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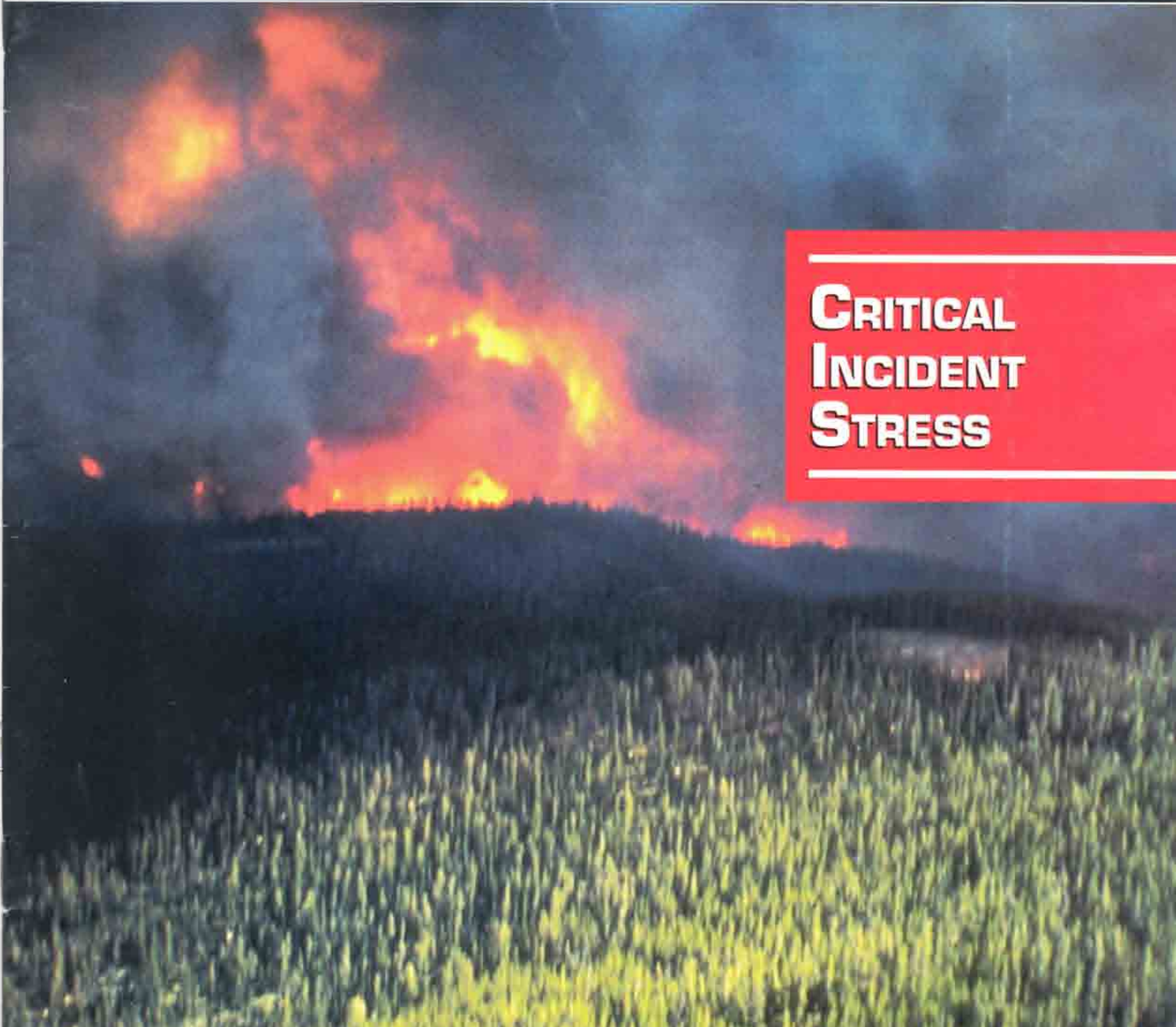

Critical Incident Stress

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On the Cover:

After a severe wildland fire such as the Butte Fire on the Salmon National Forest in 1985, there may be individuals who need critical stress debriefing. While 73 firefighters were in fire shelters from 1 to 2 hours, no significant physical injuries were reported. Emotional "injuries" also need consideration, as James Stone explains in his article beginning on page 4. Photo: Lloyd Duncan, USDA Forest Service, Intermountain Region, Ogden, UT, 1985.

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Short Features

Keetch-Byram Drought Index Revisited: Prescribed Fire Applications

Mike Melton

In volume 50, number 4, of *Fire Management Notes*, I contributed an article about the Keetch-Byram Drought Index (K-BDI), its relationship to fire suppression, and the problems that could be expected with suppression efforts at different levels of drought as measured by the index. Since that time, it has received many inquiries and comments appreciative of the practical information contained in the article. It has also been used as a training tool in a variety of fire management classes. I also learned that some wildland fire managers, especially in the Southeastern United States, have used the information found in the original article and applied it to prescribed burning. While the information contained in the original article is applicable to prescribed fire, there are some differences. With prescribed fire practitioners in mind, in this article I have expanded and addressed the K-BDI specifically from a prescribed fire perspective.

Keetch-Byram Drought Index (K-BDI) levels are calculated as part of the 1988 revisions of the National Fire-Danger Rating System (NFDRS) (Burgan 1988). Since the K-BDI calculations are simple, they are often made and kept by individuals or field offices that do not have access to NFDRS calculations or are not near an office that does.

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> Drought indexes are not designed to measure fuel moistures, rather they indicate environmental conditions that affect fuel profiles.

To calculate the K-BDI values, users need a copy of the directions found in the original documentation (Keetch and Byram 1968) and a rain gauge. Then a simple mathematical process is necessary to determine the K-BDI value on a daily basis.

In the following discussions, I have addressed the index and effects on a drought scale difference of 200, which corresponds to the loss of 2 inches (5 cm) of water from the fuel and soil profile as the drought progresses from one stage to the next.

These following discussions are based on the fact that the seasonal variations in the index generally follow the southern seasonal temperature pattern. The index will be low in the winter and spring, increase during the summer and early fall, and taper off again in winter. In my conclusion, I discuss some of the variations found when the index departs from normal, some things to be expected from rising and falling indexes, and the days-since-rain concept.

K-BDI Levels 0-200

Much of the understory prescribed fire work in the South is done at the 0 to 200 levels, which correspond to the early spring dormant season conditions following winter rains. Soil moisture levels are high, and fuel moistures in the 100- and 1,000-hour fuel classes are sufficiently high, so these larger fuel classes do not significantly contribute to prescribed fire intensity in most cases.

Fuel moistures in the 1- and 10-hour classes will vary daily with environmental conditions. On any particular day, prescribed fires should be planned based on the predicted levels of moisture within these two fuel classes in association with weather conditions. Prescribed fire planners should be aware that areas with heavy loadings of these two smaller fuel classes can exhibit intense behavior resulting from the amount of fuel to be consumed. Also, areas that are influenced by slope and aspect can experience erratic and intense fire behavior from the preheating effects. Southern aspects can produce intense fire behavior while northern aspects of the same unit may have difficulty carrying the fire.

At the 0 to 200 levels, nearly all soil organic matter, duff, and the associated lower litter layers are left intact. These layers, even though they may not be soaking

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wet, will be protected by the insulating properties of the moist layer below, will retain moisture levels close to extinction, and will resist ignition. Patches of unburned fuel can be expected with most fuel types. Burns conducted at this level can be expected to give the "mosaic" pattern of burned and unburned fuels over the burn unit, often a preferred result.

The typical burn patterns implemented at the 0 to 200 levels include a relatively fast head and strip-head fire or a backing fire that consumes the upper litter layers. Once the fire passes, remaining embers extinguish quickly. Within a few minutes, the area is completely extinguished and smoke free. Mopup efforts required on most burns are minimal. Burns that can be successfully implemented at this stage include those for fuel reduction, range improvement, or wildlife habitat, and any burn that does not require a deep burning, organic- and duff-reduction-type fire.

Smoke management concerns are primarily centered around the smoke generated during the burn and not from large smoldering materials following its completion.

Natural features such as creeks and drainages can be used as control lines. Most agencies and companies will use mechanized equipment to construct lines, but adequate lines can be constructed with hand tools. "Wet lines" can also be used in some fuel types.

A word of caution: While this part of the index represents the "wettest" part of the scale, it should not be taken as an indicator of fuel moisture (1-hour and 10-hour) in the upper layers of the fuel complex. These fuel moisture levels are totally dependent on fluctuations in daily weather variables. Dry air masses or frontal passages that pass over an area may have an insignificant effect on the K-BDI but can lower fuel moisture to critically low levels. Prescribed fire planners should ensure that acceptable fuel moisture measurements are accounted for prior to ignition, regardless of the K-BDI.

Management should consider that the mid- to upper-600 range is the limit of acceptability for igniting prescribed fires of any type unless specific locality conditions dictate otherwise.

K-BDI Levels 200-400

In normal years, the 200 to 400 levels would represent conditions found in the late spring and early growing season. Rising temperatures, increased levels of transpiration within the plants, and normal water movement reduce moisture within the soil and fuel profile.

In these index levels, lower litter layers and duff begin to show signs of water loss and will begin to contribute to fire intensity. Humidity recovery at night will have some positive effect on moisture recovery in the fuel profile. Daily temperature and humidity variations under normal burning conditions will quickly reverse this recovery.

Fire practitioners should expect an increase in fuel consumption over the area as the index moves into the upper end of this range. The increase in fuel consumption and resulting intensity can result in heavier fuel classes becoming involved in the burn. Heavier dead fuels such as downed logs and snags will now become a part of the burn process. Fire planners should also expect that some of the live fuels such as low-level brush species and vines such as honeysuckle may now receive sufficient heat to burn actively and contribute to control problems if they are close to fire lines. Patches of unburned vegetation are still common, but these conditions tend to allow for more smoldering and creeping fires that may eventually consume most surface fuels.

Fire planners wanting to initiate a burn over a forested area to "black it out" should consider the 200 to 400 range on the index as conducive for that purpose. Sufficiently intense fires can be generated with most forest fuel types to carry across the area. These conditions also allow for an increased, although not complete, consumption of the lower litter layers and duff, which tend to ensure the fire carries across the unit. Under normal conditions, the majority of the duff and organic layer will still be intact following the burn. Soil exposure will be minimal.

Smoke management can become a real hazard, especially if there are significant larger fuel classes available for ignition. Downed logs, stumps, and similar material should be expected to ignite and smolder for a considerable period of time. Also expect smoldering and the resulting smoke to carry into and possibly through the night. Smoke-sensitive areas should be thoroughly screened, and mitigation measures should be implemented when necessary.

Hand lines constructed to hold the fire should be composed of mineral soil. Managers should thoroughly check natural features used for control lines for drifted debris that could allow fire to creep across. They will need to patrol mechanical lines and clear away any ignitable materials left following construction. Fire planners should seriously reconsider line standards under conditions in the upper levels of this range.

K-BDI Levels 400-600

Levels between 400 and 600 are typical of those encountered during the summer and early fall conditions in the South. They represent the upper range at which most normal understory type burning should be implemented. Very intense fires can be generated with burns ignited in this range of conditions. Under these levels, most of the duff and associated organic layers will be sufficiently dry to ignite and contribute to the fire intensity and will actively burn. The intensity can be expected to increase at an almost exponential rate from the lower to the upper ends of this range.

Fire planners should expect a considerable amount of soil to be left exposed following a burn. Much of the site preparation burning done across the Southern United States occurs under this set of conditions. Intensity of burns under these conditions is such that most fuel classes occurring on a unit will ignite and burn. Complete consumption of all but the largest dead fuels can be expected. Larger fuels not consumed may smolder for several days, creating smoke and potential control problems.

Within the burn, expect weathered stumps, downed logs, and most snags to be completely consumed over a period of time (possibly several days). A significant portion of the duff and organic layer will be consumed, resulting in large areas of exposed mineral soil. These areas may be susceptible to sheet erosion with the next heavy rain. This potential varies with soil types. Smoke management relating to sensitive areas is of critical importance due to the length of time smoke is likely to result from the burn area.

Under normal circumstances, fire planners should have a specific resource management objective that requires an intense fire before igniting understory fires in this range. The intense fire and deep burning that often result from these conditions can do serious damage to timber resources and present an opportunity for insect pests to create additional problems. Control problems resulting from spotting should be expected.

These 400 to 600 levels indicate two things are happening: 1) Deep drying resulting from water loss is occurring in the duff and organic material in the soil, and 2) lower live fuel moistures resulting from continued water loss in the soil and the natural physiological process within the plants make understory vegetation susceptible to ignition with a minimum of preheating. These two situations amount to an increase in the fuel available for consumption and consequently increase the fire's intensity. Fire planners should consider that the outputs from computer programs and nomograms relating to intensities are underpredicted and plan accordingly.

At these levels, fire planners should seriously begin to reevaluate the line construction and location standards necessary to contain the burn. Reduced runoff levels in some drainages can preclude their use as control lines or require that they receive some refurbishment treatments. Failure to pay attention to low water levels and debris that has drifted into creek channels can create potential control problems that will continue to escalate as the index levels increase because fires can creep across such materials. Where practical, use either major natural features or roads that are suitably located. All line construction should be of mineral soil. Since duff and organic material can provide an avenue for fire to burn across the line, it is imperative that it is removed from within constructed lines. Where practical, consider line locations that would otherwise be used for fire suppression; they can give an added "edge" in maintaining the security of the lines under intense conditions.

K-BDI Levels 600-800

The 600 to 800 range of the K-BDI represents the most severe drought conditions identified within the index and results from an extended period of little or no precipitation and high daytime temperatures.

There may be exceptional cases when specific management objectives for a given area justify prescribed fire ignitions within this range. Management should consider that the mid- to upper-600 range is the limit of acceptability for igniting prescribed fires of any type unless specific locality conditions dictate otherwise. These levels of the index are often associated

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with increased wildfire occurrence, and many States and municipalities will issue burning bans when the K-BDI is this high. Burning bans, of course, should preclude any management decision regarding prescribed fire. Such bans are an acknowledgement of the seriousness of the fire situation.

Prescribed fires ignited within this range will be characterized by intense, deep-burning fires. The potential for significant down-wind spotting should be considered the rule in planning. Live understory vegetation 2 to 3 inches (5 to 8 cm) in diameter at ground level should be considered part of the fuel complex because live fuel moistures will be sufficiently low and the vegetation will burn easily with a minimum of preheating. The majority of soil organic material subject to ignition will be consumed; stump roots and other subsurface organic material that ignite will probably be completely consumed. Once ignited, large fuel classes will burn intensely with almost total consumption. In brief, expect these fires to be very difficult to contain and control.

Possibly a year or more will pass before a layer of organic material will be replaced on the area. Resource managers should expect some amount of soil loss from erosion until the area replaces sufficient vegetative cover. The significance of the loss will be determined by the specific soil type and slopes on the area. Line construction standards should follow the previous discussion standards.

Rising and Falling Indexes

This discussion primarily addresses the effects on the larger dead component fuel associated with a given fuel model and has its basis in the timelag concept associated with 100-, 1,000-, and 10,000-hour fuel classes. Indexes that have been low and begin the normal seasonal rise are characterized by the larger fuel classes being damp deep inside. Typically, a large piece of woody material will be saturated in the interior and therefore be difficult to ignite and sustain combustion. As time progresses, the exterior dries, but interior fuel moistures still remain high. For example, smoldering logs are sometimes ignited by fire intensities high enough to overcome the surface moisture levels but later go out due to the high interior moisture levels, precluding further combustion. When this occurs, there may be some concern about smoke from the smoldering debris and mop up. Dealing with this situation is relatively easy because humidity recovery at night can help extinguish this type of ignition. However, a falling index can cause an opposite reaction.

The larger fuel classes have experienced deep drying from a sustained period of little or no precipitation. The exterior surface may have a relatively high fuel moisture level from recent rain while the interior of the fuel will have lower moistures due to the longer equilibrium timelag. Prescribed fire ignited under these conditions may develop sufficient intensities to break through this outer layer of high fuel moisture. Once this happens, the fire encounters a reservoir of material with comparatively low fuel moisture levels and can be expected to burn for an extended period of time. This could go on for several days within the area and result in a large amount of smoldering material and smoke management problems, depending on the type and amount of fuels on the area. Experience has shown that this material will continue to smolder until it is consumed, mopped up, or another precipitation event raises moistures to a level of extinction. The resulting smoke problems can be compounded by fluctuations in wind direction over several days. Mop-up operations can be lengthy and expensive.

Fuels that have high moisture levels on the outside and are dry on the inside should be expected for indexes that have been in the 600+ range and have rapidly fallen into the 200 to 300 range. This could have resulted from one precipitation event, and while the 1- and 10-hour classes of fuel are immediately affected, the other fuel classes are slower to react. This is just one example of the subtleties noted from actual field experience in dealing with the index values.

Days Since Rain

Finer fuel classes are immediately affected by precipitation of any type. Since fires originate and spread within these classes, we can use this characteristic to accomplish prescribed fire objectives during what might normally be unacceptable drought conditions.

During the first few days following precipitation, the surface fuels will have been saturated and begun to dry out. The lower fuel layers and possibly even the organic layer may still have moisture-of-extinction levels. Resource objectives can be accomplished by timing the burn to occur during this period even though the drought index levels may still be high. Timing of the prescribed burn may be critical and fire planners should be fully aware of the conditions they are dealing with. Most burns should be accomplished during the first 2 or 3 days following precipitation. From a prescribed fire standpoint, the effects of precipitation will have disappeared after about 4 days of continuous drying.

Prescribed fire personnel should be especially careful in monitoring the amount of precipitation that has occurred. Once fuels have experienced deep drying, there must be a significant amount of rainfall to dampen conditions to the point where they are reasonably safe for burning. In most cases, precipitation amounts in the 1/2-inch (1.3-cm) range should be considered minimal. The prescribed burning of dry, fine fuels affected by small amounts of precipitation reflect the type of conditions and burning done in the summer growing season throughout much of the Southeast. These burns can be accomplished by careful planning and following these general guidelines.

Index Readings That Depart from Seasonal Norms

Fluctuations in weather patterns, temperatures, and precipitation levels can all coincide to create a departure from the normal yearly index pattern. An abnormally dry fall and winter season could lead into an early spring season with drought index readings in the 500 to 600 range. For example, in 1987, the Southern United States experienced a severe fall fire season and carried K-BDI readings of 600 into January and February 1988, when the normal reading would be expected to be less than 100. Since that time, other localized drought events have occurred, resulting in similar fire seasons.

Prescribed fire planners must recognize departures from normal readings in planning burns for their particular location. A burn conducted under index levels of 100 in the springtime is not the same as a burn conducted under levels of 500. Extreme caution should be used in implementing any burn under this set of conditions; they are primed for a potential escape situation.

> The ideal time for understory prescribed burning in the South is within the first 2 or 3 days after precipitation.

Closing Thoughts

Through the previous discussion, I have attempted to qualify and quantify the effects of the K-BDI as it relates to the application of prescribed fire. The variables within this application are many and their interactions complex.

Prescribed fire personnel should always remember that the K-BDI is a measure of meteorological drought; it reflects water gain or loss within the soil. It does not measure fuel moisture. Prescribed fire application is almost totally dependent on the moisture levels in the 1- and 10-hour classes, which must be measured by other means for an accurate assessment of fuel moisture, regardless of the drought index readings. Prescribed fire managers must also be aware that dry vegetation due to reduced soil moisture will create additional fuels available for fire consumption in the mid and upper ranges of the index. This condition is not accounted for in current computer technology such as BEHAVE (Andrews 1986).

The K-BDI levels discussed here and the resulting effects on prescribed fires should not be considered hard-and-fast rules but rather a reflection of my career experiences in dealing with both wildfires and prescribed fires and the levels of the K-BDI. Readers are invited to develop their own guidelines and apply this information to their particular situations. Variations in fuel types, topography and aspect, geographic location, moisture and temperature regimes, and soil types may dictate a variety of effects within the levels of the K-BDI. After all, that is why we describe the implementation of prescribed fire as an art rather than a process.

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