Changes in Fire Hazard as a Result of the Cerro Grande Fire*

Dawn Greenlee and Jason Greenlee

On May 4, 2000, a prescribed burn was ignited on the Upper Frijoles Burn Units 1 and 5 on New Mexico's Bandelier National Monument. The units were located at between 9,000 and 10,000 feet (2,700–3,000 m) elevation in the Jemez Mountains, 6 miles (10 km) west of Los Alamos, NM. The burn was part of the Valle Project, an interagency fuel reduction program designed to reduce the risk of catastrophic fire in the Los Alamos region. The burn's objectives were to reduce tree densities and fuel loads in overgrown meadows and stands of aspen, ponderosa pine, and mixed conifer (NPS 2000). Two large wildfires had threatened Los Alamos in preceding years (the 1977 La Mesa Fire and the 1996 Dome Fire), causing researchers at the Los Alamos National Laboratory to publish a prediction that proved to be an uncanny harbinger of the events that followed (LANL 2000).

On May 5 and 6, the burn escaped and suppression actions failed.**

Like similar fires elsewhere, the Cerro Grande Fire burned hotter than historical fires because of fuel buildups from years of fire suppression.

The fire moved eastward through mixed-conifer vegetation into the lower elevation ponderosa pine vegetation on the Pajarito Plateau, where Los Alamos is located. It then skirted the northern and southern edges of town (fig. 1), burning about half of the town's perimeter. Before the fire was suppressed, it burned 42,858 acres (17,344 ha) and 235 residences. Like other recent wildland fires in the United States, this fire burned hotter than historical fires because of the buildup of fuels that had resulted from years of fire suppression.

Fire Hazard Study

Following the fire, the Federal Emergency Management Agency (FEMA) was asked to facilitate a management program that would ensure that the fire hazard did not become greater than it had been prior to the fire. FEMA commissioned a study by the authors to

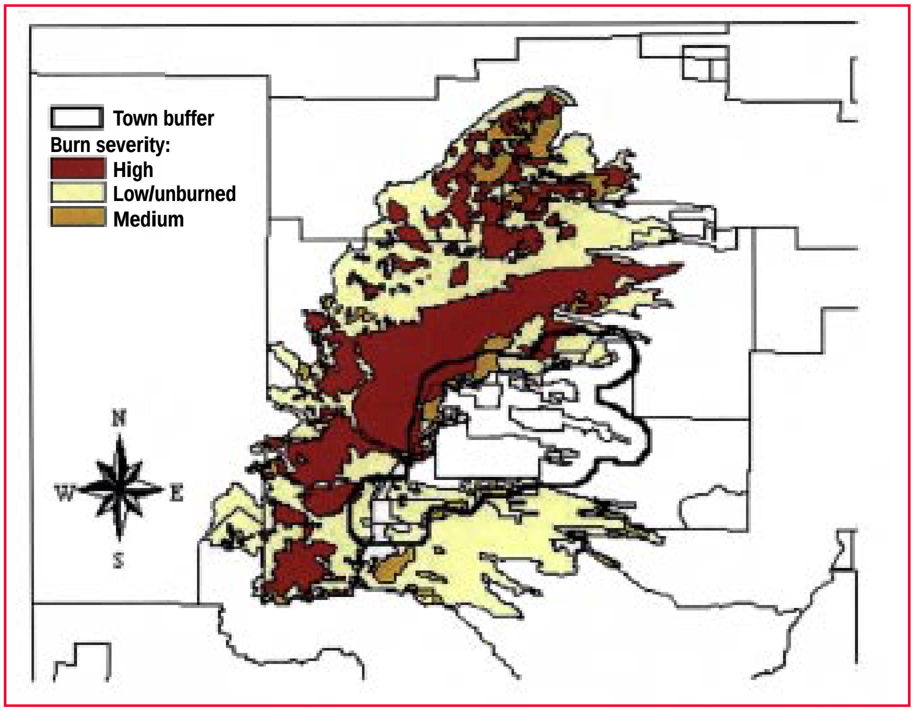

Figure 1 – *Area burned by the 2000 Cerro Grande Fire in relation to a half-mile (0.8-km) buffer zone around developed private property in the town of Los Alamos, NM. If fuels within the buffer zone resist burning, the town will be exposed at most to long-range spotting from a future wildland fire. Illustration: Based on data from the Interagency Burned Area Emergency Rehabilitation Team (2000).*

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* This article is an abbreviated version of a detailed technical report, "Predicted Changes in Fire Danger in the Los Alamos Wildland–Urban Interface as a Result of the Cerro Grande Wildfire," prepared for the Federal Emergency Management Agency. For the full report, including many tables and figures, contact Dawn Greenlee by e-mail at dawn_greenlee@fws.gov.

** See Jim Paxon, "'Remember Los Alamos': The Cerro Grande Fire," *Fire Management Today* 60(4)[2000]: 9–14.

predict changes in fire hazard in the Cerro Grande Fire area by modeling fire behavior in postfire fuels over the next 23 years. The model could serve as a tool for fire managers elsewhere in determining the importance of timber salvage and other fuel reduction treatments following high-severity wildland fires.

Whereas low- and moderate-severity prescribed burns are conducted to reduce understory ladder fuels, high-severity wildland fires can have the opposite effect. Postfire fuel conditions can become more hazardous than before the fire, because fire-killed snags fall to create thick slash fuels. Trees are often removed after high-severity fires to prevent slash fuels from developing. In about 20 percent of the area of the 1994 Tyee Fire in Washington, fire-killed timber was salvage-logged or fuels were piled and burned, particularly in wildland–urban interface (W–UI) areas, both to recover timber value and to reduce future slash accumulation (Ellis 2000; Forest Service 1994). Following the 1998 Florida fires, trees in the community of Palm Coast were salvaged both for the safety of local residents and to reduce fire hazard and facilitate suppression efforts (Kuypers 2000). Similar treatments have been applied to high-severity fires elsewhere (Keeves and Douglas 1983). The authors examined changes in fire hazard resulting from the Cerro Grande Fire and addressed the need for salvage treatments or other fuel treatments, both in the areas burned and in unburned areas near the Los Alamos townsite.

Vegetation Types

The area of the Cerro Grande Fire is characterized by three primary vegetation types: ponderosa pine, mixed conifer, and pinyon/juniper.

Fuel conditions following a high-severity fire can become more dangerous than before the fire, because fire-killed snags fall to create thick slash fuels.

Ponderosa Pine. Ponderosa pine (*Pinus ponderosa*) forests are the dominant vegetation in and around Los Alamos. This forest type extends from 6,500 feet to 8,800 feet (2,000–2,700 m) elevation and dominates south-facing aspects in the Jemez Mountains below 8,000 feet (2,400 m) (Balice and others 1997). Prior to 1900, open stands with grassy understories and only 50 to 100 trees per acre (125–250 trees/ha) were maintained by frequent low-intensity surface fires, which thinned stands and limited the buildup of dead fuels on the ground. Historical mean fire return intervals were between 5 and 15 years (Allen 1989), but most of the area burned by the Cerro Grande Fire had not burned since 1883 (Allen 1989; Foxx and Potter 1981).

Exclusion of fire produced tree densities of between 286 (Balice and others 1997) and 1,300 (Forest Service 2000) trees per acre (706–3,200 trees/ha) and an accumulation of between 8 and 40 tons of fuel per acre (18–89 t/ha) on the forest floor (Balice and others 1997; Miller 1999). Stand basal areas were 60 to 80 square feet per acre (14–18 m^2/ha) (Forest Service 2000). Crown bulk densities were estimated at between 0.02 to 0.03 pounds per cubic foot (0.3–0.5 kg/m^3) (Armstrong 2000), much more dense than the 0.006 pounds per cubic foot (0.1 kg/m^3) needed to sustain crown fire activity (Agee 1996). Armstrong (1998) calculated that these pine stands would not, on any day in the fire season, develop 4-foot (1.2-m) flame lengths, even on the steepest (40-percent) slopes.

Mixed Conifer. Mixed-conifer stands are dominated by ponderosa pine and Douglas-fir (*Pseudotsuga menziesii*). This vegetation type is found on north aspects at 7,000 feet (2,100 m) and on all aspects up to 10,000 feet elevation (3,000 m) (Balice and others 1997). Prior to the Cerro Grande Fire, stands held an estimated 686 (Balice and others 1997) to 1,000 (Forest Service 2000) trees per acre (1,694–2,500 trees/ha), with basal areas of 160 square feet per acre (37 m^2/ha) (Forest Service 2000). Prior to the Cerro Grande Fire, stands in the fire area had crown bulk densities greater than 0.006 pounds per cubic foot (0.1 kg/m^3) and continuous ladder fuels (Armstrong 1998), which would enable the initiation of a crown fire when exposed to a surface fire with flame lengths greater than 4 feet (1.2 m). Utilizing weather data from 1977–96, Armstrong (1998) predicted that, on slopes greater than 40 percent, crown fire initiation would occur on mixed-conifer sites on approximately 60 percent of the days during the fire season.

On the Cerro Grande Fire, a crown fire did start in mixed-conifer stands, as Armstrong predicted; and, due to high crown bulk densities in neighboring ponderosa pine stands, crown fires spread through the pine zone (BAER Team 2000). These crown fires burned with flame lengths greater than 100 feet

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(30 m) and moved at rates of spread greater than 1 mile per hour (0.4 m/s), with spot fires igniting more than half a mile (0.8 km) from the fire front.

Pinyon/Juniper. The dominant vegetation to the east of Los Alamos is pinyon/juniper. This vegetation type extends from 5,800 feet to 7,100 feet (1,800–2,200 m) elevation and is dominated by juniper (*Juniperus* spp.) and pinyon (*Pinus edulis*), with bunchgrass and shrub understories (Balice and others 1997).

Bark Beetles

Bark beetle outbreaks frequently follow the weakening of host trees by drought, overcrowding, and damage from windstorms, fires, and heavy snows (Amman and others 1989; Cates and Alexander 1982; Christiansen and others 1987; Furniss 1965; Hadley and Veblen 1993). Bark beetles have been reported to infest up to 87 percent of moderately to heavily fire-damaged trees (Amman 1991; Furniss 1936; Furniss 1965; Geiszler and others 1984; Hanula and others 2000; Pasek 1996; Ross 1997; Rust 1933; Safay 1981; Schultz and Kliejunas 1981; Stevens and Hall 1960). In New Mexico, stands with basal areas of 100 to 120 square feet per acre (23–27 m^2/ha) are considered to be at high risk for bark beetle infestation; when the stand's basal area is reduced below 80 square feet per acre (18 m^2/ha), the stand is safe from an outbreak (Allen-Reid 2000; Conklin 2000).

Bark beetle populations building up in fire-damaged trees can move into adjacent unburned stands (Celaya and Cain 2000). However, insect outbreaks were not seen following the Dome and La Mesa Fires (Allen-Reid 2000; Conklin 2000; Rogers 2000). USDA Forest Service entomologists tracked beetles in the Cerro Grande Fire area. On June 22, 2000, the Forest Service found that 5 to 10 percent of the trees in the burn with crown damage from 60 to 100 percent were infected with bark beetles (Conklin 2000; Rogers 2000). A high concentration of beetles was also found in the Santa Clara area within the burn (Armstrong 2000).

Calculating Fire Hazard

Our study determined changes in fire hazard and the threat of property damage by fire in the Los Alamos region by predicting changes in fire behavior that would result from fire-triggered changes in fuel. We used three fire hazard parameters to judge fire hazard in the Los Alamos area: susceptibility to crown fire, susceptibility to a fire with flame lengths greater than 4 feet (1.2 m), and susceptibility to a fire with rates of spread greater than 1 mile per hour (0.4 m/s). Flame lengths greater than 4 feet (1.2 m) are too intense to be attacked directly by firefighters, and rates of spread greater than 1 mile per hour (0.4 m/s) are difficult to suppress (NWCG 1998). Containing such fires would require bulldozers or indirect suppression tactics, such as burnout operations (which would be very difficult in W–UI areas without firebreaks between homes and the fire) or retardant drops (which are not always readily available).

We determined vegetation types, land ownership, and fire severity from maps provided by the Interagency Burned Area Emergency Rehabilitation Team (2000) and Koch and others (1997). Prefire and predicted postfire vegetation types in the Cerro Grande burn area were broken into fire behavior fuel models and National Fire Danger Rating System (NFDRS) fuel models. Fuel model assignments were based on interpretation of information from many sources (Armstrong 1998; Balice 2000; Balice and others 1997; Foxx 1996, 2000; LANL 2000; Miller 1999; Moeur and Guthrie 1981; Potter and Foxx 1981; Trader 2000; Tucker 2000), including prescribed fire prescriptions (Forest Service undated; NPS 2000) and onsite field comparisons of fuels to photo series (Anderson 1982; NWCG 1997).

We delineated a buffer area around the town of Los Alamos to focus particular attention on the fuels most critical for the safety of the town. If these fuels are resistant to fire spread, the town will be exposed at most to long-range spotting from a future wildland fire. The buffer was defined as the area within one-half mile (0.8 km) of sites classified as both developed (Koch and others 1997) and privately owned (BAER Team 2000).

We determined the average number of days when fuels would support 4-foot (1.2-m) flame lengths and/or rates of spread greater than 1 mile per hour (0.4 m/s) for each vegetation type by considering the percentage of area covered by each of

> Both the increase in fire hazard in the high-severity areas of the fire and the potential increase in bark beetles can be mitigated through fuel reduction treatments.

the various NFDRS fuel models with their predicted fire behavior characteristics. For each vegetation type, we calculated the probability of high-, moderate-, and low-severity burns for years 1 through 5, 6 through 12, and 13 through 23.

We used FireFamily Plus 2.0 (2000) with inputs of local weather conditions to determine the number of days when the fuel models within each vegetation type would exhibit extreme fire behavior. We took weather data for the years 1993–2000 from the Jemez Remote Automated Weather Station (station 290702), located near the burn at 8,500 feet (2,500 m) elevation. The number of days when flame lengths are projected to be greater than 4 feet (1.2 m) and rates of spread greater than 1 mile per hour (0.4 m/s) was calculated for the fire season (March 15 to July 15). Calculations were made based on a 26- to 40-percent slope, the average slope for the area.

We calculated the number of days during the fire season when each vegetation type would exhibit intense fire behavior by summing the number of intense-fire-behavior days for each of the NFDRS fuel models, weighted by the percentage of area within the vegetation type occupied by that fuel model. The weighted average number of days during the fire season for the buffer area within one-half mile (0.8 km) of Los Alamos residences was calculated by summing the number of high-fire-danger days for each vegetation type, weighted by the percentage of area within the buffer occupied by that vegetation type. We used the same method to determine fire hazard changes for the entire burned area. Postfire averages were compared to prefire averages to determine whether each fire parameter showed an increase or decrease from prefire levels. Results were mapped in ArcView.

Changes in Fire Hazard

In the first 5 years following the fire, our model predicts that fire hazard near Los Alamos will, on average, be lower than it was prior to the fire (fig. 2, top left). Although flashy grass vegetation regenerating on parts of the burned area will support more rapid rates of spread and/or greater susceptibility to flame lengths over 4 feet (1.2 m) in some areas near Los Alamos, the risk of crown fire will be significantly lower, so overall average fire hazard will be lower.

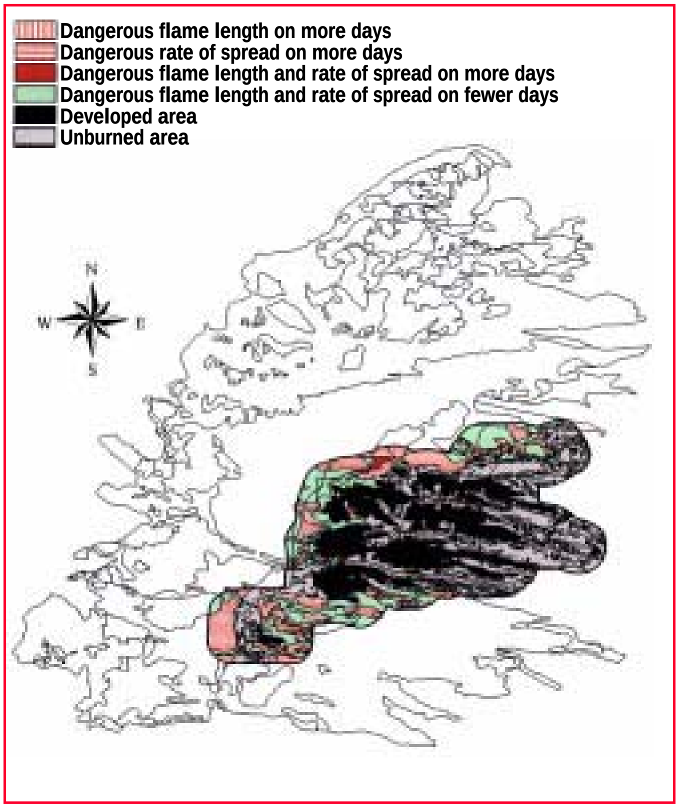
From year 6 to year 12, fire hazard will increase over much of the burned area as slash develops, particularly in high-burn-severity areas (fig. 2, top right). Because of its proximity to such areas, the northwest edge of Los Alamos will be especially subject to more days with the potential for extreme rates of spread and high flame lengths; therefore, it will be at greater risk of both dangerously intense and very fast-moving fires. Although the risk of crown fire will be significantly lower than before the fire, fuels near town could still, on average, support a fire with a 4-foot (1.2-m) flame length on the same number of days as could prefire fuels.

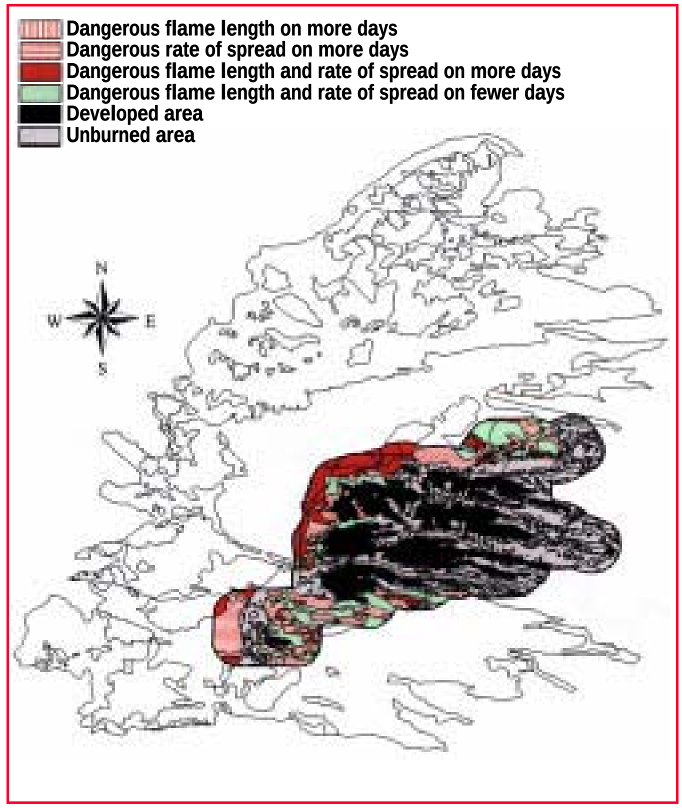
In the 13th through the 23rd postfire years, fire hazard in the Los Alamos area will subside on average to levels lower than before the Cerro Grande Fire as slash fuels compact and decay and as flashy grass fuels are shaded out by regenerating trees (fig. 2, bottom). In this period, the fuels will not support crown fires, fires with flame lengths greater than 4 feet (1.2 m), or fires with rates of spread greater than 1 mile per hour (0.4 m/s) on as many days as before the Cerro Grande Fire. Although there are areas within half a mile (0.8 km) of Los Alamos that could sustain dangerous fires, there will be enough declines in fire hazard in the area to result in a net average reduction in fire hazard from prefire levels.

Overall, our models predict that much of the Los Alamos area will be at a lower risk of fire as a result of the Cerro Grande Fire, but that some areas will be exposed to higher fire hazard. Most of the increases in susceptibility to high flame lengths and rates of spread are on the northwest corner of town, in the high-severity areas of the Cerro Grande Fire.

Implications

Whereas low- to moderate-severity wildland fires and prescribed burns generally diminish fire hazard by reducing understory and ladder fuels, a high-severity wildland fire can increase fire hazard. Where the Cerro Grande Fire burned intensely, there will be a greater threat to the W–UI than there was before the fire. Although many residences in Los





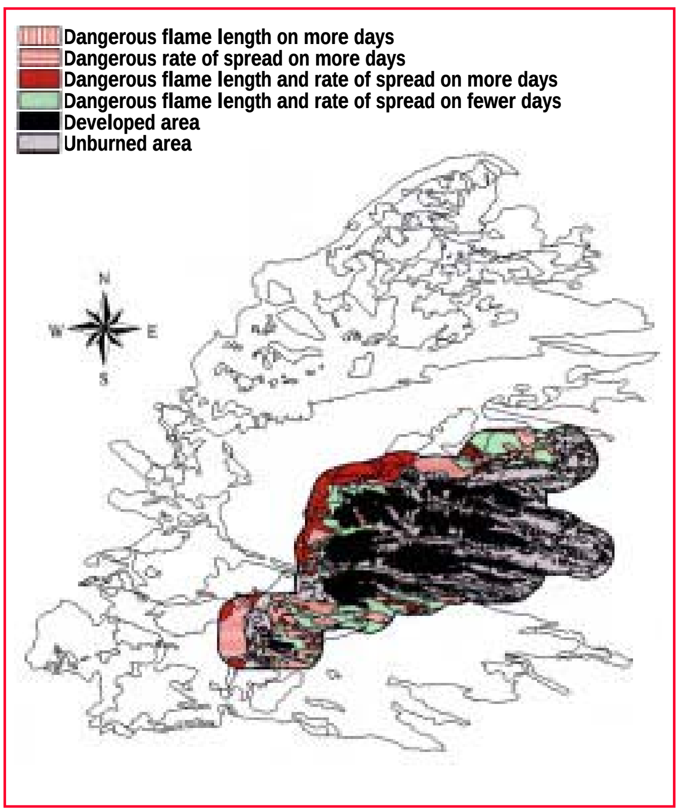


Figure 2 – *Relative fire hazard 1 to 5 years (top left), 6 to 12 years (top right), and 13 to 23 years (bottom) after the Cerro Grande Fire within one-half mile (0.8 km) of private, developed land in Los Alamos, NM. Lines outside the buffer zone delineate areas burned by the fire. Relative fire hazard is calculated in terms of the number of days when postfire fuels would support a 4-foot (1.2-m) flame length and/or rates of spread greater than 1 mile per hour (0.4 m/s) as compared to prefire fuels. Illustrations: Dawn Greenlee and Jason Greenlee, Missoula, MT, 2000.*

Alamos will be less threatened by high-intensity wildland fire because of their proximity to low-severity areas of the Cerro Grande Fire, other areas, particularly the northwestern edge of town, will be at greater risk because the fire was high severity there. If a severe bark beetle infestation occurs in the unburned areas near town as a result of the wildfire, fire hazard would increase in those areas as well. Both the increase in fire hazard in the high-severity areas of the fire and the potential increase in bark beetles can be mitigated through fuel reduction treatments.

Predicted increases in fire hazard in the high-severity areas of the fire could be mitigated by salvage logging or by otherwise removing fire-killed trees or slash. Because the primary cause of high fire hazard in these areas is the slash fuel developing as fire-killed trees fall, removal of this heavy fuel load would prevent the predicted increase in fire hazard in these areas.

If bark beetle numbers increase as a result of the fire and enable the insect's spread into the unburned vegetation near the burn site, additional tree mortality would result in increased dead fuel loads and local increases in fire hazard. The increase in fire hazard would primarily be a result of additional dead fuel after insect-killed trees fell.

This potential increase in fire hazard could be mitigated in several ways. First, trees in the unburned areas in the vicinity of Los Alamos could be thinned so that the remaining trees would be less susceptible to bark beetle attack. Stands with basal areas below 80 square feet per acre (18 m^2/ha) are considered safe from beetle infestation. Many trees in the Los Alamos area are so dense that they are stressed from competition for limited soil resources.

Second, slash should be treated or thinning conducted at a time of year when the slash produced could dry prior to bark beetle flights, because certain bark beetle species (*Ips* spp.) can be attracted to slash produced during thinning operations. Likewise, when an outbreak develops, any nearby thinning should stop, because it will only contribute to the bark beetle problem. Thinning must be conducted prior to infestation. Alternatively, insect-killed trees could be removed after they are killed in order to prevent accumulations of dead fuel on the ground.

Prediction Tool

Our study shows that postfire fuels can be projected using technologies now available, and management decisions can be made based on these technologies. In this specific case, we suggested that the fire hazard could increase over some or all of the area burned (depending on postfire insect activity), and that fuel modification should be initiated to reduce the hazard, at least in the immediate area of the W–UI.

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Kenai Peninsula Borough: A Spruce Bark Beetle Mitigation Program

Michael Fastabend

Since 1991, spruce bark beetles in Alaska—particularly on the Kenai Peninsula—have spread at an unprecedented level. The infestation, the most intensive outbreak documented in North America, has devastated more than 1.4 million acres (560,000 ha) of the peninsula. The outbreak has created an extreme wildland fire hazard and increased the risk of catastrophic loss of life and property.

Task Force Formed

In 1998, concerns regarding the impact of the spruce beetle infestation on Alaska's forests, public safety, and ecosystems prompted the USDA Forest Service to establish a multiparty task force. As the lead agency for the Spruce Beetle Task Force, the Kenai Peninsula Borough was asked to prepare an action plan to manage beetle infestations in Alaska and to rehabilitate the infested areas.

Meeting in the spring of 1998, the task force considered public safety and fire protection its priorities. Additionally, members developed 50 policy recommendations, including a prioritized action plan for areas experiencing or at potential risk of beetle infestation. In June 1998, the task force presented its recommendations to Congress in the report, "An Action Plan for Rehabilitation in Response to Alaska's Spruce Bark Beetle Infestation."

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> The Kenai Peninsula Borough and cooperating agencies developed and implemented an integrated Spruce Bark Beetle Mitigation Program.

The report provided a broad strategy for addressing the impact of the spruce bark beetle and identified more than $13 million in projects designed to mitigate the safety hazards caused by the infestation and to lower the wildland fire risks. Congressional support helped the Kenai Peninsula Borough obtain a $416,000 grant in April 1999, a $2 million appropriation in February 2000, and a $7.5 million appropriation in February 2001 to implement task force recommendations. Initial priority projects, begun in 1999, included completion of a geographical information system (GIS) wildland fire hazard/risk assessment, identification of fire escape routes, creation of community zones of refuge, and production of a GIS land cover map.

Mitigation Projects

In 2000, the Kenai Peninsula Borough took steps to develop a FireWise Community Mitigation Program, provide community slash disposal, and remove dead trees along utility corridors and hazard trees in high-use public areas. The funds received in 2001 helped to accelerate implementation of all these valuable programs.

Projects for 2001 and 2002 include clearing hazard trees from road right-of-ways, removing fuels from borough parcels, expanding the FireWise Community Mitigation Program, and providing training and technical expertise to local fire suppression agencies and departments. In 2001, the Kenai Peninsula Borough implemented a 6-year reforestation/rehabilitation effort and a 3-year technical assistance program—both designed to transfer the mitigation program to beetle-affected communities statewide.

For more information on Alaska's spruce bark beetle mitigation program, visit <www.borough.kenai.ak.us/sprucebeetle/default.htm> or contact the Spruce Bark Beetle Mitigation Office, 36130 Kenai Spur Hwy., Soldotna, AK 99669, 907-260-6202 ext. 308 (voice) 907-260-6204 (fax). ■