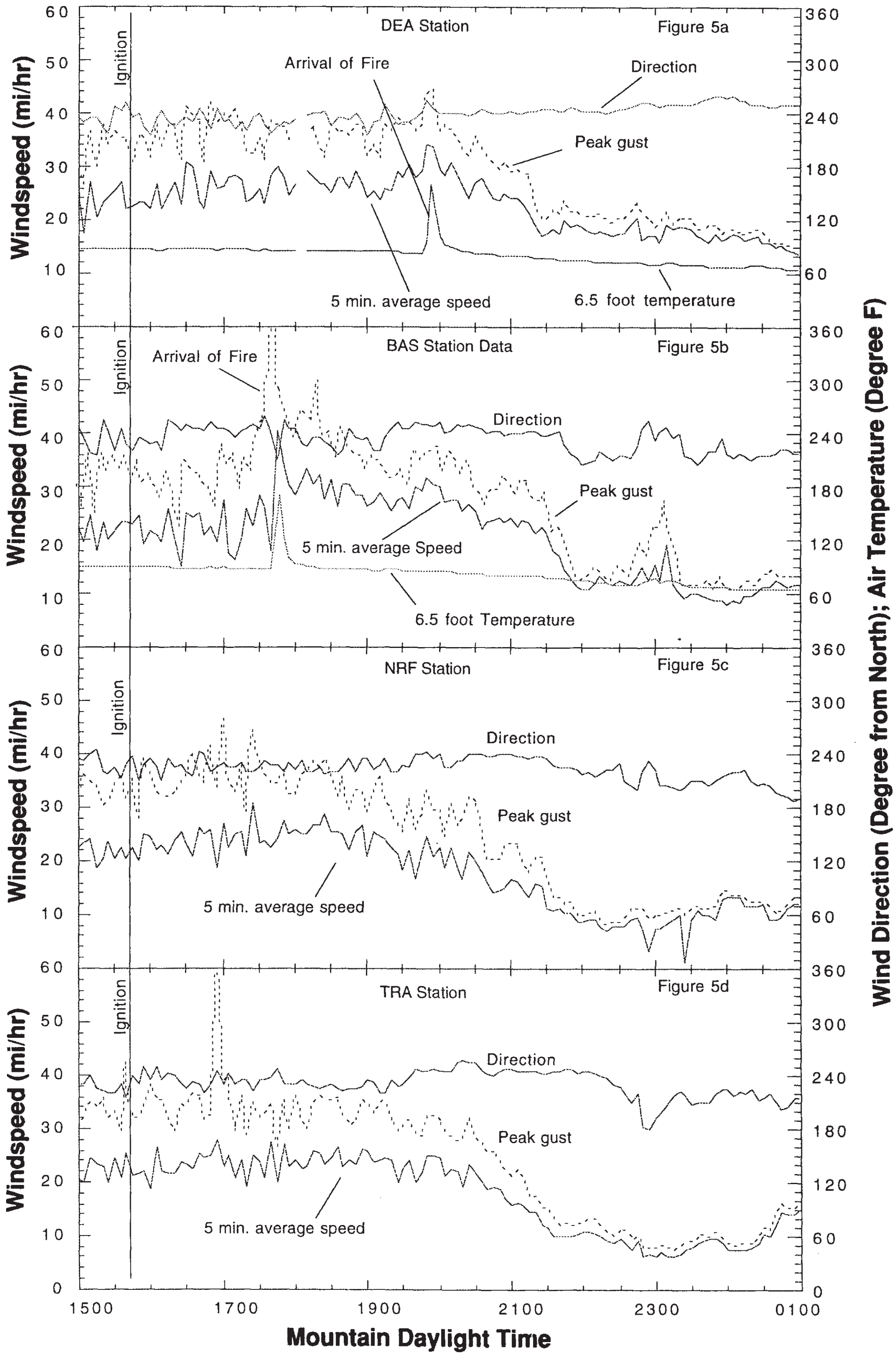

Figure 5a-d—Wind and temperature data from DEA, BAS, NRF, and TRA meteorological stations. (Data provided courtesy of NOAA Air Resources Laboratory, Idaho Falls, ID.)

windspeeds were measured at 30 miles per hour (an increase of 8 miles per hour over the prefire winds). The increase in wind behind the front was not shown by the DEA station because it was not overburned by the head of the fire but by a flanking fire.

Eyewitness accounts suggest that the rate of spread was approximately 290 ft per minute between the DEA and BAS stations. At 6:50 p.m., the overhead powerline to Howe Peak failed; either the powerline wires melted and separated or some of the poles collapsed, causing the emergency generator in the repeater station to start. The helicopter pilot reported that large fire whirls were just behind the fire front and that the fire "...is very big and threatening the west side of Highway 33." Flames along the southeast flank were 10 ft. Shortly thereafter the fire spotted across Highway 33 and began to spread along the highway with flanking runs moving northwest into the foothills. Retardant drops along the west flank and actions by Bureau of Land Management fire crews stopped further westward spread. About 7:00 p.m., winds began to decrease. By 7:50 p.m., fire crews reported that flame lengths had decreased to 3 ft, but the fire was still moving too fast for brush crews to catch the fire front.

Attempts by fire personnel to access the burned area as late as 10:40 p.m. along the UP&L powerline were blocked by significant flaming. Brush units continued attacking along the east flank until approximately 10:30 p.m. By this time the winds had decreased to less than 15 miles per hour and air temperatures were less than 70 °F (fig. 5a,b,c). By 6:00 a.m. the next day, no flaming combustion was observed on the burn site.

Discussion

Fire Behavior

Fire behavior on the Butte City Fire during the first 30 minutes consisted of an acceleration phase characterized by fire spread rates as high as 490 ft per minute as the fire accelerated from the ignition point. This was followed by a quasisteady burning phase wherein the fire moved at a steady rate until the winds and amount of combustible vegetation decreased. The following discussion compares observed rates of spread against predicted values of spread using the BEHAVE fire behavior prediction system (Andrews 1986).

BEHAVE fuel model 2 most closely represents the fuels present in the area of the Butte City Fire (Glenn 1995). In his description of this fuel type, Anderson (1982) states: "Fire spread is primarily through the fine herbaceous fuels...such stands may include clumps of fuels that generate higher intensities and that may produce firebrands." This description resembles the fuels and the fire spread mechanism observed by firefighters on the Butte City Fire.

During the majority of its run, the fire was moving so fast that firefighters were never able to safely catch and attack the fire's head. The Fire Behavior and Tactics guide included in the Great Basin Live Fuel Moisture Project (1994) provides six fire classifications as a function of live fuel moisture content. For moisture contents below 74 percent, "Fires will exhibit ADVANCED FIRE BEHAVIOR with high potential to control their environment. Large acreage will be consumed in very short time periods. Backfiring from indirect line, roads, and so forth, must be considered. Aircraft will need to be cautious of hazardous turbulence around the fire." This closely describes conditions observed on the Butte City Fire.

The spread rates of nearly 490 ft per minute, observed early in the fire, were caused by direct exposure of the fire front to the driving wind. Although winds generally increased slightly over the next 2 hours, the observed spread rates dropped by nearly 30 percent, which can be attributed to the blocking of the horizontal movement of the air mass by the smoke column produced by the fire. The general effect was to reduce the fire's rate of spread.

The spike in the 6.5 ft temperature trace at 5:45 p.m. indicated the fire front's arrival at the BAS meteorological station (fig. 5b). At the same time, windspeed increased from 23 to approximately 30 miles per hour; this was unique to the BAS station. The increase in average windspeed and a sharp jump in maximum wind gust coincides with the jump in temperature. This suggests that these factors were associated with the fire front and also illustrates the strong turbulence at the fire front. As the air was convected upward in the smoke column, a local low pressure region was formed near the ground just behind the fire front. This caused increased turbulence and windspeed directly behind the fire front. So, while the development of a large smoke column above the fire front blocked the general wind acting on the fire front, the air rushing in behind the fire to replace that convected upward in the column increased turbulence and windspeed in a localized region just behind the fire front. The effect was a generally slower spread rate from that observed early in the fire, but possibly higher flame turbulence and lengths.

Table 1 presents input and output from the BEHAVE fire behavior prediction system runs. The data represent a parametric study of the effect of fine dead fuel and live fuel moisture contents on the predicted spread rate accuracy. Live herbaceous moisture content measurements were obtained from field measurements made as part of an ongoing live fuel monitoring program. Windspeeds commonly quoted by the weather service are measured at 20 ft above the ground or

Table 1—BEHAVE model input and output values.

	Sensitivity study[a]			Predicted spread rates[b]		
BEHAVE input values						
Fuel model	2	2	2	2	2	2
1 hour fuel moisture (percent)	**1**	**2**	**2**	1	1	1
10 hour fuel moisture (percent)	**2**	**3**	**4**	2	2	2
100 hour fuel moisture (percent)	**3**	**4**	**5**	3	3	3
Live herbaceous moisture (percent)	75	75	75	**65**	**95**	**125**
Adjusted 20 ft windspeed (miles per hour)	20	20	20	20	20	20
Wind adjustment factor	0.4	0.4	0.4	0.4	0.4	0.4
Mid-flame windspeed (miles per hour)	8	8	8	8	8	8
BEHAVE output values						
Rate of spread (feet per minute)	155	134	119	160	145	130
Heat per unit area (Btu/ft^2)	675	603	552	676	670	665
Fireline intensity (Btu/ft-sec)	1,730	1,345	1,098	1,801	1,600	1,435
Flame length (feet)	14	12	11	14	13	13

[a]Sensitivity study of the predicted fire behavior compared to the dead fuel moisture content, which is shown in bold.
[b]Comparison of predicted spread rates as a function of live moisture content, which is shown in bold.

vegetation canopy. Because 50 ft windspeeds, rather than 20 ft, were measured by the meteorological stations, the 50 ft values were reduced by 0.85 to obtain the equivalent 20 ft windspeed. This correction was calculated from the logarithmic wind profile suggested by Albini and Baughman (1979). Then, a wind adjustment factor of 0.4, as suggested by Rothermel (1983) and Baughman (1980), was applied to the estimated 20 ft windspeeds to obtain the midflame windspeed.

We questioned the relative importance of the dead fuel moisture content levels relating to the accuracy of the predicted spread rates. The first three columns of table 1 represent a sensitivity study of the predicted fire behavior values compared to the dead fuel moisture content (shown in bold). The moisture contents used for this fire were calculated from temperature and relative humidity measurements made “on site.”

The results indicate that the model is relatively sensitive to dead fuel moisture content. An increase in 1 hour through 100 hour timelag fuels by 1 percent results in an 8 percent decrease in the predicted spread rate. A 2 percent increase in dead fuel moisture contents results in a 23 percent decrease in predicted spread rate.

The last three columns of table 1 show a comparison of predicted spread rates as a function of live fuel moisture content (shown in bold). In general, a 25 percent change in live fuel moisture content will cause a proportional 8 percent change in fire spread rate. This suggests that for this fuel type, predicted rate of spread is not highly sensitive to live fuel moisture content. This implies that reasonable predictions of fire spread can be obtained even when using estimated live fuel moisture contents based on measurements and weather during the preceding days and weeks.

Table 2 presents predicted and observed spread rates. Observed rates of spread were calculated by identifying fire front locations and times from the firefighter statements and dispatch logs. The BEHAVE fire behavior prediction system was used to make two sets of predictions: the first using average wind data and the second using maximum wind gust.

With the exception of windspeed, the fuel conditions used for these predictions were the same as those listed in the first column of table 1. The windspeeds used in these predictions were taken from the meteorological station nearest the fire front at the time of interest (fig. 5a,b). In general, for these input conditions, a 10 percent change in windspeed will result in a corresponding 20 percent change in the predicted spread rate.

The results from this first set of predictions are listed in table 2 under the column titled “Predicted using average windspeed.” The model is not accurate when used to predict spread rates associated with acceleration from a point ignition to quasisteady conditions. This is indicated in figure 6 where the predicted spread rate 30 minutes after ignition is approximately one half the observed value. One and a quarter hours later (5:25 p.m.), the predicted spread rate is 73 percent of the observed value. However, as the fire continues to burn (the next 4 hours), the predicted spread rate matches the observed value to within 7 percent. These data clearly demonstrate that the fire spread rate model is a useful tool for predicting steady state fire spread rates, but it is not accurate during the

Table 2—Observed versus predicted rates of spread.

Fire front location	Time	Distance	5 minute windspeed Average	5 minute windspeed Peak	Rates of spread Observed	Rates of spread Predicted using average windspeed	Rates of spread Predicted from peak windspeed
	MDT	*Mile*	*Mile/hr*	*Mile/hr*	*Ft/min*	*Ft/min*	*Ft/min*
Ignition	1544		24	34		160	295
2.5 mi NE of ignition point	1611	2.5	25	36	489	172	328
1 mi NE of UP&L powerline	1725	4	28	36	286	209	328
2.5 mi NW of NRF	2112	6	22	30	140	138	238
NE edge of burn	2230	1	14	16	68	63	77

early phase when a fire is accelerating from a point ignition (Rothermel 1972).

A second BEHAVE run using maximum wind gusts rather than average windspeed underpredicted the extremely high initial values and overpredicted the steady state spread rates. These data are listed in the last column of table 2 and are also shown in figure 6. During the period of steady state fire spread, the spread rates predicted using the maximum wind gust were as much as 70 percent higher than the observed values. These observations indicate that maximum wind gusts are not appropriate for BEHAVE fire behavior prediction system input when calculating fire spread rates.

Figure 7 is a Fire Characteristics Chart. Fireline intensities on the Butte City Fire, shown in the shaded ellipse, were between 2,000 and 3,000 Btu/ft-s. Spread rates varied from 63 to 290 ft per minute. Control problems associated with the fire are well described by Andrews and Rothermel (1982): "...for fireline intensities greater than 1,000 Btu/ft-s, control efforts at the head of the fire are ineffective." This was the case with the Butte City Fire until very late in the burning period when firefighters were able to successfully attack the fire's flank with ground-based equipment.

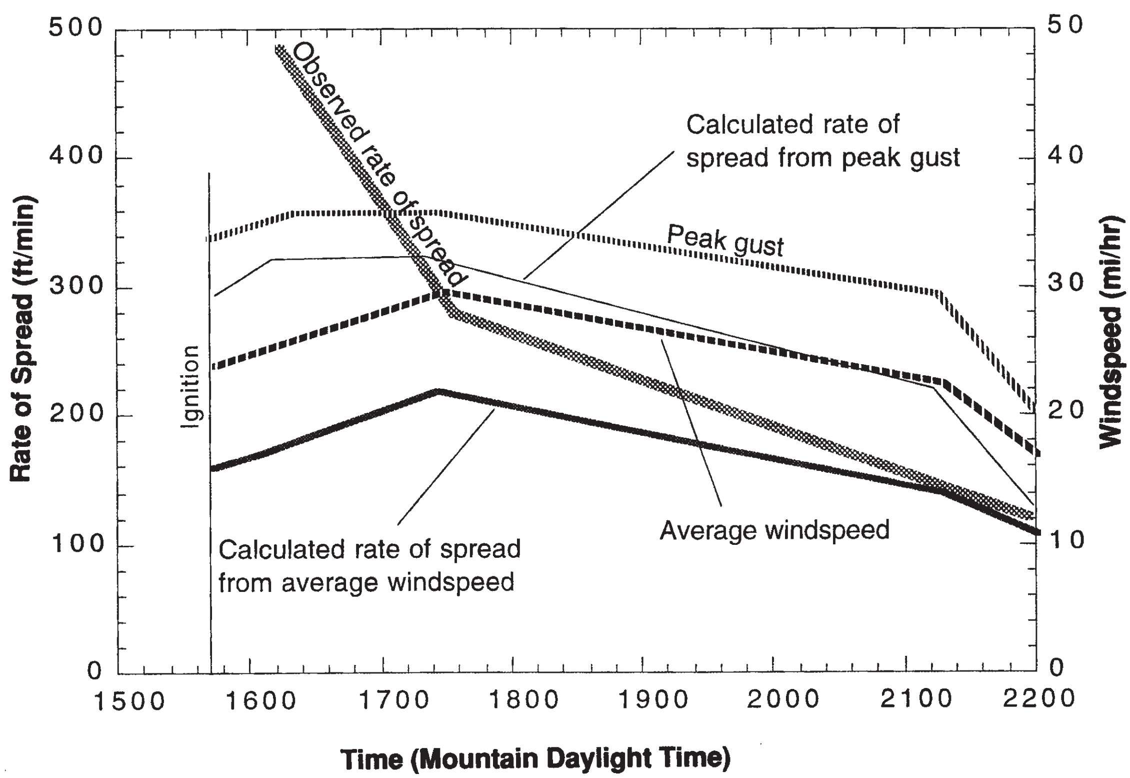

Figure 6—Observed versus predicted rate of spread using the BEHAVE fire behavior prediction system.

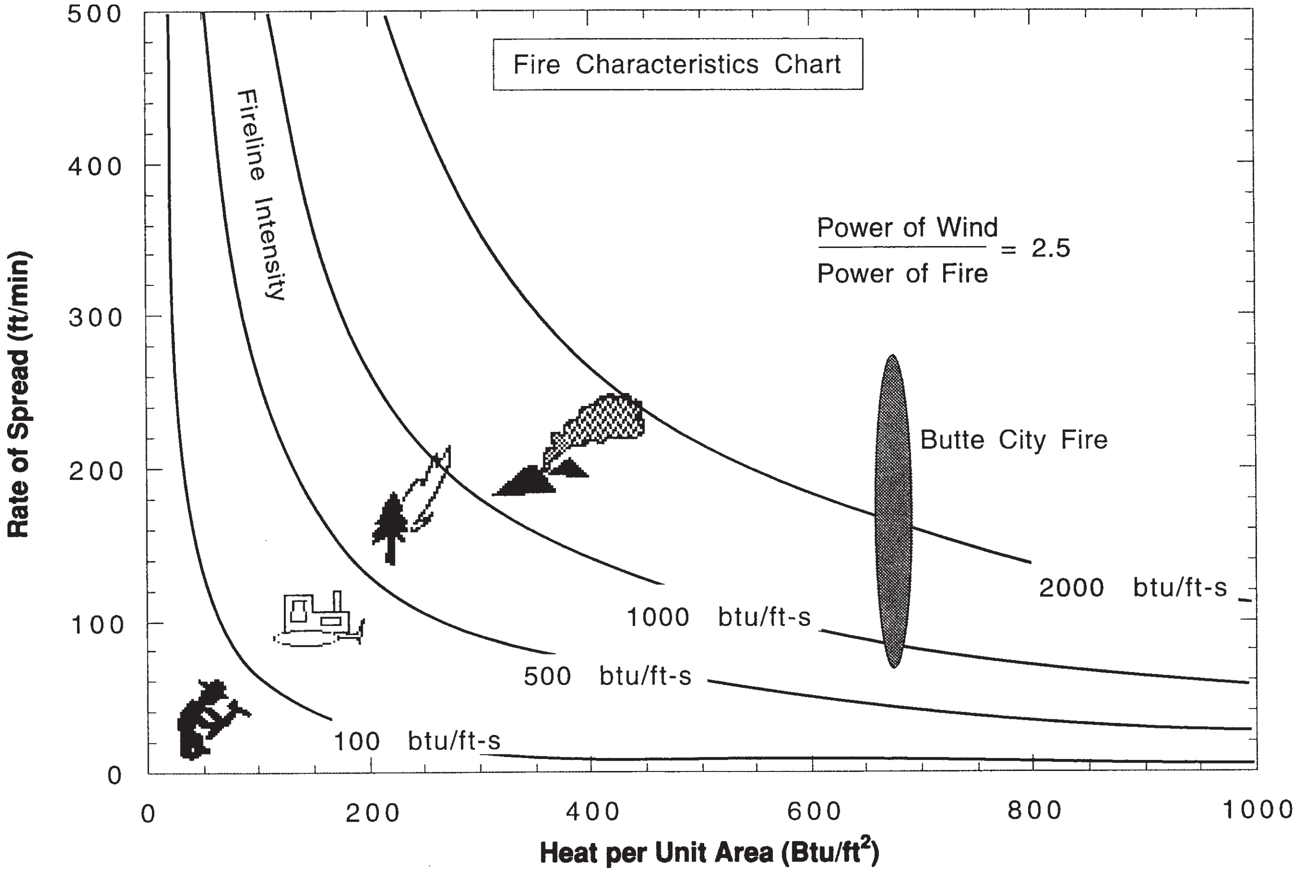

Figure 7—Fire characteristics chart for the Butte City Fire.

Following Rothermel (1991) guidelines, the power of the wind was found to be more than double that of the fire. Rothermel (1991) indicates that if a fire is clearly wind-dominated, flanking actions are often the only option available to firefighters. This aptly describes conditions on the Butte City Fire. However, if the power of the fire is greater than that of the wind, suppression actions should focus on fuel reduction ahead of the fire front. Thus, calculation of the power of wind to power of fire ratio can be useful in deciding attack options. As a note of interest, if the windspeed had been nearer 10 miles per hour in these fuels, the power of wind to power of fire ratio would have been approximately 0.7. The fire could then be controlled using ground-based equipment and fuel reduction techniques.

Most "problem" fires in these fuel types will be wind-dominated. Nevertheless, one should calculate the power ratio to serve as an aid in selecting fire control options. Although the crown fire nomograms as presented by Rothermel (1991) are not appropriate for this fuel type, the methods for calculating the power of the wind and power of the fire are.

Fire Effects

Sagebrush-grass vegetation types occupy nearly 100 million acres in the Western United States (Wright and Bailey 1982). Fire frequency for pre-European settlement in sagebrush-grass communities on the Snake River plain in eastern Idaho has been estimated at 20 to 25 years (Houston 1973). During the last century, this interval has lengthened significantly due to effective fire suppression. The result has been a change toward sagebrush-dominated communities and fewer fire adapted plants, such as rabbitbrush and horsebrush (Harniss and Murray 1973; Houston 1973).

After the Butte City Fire was extinguished, questions arose regarding the long-term effects on local plant and animal communities. The Department of Energy has taken great care and effort to protect the native plant and animal populations found on the INEL site. The most dramatic effect of the Butte City Fire was the nearly complete consumption of all vegetation both dead and live; the exposed vegetation was consumed down to the soil level, and the postburn area resembled a moonscape (fig. 8). Due to the lack of

Figure 8—Photograph of soil erosion after Butte City Fire (note pen next to sagebrush stub in center of photo).

soil-anchoring vegetation, wind erosion in the weeks following the burn removed more than 3 inches of topsoil. Soil erosion rates as high as 75 tons per acre per month (nearly 0.5 inches per month), were measured at some locations (Jeppesen 1994). These were the highest wind-caused soil erosion rates ever monitored in the Bureau of Land Management Idaho Falls District. During this time, commercial aircraft flying over the area reported dust plumes reaching 5,000 ft above ground level on windy days (Jeppesen 1994). Subsurface grass and shrub root structures were exposed within 1 month. Soil erosion nearly stopped with the vegetational sprouting and growth in spring 1995.

Fire occurrence in sagebrush grasslands results in preferential growth of resprouting perennials and annuals with soil seed reservoirs (Wright and Bailey 1982). We expected that regrowth would consist largely of bunchgrasses and rabbitbrush because sagebrush had been totally eliminated from the site and it does not normally resprout. One major question immediately after the burn concerned the necessity for reseeding to minimize soil erosion and to initiate native plant regrowth while inhibiting encroachment of exotic species. However, others have compared seeded and unseeded sites on similar ecosystems and have found that seeding is not necessary (Ratzlaff and Anderson 1995).

A significant regrowth of native grass species did occur the following year without reseeding. A 21 percent canopy cover of bunchgrasses and forbs (such as rabbitbrush and horsebrush) has been reported (Anderson and others 1996). A 33 percent cover has been measured on adjacent unburned areas. It appears that the grass and forb species will reach preburn density levels within a few years after the burn. However, the shrub component will require a significantly longer regeneration period. The spring of 1995 was relatively wet, which provided plenty of water for plant growth. Grass grew greater than 3 ft. This “new” fuel bed has some significance with respect to the potential fire behavior. The lack of any appreciable shrubs suggests that a fuel model containing more grass is appropriate (such as a BEHAVE fuel model 1 or 3). This change in the fuel complex could result in a doubling or possible tripling of the fire spread rate, but intensities can be expected to be lower than exhibited by the Butte City Fire. It is likely that the grass-dominated vegetative community will be more fire resistant, implying less likelihood of repeated extreme soil erosion rates such as occurred after the Butte City Fire.

Conclusions

The rapid growth of the Butte City Fire was impressive from a fire behavior point of view and potentially dangerous from a fire protection point of view; however, such behavior (spread rates and flame intensities) is typical of wildfires in these fuel types. The fire behavior was extreme but understandable when using readily available predictive models. Similar fire behavior can be expected to occur, given strong winds, in these fuel types during almost any fire season. A nearly identical ignition occurred in August 1995 on the INEL. Again, southwesterly winds caused the ignition to quickly develop into a wind-driven fire front that spread over approximately 6,800 acres within 4 hours. The scenario was repeated in July 1996 when nearly 40,000 acres were burned in another fire on the INEL site.

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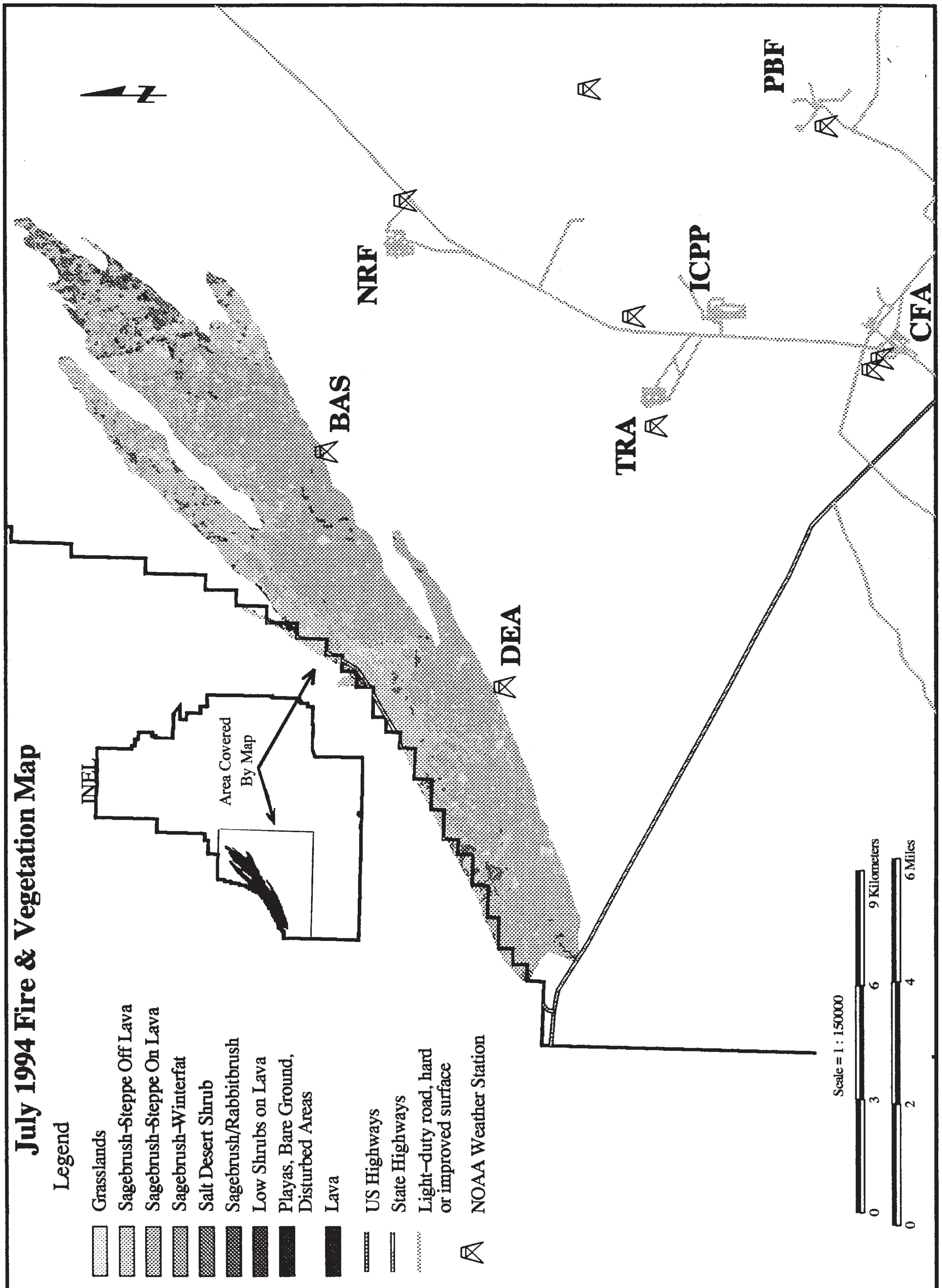
Appendix A: Fuel Map and Final Fireline Location



Appendix B: Meteorological Station Data

Time (hhmm)	ARC 15S (mi/hr)	ARC 15D (Deg)	ARC 15G (mi/hr)	ARC 2MaxT (Deg F)	ARC 2RH (%)	BAS 15S (mi/hr)	BAS 15D (Deg)	BAS 15G (mi/hr)	BAS 2MaxT (Deg F)	DEA 15S (mi/hr)	DEA 15D (Deg)	DEA 15G (mi/hr)	DEA 2MaxT (Deg F)	HOW 15S (mi/hr)	HOW 15D (Deg)	HOW 15G (mi/hr)	HOW 2MaxT (Deg F)	NRF 15S (mi/hr)	NRF 15D (Deg)	NRF 15G (mi/hr)	NRF 2MaxT (Deg F)	RWM 15S (mi/hr)	RWM 15D (Deg)	RWM 15G (mi/hr)	RWM 2RH (%)	TRA 15S (mi/hr)	TRA 15D (Deg)	TRA 15G (mi/hr)	TRA 2MaxT (Deg F)
1435	18.9	230	25.5	85.26	12.8	23.4	244	33.5	90.59	27.2	243	35.3	87.85	22	200	32.2	85.77	22.6	213	36.2	89.22	20.4	233	33.5	10	21	231	29.5	89.47
1440	22	227	29.1	85.06	12.7	23.3	227	36.2	89.83	22.1	252	35.3	87.78	24.8	199	31.7	85.66	20.5	227	31.7	90.34	19.8	228	25.5	9.9	25.5	214	42.4	89.55
1445	18.3	215	27.3	85.57	12.4	22.7	220	31.3	89.73	22.5	235	30.8	88.14	23.2	202	33.5	86.43	22.5	237	35.3	89.8	21.8	229	34.9	10	21.4	239	32.2	89.53
1450	15.2	208	29.1	85.41	12.1	24.7	235	34.9	90.63	23.3	239	36.2	88.97	20.5	222	29.1	86.38	20	211	27.3	89.49	24.6	244	36.6	10	21.6	229	32.2	89.62
1455	24.5	230	38.4	85.42	12.4	19	233	30.8	89.64	23.1	226	35.3	87.26	20.1	212	26.4	86.34	25	227	39.3	89.76	22.3	237	31.3	10	22.1	249	34.4	90.07
1500	20.1	236	27.7	85.03	12.5	21.8	228	32.6	89.78	22.1	216	31.3	88.09	24.4	214	41.5	85.95	24.6	234	36.2	88.77	22.1	235	29.1	9.9	18.6	234	38.4	89.67
1505	20.3	227	30	85.1	12.5	20.6	230	29.5	89.82	26.8	236	38	86.34	17.7	211	30.8	86.22	22.1	224	33.1	89.1	23.1	231	35.7	10	26.5	249	35.7	90.77
1510	19	220	28.6	84.92	12.3	19.6	219	27.7	89.82	22.1	242	33.5	87.28	17.5	221	31.3	86.72	23	211	32.2	90.61	19.6	225	33.1	10.1	22.1	234	35.3	89.83
1515	19.8	232	26.8	85.1	12.4	25.7	254	33.1	90.03	24.7	229	38.4	88.72	19.9	230	28.2	86.43	21.4	235	32.2	89.55	21.5	226	34.9	10	21.7	243	31.7	90.03
1520	17.7	232	27.7	84.6	12.4	20	251	28.2	89.06	26.9	225	38	87.53	14	235	24.6	86.67	23.8	224	33.1	89.08	22.4	253	30	10	21.5	240	29.5	90.16
1525	19.3	230	30.4	84.83	12.4	14.9	243	21.9	87.53	22.8	232	31.3	87.58	16	230	27.3	86.38	25.2	227	34.9	89.49	21.7	231	32.6	10	23.9	231	34.4	91.29
1530	24.1	225	33.1	85.24	12.4	24.9	251	34.9	88.88	31	234	41.1	87.6	17.2	251	32.2	86.92	23.2	220	35.7	88.68	23.6	234	34	10	23.4	226	34	91.13
1535	20.2	229	29.5	85.46	12.4	24.1	245	33.1	88.38	29.8	230	39.3	87.22	16.3	264	30	87.46	20.6	215	40.6	88.43	24.6	238	32.6	9.8	22.3	233	36.6	89.17
1540	21.7	235	28.6	85.33	12.5	25	244	32.6	89.17	23.1	244	38.9	87.37	14.2	227	23.3	87.03	26.4	242	36.2	88.2	20.8	231	34.9	9.9	25.5	231	36.2	90.75
1545	19.1	224	27.3	85.28	12.5	20.9	242	30.8	88.83	22	237	30.8	88.36	24.1	217	35.7	86.05	24.9	241	34.4	88.79	27	230	34.9	9.9	24.6	220	31.7	89.76
1550	25	228	34	85.28	12.4	22.6	253	30	89.37	29.2	223	42	87.28	18.2	225	28.2	85.78	26	219	41.5	89.15	22.3	231	33.5	10	25	229	32.6	89.22
1555	24.7	230	34.4	85.17	12.4	19.4	245	26.4	89.38	25.7	245	38.4	86.97	18.1	209	29.5	85.86	18.7	225	33.5	89.76	24.4	244	31.7	10	27.7	245	67.8	89.24
1600	17.3	256	23.7	84.78	12.4	27.6	246	38	90.45	26.4	230	39.8	87.64	15.7	219	23.7	85.78	26.9	230	46.9	89.76	22.9	235	35.7	10	22.7	230	39.3	90.07
1605	19.6	226	32.6	85.1	12.6	17.6	242	34	88.23	28	232	39.3	87.78	17.1	223	30.4	86.07	22.5	224	34.4	86.47	27.7	230	40.6	10	24.8	242	39.8	90.45
1610	17.2	218	23.7	85.23	12.4	16.4	234	36.2	86.92	28.1	222	41.1	87.8	18.9	216	28.6	85.86	24.9	226	33.1	88.68	24.5	229	38.9	10	21	231	29.5	89.29
1615	17.3	253	25.1	85.15	12.4	20.4	242	29.5	87.13	27.5	230	36.6	87.01	19.9	201	29.5	84.96	25.3	229	38	88.34	27.5	240	42	10	24.2	234	36.2	89.26
1620	21.2	233	27.7	85.05	12.6	25.9	245	35.3	89.17	23.5	219	32.6	88.05	23.7	215	34.4	85.32	20.8	221	29.1	89.29	25.2	234	35.3	10	19.1	234	28.2	89.28
1625	22.5	234	31.3	84.83	12.5	22.5	251	33.1	88.32	24.2	234	32.6	87.28	21.8	218	31.7	85.23	30.8	219	44.6	89.26	22.5	243	30.4	10	24.9	222	34.9	89.04
1630	23.3	233	30.8	84.78	12.3	28.3	246	41.1	89.26	26	241	35.3	86.47	16.9	244	29.1	85.68	23.4	224	38	89.55	21.5	248	31.7	10	23.7	234	32.2	88.68
1635	18.1	236	25.1	84.36	12.4	26.3	259	42.4	88.68	23	228	31.3	87.37	16.8	237	30	85.78	23.6	232	36.2	89.19	25.7	234	35.3	10	20.9	236	33.1	88.59
1640	21	223	32.2	84.67	12.3	18	240	52.6	91.09	28.1	218	38.9	86.72	18.9	229	27.7	85.44	22.5	227	34.4	87.8	25.8	238	34.9	10.1	27.5	237	34.9	88.66
1645	20.2	244	28.2	84.49	12.4	40.3	211	70.4	169.4	30	225	38	86.43	20.6	214	30.8	85.1	24.3	228	34.4	88.41	26.6	234	38	10.1	19.9	247	26.4	88.32
1650	21.3	242	29.5	83.91	12.5	33.8	255	45.5	152.6	27.9	231	37.5	87.39	15	231	27.3	85.57	27.4	220	37.1	88.57	22.9	231	31.3	10.1	27	231	35.3	88.52
1655	23.3	248	34.4	83.88	12.5	30.6	246	43.3	104.6	24.7	228	34.9	87.19	15.1	228	26.4	85.55	25	230	32.6	87.93	25.2	233	36.2	10.1	23	231	29.5	88.66
1700	22.3	249	30.4	83.57	12.5	28.2	245	39.3	99.52	26.7	232	34.4	86.7	19.6	216	26.8	84.74	25.9	222	32.6	87.13	25.4	228	33.5	10.1	24.2	230	36.2	88.68
1705	22.3	247	30.4	83.26	12.5	31.2	227	44.6	95.16	0	0	0	0	18	224	26.4	84.65	25.1	232	36.2	88.03	24.2	235	31.3	10.1	22.5	235	31.3	88
1710	20.7	229	28.2	83.68	12.5	33.4	226	43.8	93.74	29.2	238	36.6	85.62	17.3	221	28.2	84.76	25.1	220	36.6	88.03	21.8	220	30.4	10.2	23	229	30	87.76
1715	19.8	228	33.5	83.97	12.5	30.2	236	42	91.65	27.7	239	37.5	86	20.9	218	34.9	84.61	26.7	221	38.9	88.56	25.7	230	34.9	10.2	25.8	228	34.9	87.78
1720	21.5	234	32.2	83.91	12.5	31.9	236	50	94.48	26.7	240	33.5	85.64	16.6	218	23.7	84.81	26.8	224	37.5	87.49	25.3	234	37.1	10.2	25.3	224	36.2	87.3
1725	18.3	225	29.5	83.71	12.4	27.3	230	39.3	90.09	26.6	243	31.7	85.73	17.5	218	23.7	84.27	28.9	217	39.3	87.33	21.3	227	31.7	10.3	23.1	228	35.7	87.55
1730	18.3	261	27.3	83.53	12.4	31.4	225	40.6	88.9	25	225	38	85.32	18.5	228	27.3	84.69	25.4	221	35.7	87.58	26.4	245	32.6	10.3	24.6	229	35.3	86.99
1735	21.4	240	29.5	83.14	12.6	26.2	215	35.3	88.79	27.8	235	36.2	85.96	12.6	240	20.6	84.9	25.4	220	32.2	87.82	22.1	230	31.7	10.3	26.5	225	35.7	87.06
1740	17.6	248	28.6	82.96	12.6	30.4	219	41.1	89.91	27.7	236	36.6	85.53	15.8	240	22.4	85.03	25	224	35.7	87.67	22.5	231	31.7	10.3	22.7	222	32.6	87.17
1745	18.1	235	24.2	82.81	12.7	30.4	244	37.5	89.01	25.8	233	35.7	85.41	17.3	240	28.2	84.92	22.2	234	29.1	87.12	20.6	228	26.8	10.4	24.2	226	30.8	87.1

(con.)

Appendix B: (Con.)

Time (hhmm)	ARC 15S (mi/hr)	ARC 15D (Deg)	ARC 15G (mi/hr)	ARC 2MaxT (Deg F)	ARC 2RH (%)	BAS 15S (mi/hr)	BAS 15D (Deg)	BAS 15G (mi/hr)	BAS 2MaxT (Deg F)	DEA 15S (mi/hr)	DEA 15D (Deg)	DEA 15G (mi/hr)	DEA 2MaxT (Deg F)	HOW 15S (mi/hr)	HOW 15D (Deg)	HOW 15G (mi/hr)	HOW 2MaxT (Deg F)	NRF 15S (mi/hr)	NRF 15D (Deg)	NRF 15G (mi/hr)	NRF 2MaxT (Deg F)	RWM 15S (mi/hr)	RWM 15D (Deg)	RWM 15G (mi/hr)	RWM 2RH (%)	TRA 15S (mi/hr)	TRA 15D (Deg)	TRA 15G (mi/hr)	TRA 2MaxT (Deg F)
1750	20.4	229	29.5	82.92	12.6	28.4	234	36.2	88.5	29.1	241	38	85.12	15.9	238	25.5	85.01	25.5	220	33.5	87.24	23.5	226	31.3	10.4	23.3	226	31.3	86.79
1755	20.8	229	28.6	83.01	12.6	28.3	233	35.7	89.56	26.6	229	37.5	84.9	13.4	229	17.9	85.06	26.7	234	33.1	86.58	22.3	237	30	10.4	26.1	227	35.3	86.54
1800	18.8	248	26.4	82.74	12.6	26.4	234	33.5	88.59	24	214	32.2	84.88	18.3	228	27.3	85.48	20.9	234	29.1	85.95	20.4	229	27.3	10.4	25.6	235	34.9	86.72
1805	21.6	251	29.5	82.35	12.5	26.9	220	35.7	88.83	25.5	231	34	85.24	15.5	222	23.7	85.51	25.3	222	33.1	86.2	22.9	232	32.2	10.4	23.9	232	33.1	86.31
1810	23	246	30	81.95	12.6	28.9	220	34.9	88.3	23.6	233	31.7	84.61	17	212	25.5	85.44	24.6	227	36.2	86.85	19.9	242	30	10.4	24.1	219	34.9	86.41
1815	22.7	240	30	81.64	12.5	27.5	234	33.5	89.04	25.9	251	38	85.93	14.9	222	22.4	85.05	24.1	234	32.2	85.64	23	223	34	10.5	24.4	220	35.3	86.29
1820	24.1	234	29.5	81.45	12.6	25.4	245	31.7	89.1	25.4	237	36.6	85.77	16.5	231	24.6	84.7	22.5	220	29.5	85.3	23.6	244	31.7	10.5	24.2	234	31.7	85.8
1825	19.1	230	29.1	81.19	12.6	27.5	252	32.2	89.15	29.3	228	39.3	83.98	15.5	218	21.9	84.51	21.3	221	26.8	84.99	19.9	245	29.1	10.6	20	228	29.5	85.78
1830	19	234	25.9	81.1	12.8	27.8	245	33.5	88.75	28	230	38	83.77	13.8	220	18.4	84.04	18.2	228	25.5	84.6	17.2	249	23.7	10.6	22.4	229	30.8	86.04
1835	21.6	242	27.3	80.83	12.7	25.7	246	30.4	87.21	30.4	229	38.4	83.01	17.1	221	26.8	83.73	22.2	224	31.7	84.69	21.4	255	28.6	10.6	24	237	31.7	86.04
1840	18.4	243	25.1	80.51	12.9	30	252	37.1	87.58	27.8	236	36.6	82.83	15.8	236	22.4	83.26	16.6	239	25.9	84.63	23.2	260	33.1	10.7	20	247	29.1	85.77
1845	21.1	240	28.2	80.26	13	29.2	250	34.9	88.18	29.3	243	38	84.61	15	244	20.2	82.81	21.7	241	29.1	84.02	25.2	257	34.4	10.8	21.9	244	28.6	85.32
1850	18.9	235	28.6	79.77	13	31.5	250	36.2	87.35	34.2	254	43.8	152.3	14.4	220	24.6	82.58	24.4	242	33.5	83.55	23.6	257	30.4	10.8	25.1	246	33.1	84.83
1855	22.8	246	29.5	79.56	13	30.2	248	36.6	88.09	33.8	244	44.6	153.9	14.3	213	21.5	82.11	20.7	234	29.5	83.35	21	256	27.3	10.8	25.1	248	32.6	84.25
1900	21.6	245	28.2	79.12	13.1	30	252	37.5	86.2	29.5	239	36.6	113	13.9	232	18.8	81.59	22.3	240	29.5	83.32	23.8	261	30.4	10.9	24.4	246	31.7	84.09
1905	21.8	246	28.6	78.84	13.1	27.2	240	33.1	85.91	28.3	239	38	95.85	12.6	236	20.2	80.83	18.7	224	24.6	83.28	23.1	261	28.6	11	21.4	246	29.5	83.64
1910	20.2	246	25.9	78.67	13.2	27.6	243	36.6	87.24	30.8	240	37.1	91.18	13.2	236	19.3	79.97	22.3	224	30.8	83.16	19.9	245	26.4	11	22.6	244	28.6	83.55
1915	16	253	21.9	78.39	13.2	27.5	249	34.4	85.64	28.1	241	34.9	87.66	11.5	227	17.1	79.34	18.8	233	26.8	82.72	19.3	247	25.1	11	22	255	27.7	83.25
1920	17.7	256	24.6	78.12	13.1	25.5	248	32.6	84.79	26.5	240	33.5	86	14	218	20.2	78.6	16.6	233	28.2	82.4	17.8	256	23.3	11.1	19.1	257	28.2	82.87
1925	16.6	252	21.1	77.97	13.2	26.7	249	34.9	84.38	24.1	238	32.2	84.78	12	230	16.2	77.67	21.8	239	32.2	82.04	17.1	253	24.6	11.1	23.5	254	32.2	82.51
1930	16.1	257	21.9	77.7	13.1	25.5	248	30	83.8	26.9	241	35.7	83.77	13.6	227	21.1	76.71	19.9	240	31.3	81.91	15.6	257	22.4	11.2	21.7	255	28.2	82.22
1935	16.3	259	23.3	77.43	13.2	22.1	246	28.6	83.19	27.8	246	33.5	83.89	15.1	228	27.3	75.99	17.7	239	25.5	81.45	16.3	255	21.1	11.2	19.9	244	27.3	81.86
1940	16.6	261	22.8	77.07	13.2	23.4	241	26.8	81.72	26.4	243	32.2	82.81	14.9	226	21.1	75.69	16.2	238	20.2	81.05	16.1	252	20.2	11.3	18.6	243	25.5	81.14
1945	13.7	263	16.6	76.93	13.4	23.8	243	30	82.62	24.2	241	30.4	82.09	22.8	236	30.4	76.12	14.2	237	20.2	80.92	14.2	252	19.7	11.3	19	241	25.9	81.21
1950	13.3	267	18.8	76.44	13.5	24.2	242	29.5	81.14	23.6	239	29.5	81.45	20.8	239	27.7	77.05	14.7	239	20.2	80.44	13.6	253	18.4	11.5	18.6	244	23.7	80.87
1955	14.1	274	21.1	75.76	13.7	23.4	238	32.2	81.05	25.1	240	30.8	81.12	22.1	244	29.1	77.76	15	241	23.3	80.2	14.1	250	18.8	11.6	16.9	248	22.4	80.29
2000	14.5	271	17.9	75.4	13.7	24.2	241	31.3	80.64	24.2	242	29.1	80.44	22.3	240	31.3	77.99	16.6	240	23.3	80.08	14.5	255	17.9	11.6	15.8	247	21.1	79.7
2005	12.1	266	15.3	75.13	13.9	22.6	241	28.6	80.1	24.1	240	29.5	80.31	22.8	242	29.1	78.1	16.2	238	23.3	79.92	13.6	255	16.6	11.8	16.2	246	22.4	79.3
2010	11.3	265	15.3	74.53	14	23.9	240	31.3	80.02	23.1	241	29.1	79.56	18.4	242	30	78.15	15	237	20.2	79.86	12.9	252	16.2	12	15.7	245	20.6	78.96
2015	9.1	260	11.3	73.51	14.5	23.4	243	31.3	79.97	21.8	243	28.6	79.45	22.1	250	30.4	77.95	13.3	236	17.9	79.02	13.6	252	16.6	12.1	14.4	246	17.5	78.37
2020	9.5	258	12.2	71.92	15	21.2	243	27.3	80.08	19	243	23.3	78.78	22.4	252	31.7	77.68	15.8	238	20.6	79.16	13.9	251	16.2	12.3	14.5	245	17.5	77.95
2025	9.3	256	10.8	70.47	15.6	22.3	238	27.3	80.19	17.1	245	20.2	78.08	24	251	31.3	78.15	15.4	238	20.6	78.85	13.5	252	16.6	12.3	12.1	242	15.3	77.27
2030	6.7	265	9.5	69.55	16.1	21.2	238	29.1	79.38	17.3	244	20.2	77.5	19.4	254	23.7	78.13	11.3	234	17.1	78.66	13	252	14.4	12.5	11.7	242	15.3	76.5

15S is average windspeed (mi/hr) measured 50 ft aboveground level averaged over the last 5 minutes, 15D is wind direction (degree from north) measured 50 ft aboveground level averaged over the last 5 minutes, 15G is maximum gust speed over the last 5 minutes (mi/hr) measured 50 ft aboveground level, 2MaxT is maximum air temperature measured 6.5 ft aboveground over the last 5 minutes (°F), 2RH is average relative humidity measured 6.5 ft aboveground (%) during the last 5 minutes.

Butler, Bret W.; Reynolds, Timothy D. 1997. Wildfire case study: Butte City Fire, southeastern Idaho, July 1, 1994. Gen. Tech. Rep. INT-GTR-351. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 15 p.

The Butte City Fire occurred on July 1, 1994, west of Idaho Falls, ID. Ignited from a burning flat tire, the blaze was driven by high winds that caused it to cover over 20,500 acres in just over 6.5 hours. Sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) is the principal shrub species of this high desert rangeland. With the absence of vegetation after the fire, erosion increased tremendously. Because the fire occurred on the Idaho National Engineering Laboratory, researchers were able to gather weather information from remote meteorological stations positioned on and around the site.

Keywords: wildland fires, rangeland fires, fire behavior, fire growth, fire effects

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