**Appendix 1.**

## NFDRS Overview

**This Appendix contains portions of the NWCG Publication "Gaining an understanding of the National Fire Danger Rating System" compiled by Paul Schlobohm and Jim Brain, May 2002. It is only intended to provide limited information regarding the National Fire Danger Rating System. For a complete description of the system please see the document referenced above. **

### Defining Fire Danger Rating

Before one can discuss fire danger rating, they must define "fire danger." The most commonly accepted definition of fire danger today is:

> "The resultant descriptor of the combination of both constant and variable factors which affect the initiation, spread and difficulty of control of wildfires on an area" (from Deeming et al. 1972).

The various factors of fuels, weather, topography and risk are combined to assess the daily fire potential on an area. Fire danger is usually expressed in numeric or adjective terms.

Fire danger rating is a system that integrates the effects of existing and expected states of selected fire danger factors into one or more qualitative or numeric indices that reflect an area's protection needs. The fire danger rating of an area gives the manager a tool to assess the day-to-day "fire business" decisions. The emphasis is on tool because fire danger rating information is not the answer by itself; it must be considered along with the manager's local knowledge of the area and consequences of the decision when arriving at the best solution to a fire business decision or problem.

Fire danger ratings are typically reflective of the general conditions over an extended area, often tens of thousands of acres, affecting an initiating fire. Ratings can be developed for either current (observed) or future (predicted) situations. They can be used to guide decisions two or three days in advance (subject to the limits of the forecasting system) as well as to compare the severity of one day or season to another.

Since many of the factors (fuels, weather and topography) and terminology (spread and intensity) that are part of fire danger rating are very similar to those that affect fire behavior predictions, fire danger and fire behavior are often confused and misused. The principle difference is that fire danger is a broad scale assessment while fire behavior is site specific. Fire danger ratings describe conditions that reflect the potential, over a large area, for a fire to ignite, spread and require suppression action. Fire behavior on the other hand deals with an existing fire in a given time and space. Fire behavior describes the movement (rate of area increase), intensity (flame length), and indicators of rapid combustion (spotting, crowning, and fire whirls) of that fire. It is expressed as real time or predicted conditions for ongoing fires. As you learn more about fire danger, the differences will become more obvious.

### Fire Danger Rating Systems

As one might expect, there are many parts to a fire danger rating system. It is a complex mixture of science, technology and local experience. The five key components of a fire danger rating system are:

a. Models representing the relationships between fuels, weather, and topography and their impact on fire business.
b. A system to gather data necessary to produce the rating numbers.
c. A processing system to convert inputs to outputs and perform data analyses.
d. A communication system to share the fire danger rating information between entities.
e. A data storage system to retain data for historic reference.

### Key Assumptions within the National Fire Danger Rating System

There are four fundamental assumptions associated with the National Fire Danger Rating System (NFDRS) that must be understood if the system is to be properly applied and interpreted. They include:

1. NFDRS outputs relate only to the potential of an initiating fire, one that spreads, without crowning or spotting, through continuous fuels on a uniform slope.

2. NFDRS outputs address fire activity from a containment standpoint as opposed to full extinguishment.
3. The ratings are relative, not absolute and they are linearly related. In other words if a component or index doubles the work associated with that element doubles.
4. Ratings represent near worst-case conditions measured at exposed locations at or near the peak of the normal burning period.

In summary, fire danger rating is a numeric scaling of the potential over a large area for fires to ignite, spread, and require fire suppression action. It is derived by applying local observations of current or predicted conditions of fuel, weather, and topographic factors to a set of complex science-based equations. The outputs of a fire danger rating system are numeric measures of fire business that provide a tool to assist the fire manager in making the best fire business decisions.

**Data**

The data used to calculate daily fire danger rating indices and components comes in two forms. The first is the daily weather observations and the second is the parameters that the user sets to control the actual calculations within the NFDRS processor. Each is discussed below.

*Weather Inputs***:** Of the factors that affect the daily changes in fire danger, weather data are the most significant. Data should be reflective of conditions experienced or anticipated to occur within the fire danger rating area. The National Fire Danger Rating System can be operated on either observed data to produce indices and components reflective of today's conditions or on forecasted data to predict tomorrow's conditions. The data needs are the same; where they come from is the only difference. Observed data is obtained from locally operated manual and automatic NFDRS weather stations. Weather forecasters of the National Weather Service develop the predicted data using trends applied to observed conditions within a fire weather forecast zone. (As an example a forecaster might develop a trend forecast for a specific weather zone that tomorrow's temperature will be up 3 degrees, relative humidity will be down 5 percent and there will be no change in wind speed.) Once this information is provided by the forecaster, it is applied automatically within the NFDRS processor to today's observed conditions at all stations within the fire weather forecast zone to calculate the forecasted conditions. NFDRS calculations are usually done on data representative of 1 PM local standard time conditions. Quality control is very important, of both the data and the instruments used to collect them.

Individuals responsible for the daily input of weather data into NFDRS should be familiar with the normal or expected ranges in environmental conditions (such as temperature, relative humidity, and wind speed) for their local area and take appropriate actions to validate observations that are outside the normal range. Similarly, they should be aware of weather data values that change little from day-to-day. This could be a sign that a sensor or instrument is not working properly. Errors in some data elements, such as relative humidity, have cumulative effects on fire danger rating if allowed to continue over extended periods of time.

A continuous stream of data is just as important as the quality of the data itself. If daily observations are missed two things happen. First, you lose the effects of the day on the drying or wetting of the fuels which may be significant in the early and later parts of the fire season. Secondly, there is no data for the National Weather Service forecasters to use in developing their forecasts or to apply their trends or point forecasts to; thus no forecasted fire danger for the next day.

*Other NFDRS Parameters*: The mathematical equations that generate the outputs of the NFDRS are simply models of actual circumstances. There are certain conditions and observations that users of the system must input periodically for the outputs to be truly representative of their local conditions

**NFDRS Outputs**

The NFDRS calculations result in two types of outputs. These are intermediate outputs that serve as the "building blocks" for the next day's calculations and the indexes and components that actually measure the fire danger. An understanding of both is important if the user is to properly manage and utilize the National Fire Danger Rating System.

**Intermediate Outputs**

These are the calculated fuel moisture values for the various classes of live and dead fuels used to produce the final indices and components. An understanding of these values, including their ranges, seasonal patterns, and associated impacts on indices and components is critical in maintaining the quality of the overall outputs of the system. A trained eye can look at the intermediate outputs and tell what the model thinks is happening on the ground. If they are not representative of what the local fire manager sees happening, they can be adjusted to "fine tune" the system outputs to better fit the local conditions.
*Herbaceous Fuel Moisture*: This calculated value represents the approximate moisture content of live herbaceous vegetation expressed as a percentage of the oven dry weight of the sample. Both the herbaceous vegetation type (annual or perennial) and the climate class control the rate of drying in the NFDRS processor. Faster drying occurs in annual plants than in perennials. Also, plants native to moist climates respond differently to a given precipitation event than plants native to arid climates would to an event of the same magnitude. For example, modeled fuel moistures respond more drastically to periods of drought in climate class 4 than in climate class 1. Accurate recording of the herbaceous vegetation type and the climate class is critical if the calculated herbaceous fuel moisture is to be representative of the local area.

Typical herbaceous fuel moisture values start out low (equal to 1- hour fuel moisture), then increase rapidly as the growing season progresses. They may range from a high of 250, typical of the peak of the growing season, to as low as 3 or 4 when the foliage is dead or has reached maximum dormancy and responds as a dead fuel would to changes in external moisture influences. Fire managers should monitor the trend of herbaceous fuel moisture values as part of their validation of NFDRS outputs.

*Woody Fuel Moisture*: This calculated value represents the approximate moisture content of the live woody vegetation (shrubs, small stems, branches and foliage) expressed as a percentage of the oven dry weight of the sample. As with the herbaceous fuel moisture, it varies significantly by climate class. Plants native to moist environments tend to have higher woody fuel moisture values than those native to more arid climates. Woody fuel moisture values typically range from a low of 50 or 60 observed just before the plant begins to grow in the spring to a high of approximately 200 reached at the peak of the growing season. The default value used in NFDRS processors to initiate the season varies by the climate class. In climate class 1 the default value is 50. For climate class 2 it is 60. Climate class 3 uses 70 and climate class 4 uses 80.

*Dead Fuel Moisture:* This is the moisture content of dead organic fuels, expressed as a percentage of the oven dry weight of the sample, that is controlled entirely by exposure to environmental conditions. The NFDRS processor models these values based on inputs such as precipitation and relative humidity. There is modeled fuel moisture for each of the four-timelag fuel classes recognized by the system. Timelag is the time necessary for a fuel particle of a particular size to lose approximately 63 percent of the difference between its initial moisture content and its equilibrium moisture content in its current environment.

> <u>1-Hr Fuel Moisture Content</u>: – The 1-hour fuel moisture content represents the modeled fuel moisture of dead fuels from herbaceous plants or roundwood that is less than one quarter inch in diameter. Also estimated is the uppermost layer of litter on the forest floor. Due to its size, this fuel is very responsive to the current atmospheric moisture content. It varies greatly throughout the calendar day and is principally responsible for diurnal changes in fire danger. Values can range from 1 to 80.
> <u>10-Hr Fuel Moisture Content</u>: – This is the moisture content of dead fuels consisting of roundwood in the size range of one quarter to 1 inch in diameter and very roughly, the layer of litter extending from just below the surface to three-quarters of an inch below the surface. Currently, the NFDRS code models this moisture value based on length of day, cloud cover, temperature and relative humidity. It is planned that by Summer 2002, the NFDRS code will begin modeling this moisture using solar radiation instead of cloud cover for those stations collecting solar radiation measurements. Ten-hour fuel moisture values vary somewhat with diurnal changes but vary more so with day-to-day changes in weather. Values can range from 1 to 60.
> <u>100-Hr Fuel Moisture Content</u>: – The 100-hour fuel moisture value represents the modeled moisture content of dead fuels in the 1 to 3 inch diameter class. It can also be used as a very rough estimate of the average moisture content of the forest floor from three- fourths inch to 4 inches below the surface. The 100- hour timelag fuel moisture is a function of length of day (as influenced by latitude and calendar date), maximum and minimum temperature and relative

humidity, and precipitation duration in the previous 24 hours. Values can range from 1 to 50 percent. A default value based on the climate class of the first priority fuel model module in the station catalog will automatically be used if there is a break of 30 days or more in the observations entered.

1000-Hr Fuel Moisture Content: **-** This value represents the modeled moisture content in the dead fuels in the 3 to 8 inch diameter class and the layer of the forest floor about 4 inches below the surface. The value is based on a running 7-day average. The 1000-hour timelag fuel moisture is a function of length of day (as influenced by latitude and calendar date), daily temperature and relative humidity extremes (maximum and minimum values) and the 24- hour precipitation duration values for a 7-day period. Values can range from 1 to 40 percent.

*X-1000 Hr Fuel Moisture Value*: **-** The X-1000 value is not truly a dead fuel moisture value. It is the live fuel moisture recovery value. It is discussed here since it is derived from the 1000-hr fuel moisture value. It is an independent variable used in the calculation of the herbaceous fuel moisture. The X-1000 is a function of the daily change in the 1000-hour timelag fuel moisture, and the average temperature. Its purpose is to better relate the response of the live herbaceous fuel moisture model to the 1000- hour timelag fuel moisture value. The X-1000 value is designed to decrease at the same rate as the 1000-hour timelag fuel moisture, but to have a slower rate of increase than the 1000-hour timelag fuel moisture during periods of precipitation, hence limiting excessive herbaceous fuel moisture recovery. The X-1000 value can vary between fuel models at the same station.

NFDRS model outputs for 1-, 10-, 100-, and 1000-Hr fuel moistures may be a representation or estimate of the moisture of subsurface organic material as described above; however, the NFDRS processor does not include subsurface parameters in these calculations. Dead fuel moistures are based solely on roundwood fuel moisture parameters.

Weather observations must be started 30 to 45 days prior to the onset of green-up to assure that the 1000-hour timelag fuel moisture and associated X-1000 have stabilized at a reasonable value for the current weather conditions.

**Indices and Components**

The following paragraphs address each component and index of the National Fire Danger Ra ting System. They include a definition of each, its numeric value ranges, and the designed function of the component or index. The numbers generated by NFDRS are relative in the sense that as the value of a component or index doubles, the activity measured by that component or index doubles. (An Ignition Component of 60 has twice the ignition probability of an Ignition Component of 30.) This helps the users of the NFDRS interpret the meaning of the numbers produced for their protection area.

*Ignition Component – (IC)*: The Ignition Component is a rating of the probability that a firebrand will cause a fire requiring suppression action. Since it is expressed as a probability, it ranges on a scale of 0 to 100. An IC of 100 indicates that every firebrand will cause a fire requiring action if it contacts a receptive fuel. Likewise an IC of 0 would mean that no firebrand would cause a fire requiring suppression action under those conditions. Note the emphasis is on action. The key is whether a fire will result that requires a fire manager to make a decision. The Ignition Component is more than the probability of a fire starting; it has to have the potential to spread. Therefore Spread Component (SC) values are entered into the calculation of IC. If a fire will ignite and spread, some action or decision is needed.

*Spread Component – (SC):* The Spread Component is a rating of the forward rate of spread of a headfire. Deeming, et al., (1977), states that “the spread component is numerically equal to the theoretical ideal rate of spread expressed in feet-per-minute”. This carefully worded statement indicates both guidelines (it’s theoretical) and cautions (it’s ideal) that must be used when applying the Spread Component. Wind speed, slope and fine fuel moisture are key inputs in the calculation of the spread component, thus accounting for a high variability from day-to-day. The Spread Component is expressed on an open-ended scale; thus it has no upper limit.

*Energy Release Component* **-** *(ERC)*: The Energy Release Component is a number related to the available energy (BTU) per unit area (square foot) within the flaming front at the head of a fire. Daily variations in ERC are due to changes in moisture content of the various fuels present, both live and dead. Since this number represents the potential "heat release" per unit area in the flaming zone, it can provide guidance to several important fire activities. It may also be considered a composite fuel moisture value as it reflects the contribution that all live and dead fuels have to potential fire intensity. The ERC is a cumulative or "build-up" type of index. As live fuels cure and dead fuels dry, the ERC values get higher thus providing a good reflection of drought conditions. The scale is open-ended or unlimited and, as with other NFDRS components, is relative. Conditions producing an ERC value of 24 represent a potential heat release twice that of conditions resulting in an ERC value of 12.

As a reflection of its composite fuel moisture nature, the ERC becomes a relatively stable evaluation tool for planning decisions that might need to be made 24 to 72 hours ahead of an expected fire decision or action. Since wind and slope do not enter into the ERC calculation, the daily variation will be relatively small. The 1000-hr timelag fuel moisture (TLFM) is a primary entry into the ERC calculation through its effect on both living and dead fuel moisture inputs.

There may be a tendency to use the 1000- hr TLFM as a separate "index" for drought considerations. A word of caution – any use of the 1000-hr TLFM as a separate "index" must be preceded by an analysis of historical fire weather data to identify critical levels of 1000- hr TLFM. A better tool for measurement of drought conditions is the ERC since it considers both dead and live fuel moistures.

*Burning Index (BI)*: The Burning Index is a number related to the contribution of fire behavior to the effort of containing a fire. The BI (difficulty of control) is derived from a combination of Spread Component (how fast it will spread) and Energy Release Component (how much energy will be produced). In this way, it is related to flame length, which, in the Fire Behavior Prediction System, is based on rate of spread and heat per unit area. However, because of differences in the calculations for BI and flame length, they are not the same. The BI is an index that rates fire danger related to potential flame length over a fire danger rating area. The fire behavior prediction system produces flame length predictions for a specific location (Andrews, 1986). The BI is expressed as a numeric value related to potential flame length in feet multiplied by 10. The scale is open-ended which allows the range of numbers to adequately define fire problems, even during low to moderate fire danger.

A cross-reference for BI to potential flame length, fireline intensity and descriptions of expected prescribed burning and fire suppression conditions is provided in Table 1 (adapted from Deeming et al. 1977). It is important to remember that a computed BI value is an index representing the near upper limit to be expected on the rating area. In other words, if a fire occurs in the worst fuel, weather and topography conditions somewhere in the rating area, these numbers represent the potential fireline intensity and flame length. These conditions are not expected throughout the entire fire danger rating area at any one time or under less severe conditions. Local relationships of fire danger outputs to fire activity are also portrayed effectively on Fire Danger Pocket Cards.

*Keetch-Byram Drought Index (KBDI)*: This index is **not** an output of the National Fire Danger Rating System itself but is often displayed by the processors used to calculate NFDRS outputs. KBDI is a stand-alone index that can be used to measure the effects of seasonal drought on fire potential. The actual numeric value of the index is an estimate of the amount of precipitation (in 100ths of inches) needed to bring the soil back to saturation (a value of 0 is complete saturation of the soil). Since the index only deals with the top 8 inches of the soil profile, the maximum KBDI value is 800 or 8.00 inches of precipitation would be needed to bring the soil back to saturation. The Keetch-Byram Drought Index's relationship to fire danger is that as the index value increases, the vegetation is subjected to increased stress due to moisture deficiency. At higher values, desiccation occurs and live plant material is added to the dead fuel loading on the site. Also, an increasing portion of the duff/litter layer becomes available fuel at higher index values. If you are using the 1978 version of NFDRS, KBDI values can be used in conjunction with the National Fire Danger Rating System outputs to aid decision- making. If you are using the 1988 version of NFDRS, KBDI values are a required input to calculate daily outputs.

**Quality Control**

Fire danger ratings are no better than the data used to derive them. If fire danger ratings are to be used with confidence, uniform standards and procedures must be correctly followed. The NWCG NFDRS Weather Station Standards establish national weather data measurement standards. Fire danger operating plans establish local procedures, responsibilities, and actions related to fire danger rating. Other uses of the climatological database also require that data are accurate. Quality control is recognized as an integral part of the fire danger rating system application.

**NFDRS Structure**

The graphic below displays the relationship of many of the inputs and out puts from NFDRS.