The Keetch/Byram Drought Index: A Guide to Fire Conditions and Suppression Problems

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The 1988 version of the National Fire Danger Rating System (NFDRS) has been completed and should be operational by the first part of 1991. The NFDRS has an important new addition: The Keetch/Byram (K/B) Drought Index calculations have been added to the system. As a part of the NFDRS, the K/B index will be the most widely used drought index for fire danger rating. Fire personnel will need to know specifically the effect of drought on both wildfire and prescribed fire and the significance of the index and its relationship to the fire environment. This means fire managers must understand the K/B index system, be able to interpret the data from the system, and apply that knowledge to the local fire situation.

The K/B Index

John Keetch and George Byram developed the K/B index at the Southern Forest Fire Laboratory to evaluate the effects of long-term drying on litter and duff and subsequently, on fire activity (1968). The index is based on a measurement of 8 inches (0.2 m), of available moisture in the upper soil layers that can be used by vegetation for evapotranspiration. The index measure is in hundredths (0.01) of an inch of water and has a range of 0 through 800, with 0 being saturated and 800 representing the worst drought condition. The index indicates deficit inches of available water in the soil. A K/B reading of 250 means there is a deficit of 2.5 inches (6.4 cm) of ground water available to the vegetation. As drought progresses, there is more available fuel that can contribute to fire intensity.

Fire Behavior at Selected K/B Levels

The following information is a compilation of data and observations fire managers and I have made from field observations of both wild and prescribed fire at numerous locations. It is an attempt to qualify and quantify in common terms the effect of continued drought on forest fuels and the problems arising from drought conditions during the course of wildfire and prescribed burns. This information should help fire practitioners to more fully understand the relationship between the K/B index readings—which indicate the extent of drought—and the fire environment.

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The effect of drought on fire behavior will vary between fuel types and topographic regions. Mountainous hardwood fuels will react differently than the Southern pine fuels to drought and consequently fire effects will also differ. Rain or relative humidity and wind may also require an adjustment to K/B level interpretation. For instance, even if the K/B level is extremely high, a brief rain will temporarily render fuels incapable of burning. Yet on the other hand, the K/B index can be low (<100) and high wind and low relative humidities can create an extreme situation in some fuel types. The following descriptions of conditions at various K/B levels is primarily related to the Southern Coastal Plain and Piedmont regions, but these can be considered applicable in many areas of the country. Fire personnel should remember that specific situations may be different than those described and should use this information to complement his or her experiences at a particular location.

K/B Levels 0–150. During this stage of drought, the fuels and ground are quite moist. Fine fuels exhibit daily drying, burning readily at times but also recovering to a high moisture content at night. This level is ideal for winter or spring prescribed burns. Most fires are easily suppressed with normal practices and generally are not a problem. The lower litter and humus layers are moist and not affected by fire. Most fires die out at night due to humidity recovery and its dampening effect on the fine fuels. Some fuel types (grasses) burn actively, but seldom create much problem with control efforts. Generally, extensive mop-up is not required, since most heavy fuels (100 and 1000 h) are too wet to ignite. Ignition of snags is not normally a problem on wild or prescribed fires. The spring fire season can still generate some extremes in behavior on wildfires due to the nature of fine fuels, especially in fuel types with a heavy loading of grasses. Drying is generally limited to the fine surface fuels and the organic layers still retain sufficient moisture to resist burning. This could be considered the business-as-usual period.

K/B Levels 150–300. Within this range, scattered patches of surface

litter remain in low-lying or damp areas following a fire, and the organic layer remains basically undisturbed. Both pine and hardwood stumps may ignite but seldom burn below ground. Most will go out. Hardwood snags less than 10 inches or 0.3 meter in diameter at breast height may ignite and burn while larger snags (>14 in or 0.4 m) still resist deep burning due to high interior moisture levels. Generally snags are not a serious threat to control efforts, and most will go out during the night. However, snags within falling distance of the lines should be considered a major threat for potential fire escape. Normally, escaped fires pose little problem to standard suppression tactics. Fire behavior is predictable. Spotting is usually minimal.

When the K/B level exceeds 200 and approaches 300, a more intense and active fire situation develops, requiring closer attention by fire personnel. Usually at this level, minimum mop-up is required. Normal fire personnel and equipment levels are adequate, especially for most forest type fuel models. Wildfires can generally be suppressed with direct attack. Humidity recovery at night will aid in the control of fires during the night hours making suppression simple. Fire personnel should keep in mind that the 300 level represents the upper range that can be considered acceptable for normal winter or spring burning. Large acreages (500 acres or 202.4 ha) ignited at this level can create intense conditions that are difficult to control during the peak burning period and can do unnecessary damage to timber stands (scorch and bole damage).

A backing prescribed fire carried out when K/B index was below 100. Note absence of smoke following the fire. This indicates only fine surface fuels are being consumed and no deep burning of litter or soil organic layer.

Fire personnel should be especially careful with helicopter operations that ignite large areas of fuels simultaneously. Larger downed fuels will ignite, sometimes creating hazardous smoke conditions at night along nearby highways. Topographic features and drainages normally used for control lines can be expected to hold both wild and prescribed fires.

K/B Levels 300–500. At the K/B 300 to 500 level, fire consumes most surface litter along with a significant loss in organic soil material. Site preparation burns expose mineral soil, producing areas causing erosion problems. The heavier fuel complexes (100 and 1000 h) ignite readily, contributing to fire intensity. For instance, stumps are ignited readily and burn underground. Pine "lighter" stumps are totally consumed, but most hardwood stumps still resist deep burning, especially underground. Both pine and hardwood snags ignite at this level, although larger snags (20 in or 0.5 m and over) still resist deep burning. Hardwood snags ignite readily and pose control problems when located near lines.

Fire intensity increases dramatically in this range due to the increased burning of heavier fuel classes. Spotting begins to be a major problem and in some fuel types could be considered the rule. Escaped fire is difficult to control because heavier fuels are contributing to intensity, especially during the peak burning period. Fire behavior is still predictable but situations may require additional personnel and equipment to control a fire. Escaped fire in both prescribed and wildfire situations holds over during the night and burns again the next day. Humidity recovery is generally insufficient to extinguish heavier fuels, resulting in a large number of hold-

over fires. Increased mop-up and patrol activities are required. All normally planned winter or spring understory fire should be canceled when the K/B index exceeds 350. Direct attack on wildfires is difficult due to intensity. Topographic features used for lines in prescribed fire and wildfire suppression will hold, but smaller drains begin to dry up, and drifted debris is dry enough to allow fires to creep across drains. Swamps begin to show reduced water levels.

K/B Levels 500–700. Generally, all surface litter and most of the organic layer is consumed by fire. Site preparation operations consisting of broadcast chemical application followed by fire ("brown and burn") result in almost complete removal of organic material from the site. At this level, 1000 hour fuels contribute readily to fire intensity.

When the K/B index is above 600, expect the following:

- Stumps burn to the end of the roots and all large downed fuels (logs and so on are totally consumed over a period of 48–72 hours. This will result in a massive amount of smoldering fire in the burned area.
- Dead snags ignite. Large dead snags will create a safety hazard due to the potential for falling.
- Dead limbs on trees ignite from sparks, sometimes at considerable height above the ground (50 ft or 15 m and over).
- Spotting is difficult to control.
- Escaped fire continues to burn through the night and into the next day.
- Burns leave excessive site damage.

Above the 600 K/B level, fire suppression is a major problem. Direct attack is generally not effective due to increased intensity and spotting. Extreme intensities add to the control efforts. When winds approach 10 miles per hour (16 km), spotting is the rule. Some nighttime activity can be extreme, dependent on fuels available. Fire personnel should expect and prepare for the previous day's fire to escape the next day during the peak burning period. Summer site preparation burns should be canceled when the K/B index reaches the mid-500's. Fire behavior is still predictable but tends to be underpredicted, since extreme intensity levels caused by the heavier fuel complexes might be overlooked. Extensive mop-up is critical to fire suppression. Increased need for fire suppression personnel and equipment can be expected.

As the K/B level approaches 700, understory vegetation wilts and is consumed by fire. All ephemeral drains and intermittent drains are dry. Only larger river drainages contain enough water to be useful in fire

A summer site preparation burn area, 1 year after an intense fire consumed basically all the organic layer, penetrating the mineral soil. The K/B index was over 600 at the time of the burn. Note almost total exposure of soil with no ground cover remaining and only one sprout showing.

control, and these are easily compromised by spotting. Most larger swamps will show significant water loss and intense fires can be expected if they occur in these areas.

As the K/B index goes into the upper 500 range, fire personnel can expect to encounter more urban interface type fire starts. Experience has shown that the general public is not aware of the volatile situation and more wildfire starts will tend to originate from "normal" burning by the public. At this point, only a major rainfall will reduce the fire hazard.

K/B Level 700 Plus. Expect more of the same, only worse! At the 700-plus level, many understory species with shallow root systems continue to exhibit extensive wilting and contribute to fire activity by acting as ladder fuels and increasing the chance of extreme fire behavior. All burning should be banned until the K/B index falls below 500, the minimum. Only rapid response time to wildfires along with intense suppression efforts will keep a major fire situation from developing. Most fire agencies and State organizations will issue burning bands on all outside burning, especially if wildfires have developed. At this K/B level, urban-interface fires become a major problem. Increasing numbers of wildfires originate from the vicinity of homes and residences since the general public does not adequately understand the care that must be taken in this kind of drought situation.

Additional Observations

There are two other conditions worth mentioning here that may affect the danger level as indicated in the K/B index. These are days-since-rain and humidity recovery. During the normal fire year, there will be a rise and fall of the drought conditions. The index is usually low in the spring and rises as summer progresses on into fall and then begins a slow decline as winter rains return.

Days-Since-Rain. During the early spring when the K/B index would normally show a level below 200, the days-since-rain number represents valuable information to the fire manager. If focusing on the drought index as a chief indicator for danger of wildfire occurrence, it is easy to forget that fine fuels readily burn and can create relatively intense conditions even at low K/B levels. At low K/B levels, days-since-rain is a better indicator of actual burning potential than the drought index. As the index rises into the 300 range and above, days-since-rain is of less importance because of the deep drying occurring in the lower fuel layers and in larger fuels with resulting increase in fire intensity. Very intense fires can occur in only 2 or 3 days following rain, if the drying of fuels is deep and requires significant moisture to saturate to near the moisture of extinction point. Consequently, the more advanced the drought, days-since-rain becomes less important. At this point, more emphasis should be placed on the K/B level.

Humidity Recovery. Humidity recovery normally happens to some extent each night. In the South, normal night humidities can average over 90 percent, while in the West 40 percent might be considered high. Regardless of the location, this increase in humidity has an effect on the availability of fuels to be consumed by fire. During the early stages of drought (below the 300 level), humidity recovery can actually control fires at night by raising the fuel moisture of fine fuels near or above the extinction level. Moisture is transferred from the atmosphere to the fuels and also from the lower fuel layers and soil which are very moist. As the drought increases, there is less moisture available from the lower fuel layers and soil and consequently fires can continue to burn through these deeper fuel layers at night. The resulting increase in fire intensity can effectively counter any increase in night humidity. Generally, as the K/B index approaches and exceeds the 500 level, humidity recovery alone will not stop the combustion process.

Summary

In review, and this is particularly true in the Southern States, normal spring or winter prescribed fires should be curtailed when the K/B index exceeds 350, and summer site preparation fire should be reduced when the K/B index exceeds 500. Wild and prescribed fires that occur when the K/B index approaches and exceeds 300 will cause increasing difficulty of control as the index goes higher. Wildfires that occur below the 300 level in fine fuel types or in steep topography can still be extremely difficult to control even though the soil and lower fuel layers are moist.

Fire personnel need to be especially cautious in using prescribed fire if the K/B index has been high and is falling into the upper 200-to-300 range. The heavier fuel

classes will still be sufficiently dry inside to burn for extended periods and can result in smoldering fuels and subsequent smoke problems if near any smoke sensitive locations. Hazardous nighttime smoke conditions can reoccur for several nights. These heavier fuels will continue to smolder and burn until the next rain or until they are essentially consumed.

Fire personnel should be alert for K/B levels that depart from the normal precipitation yearly patterns, especially during spring or fall fire seasons. Figure 1 illustrates the typical K/B index readings for a year of normal precipitation. Figure 2 shows how the K/B readings in one period of the year can be used to predict fire danger later in the year. Spring fire seasons that coincide with increasing K/B levels of 300 and above can lead to increasingly hazardous fire conditions. Since most of the smaller fuel classes are cured at this time, they readily burn with increasing intensity as deep-drying continues. Likewise, fall fire seasons that coincide with K/B levels of 400 and above through October and November are usually busy seasons for fire personnel. Fall fires that occur during this situation will be extremely difficult to control and require extensive mop-up, since all of the fuel classes and soil were abnormally dry from the summer's heat, and fires will basically consume every class of fuel that can be ignited. For example, the fall fire season of 1987 had K/B level readings in excess of 700 through November, falling into the 600 level in December. Consequently, the spring season of 1988 was basically a carryover from the previous season with K/B readings in the 600 level common until mid-June in many parts of the South. ■

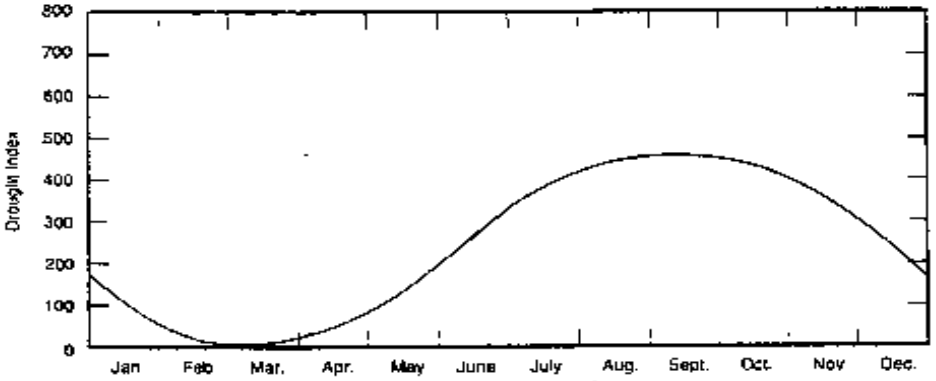

Figure 1—*A typical annual Keetch/Byram curve that can be expected with normal precipitation levels. (Actual levels may be different, depending on the locale, but the curve shape will be similar.)*

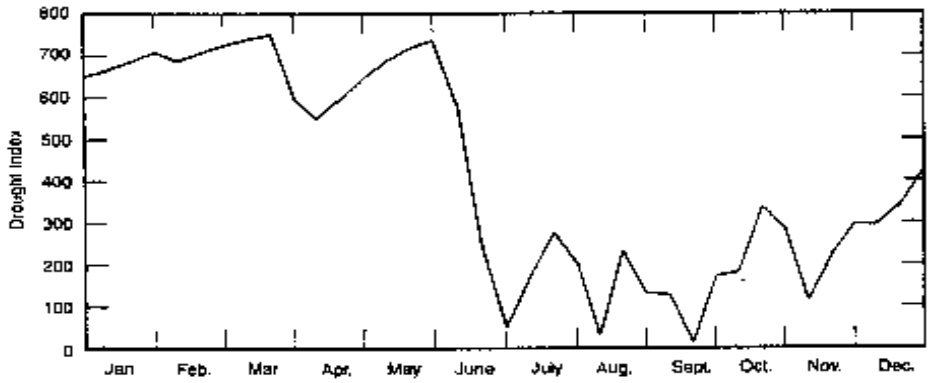

Figure 2—*A Keetch/Byram curve showing abnormally high spring readings. Situations such as this can result in extreme fire seasons in the spring. The reverse of this curve indicates the potential for a heavy fall fire season such as was experienced in 1987.*

Literature Cited

Keetch, J. and Byram, G. 1968. A drought index for forest fire control. Res. Pap. SE–38. Asheville, NC: USDA Forest Service, Southeastern Forest Experiment Station. p. 32.