

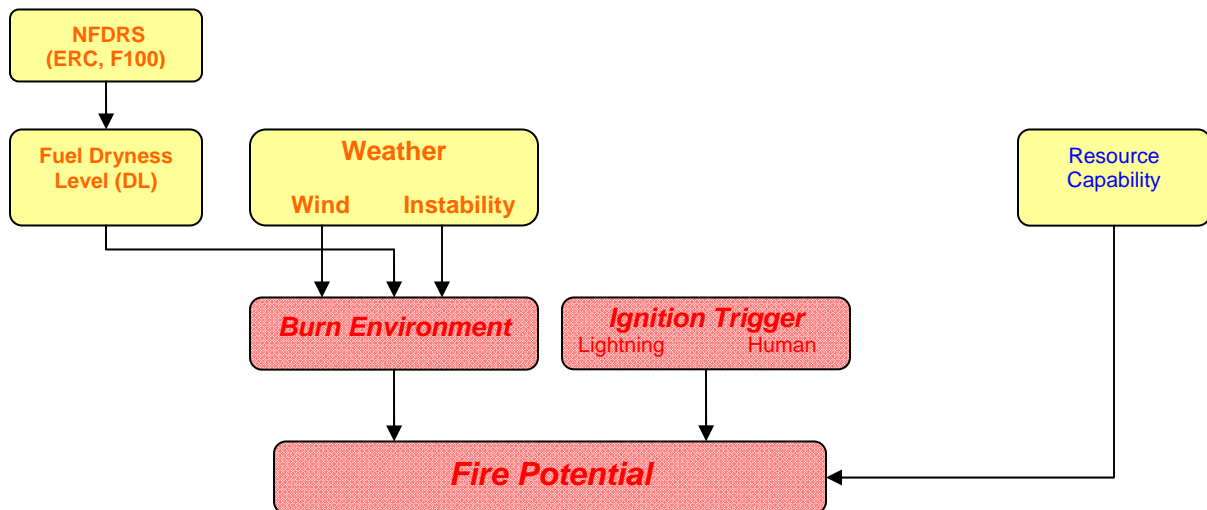
Assessing Daily Fire Potential

Step One – Developing a “Fuel Dryness Level”

Terry Marsha - Meteorologist
Predictive Services, NWCC
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Introduction

A major responsibility of the **Predictive Services Unit** at the Northwest Coordination Center (NWCC) is to assess, daily, the fire potential across the northwest region. The following schematic represents our conceptual model used for this purpose.



At present, the **Burn Environment** and **Ignition Trigger** components are the two main predictors in our model. Each is vitally important in determining the daily fire potential. Resource Capability is equally important but further research is necessary before it can be objectively included in our procedure.

This paper will document one part of this model, the fuel **Dryness Level (DL)** which is a major component of the Burn Environment.

What is Fire Potential?

Specifically when we talk about fire potential we mean the probability of occurrence of at least one new “**Significant Fire**”, i.e. a fire that would require mobilization of additional resources from outside the immediate area where the fire originated. A type 1 or type 2 Incident Management Team would likely be needed for such an event. Regional and probably national level resource managers would get involved. If large fires are currently in progress, significant fire potential might also represent conditions that would result in large fire growth on the existing fires.

We have established a ‘*large fire size*’ unique to each of our PSAs (forecast areas) based on approximately the 95th percentile size of all historic daily largest fires for that PSA.

Factors Influential in Large Fire Occurrence

Large Fire growth or occurrence is influenced by numerous factors, some of which can be assessed and forecasted readily and some which are more elusive. A partial list of such influences include:

1. **Burn Environment** - Fuel conditions (dryness) in conjunction with various weather conditions, most importantly airmass instability and wind. Whenever the burn environment becomes elevated fire growth and behavior can become problematic.
2. **Ignition Triggers** - probability and extent of ignition sources. Most important here is lightning but can also include significant recreation events such as the 4th of July, Labor Days weekend etc. Mass ignitions can overwhelm Initial Attack resources resulting in an increased probability of large fires.
3. **Resource Capability** – resource type and amount need to be commensurate with the fire threat to prevent large fires.
4. **Fire fighting strategy and tactics** -varies over time for various reasons and can affect the probability of whether or not a fire becomes large.
5. **Fire Accessibility** – distance and/or ruggedness of terrain can play a huge role in whether or not a fire gets large making certain PSAs more susceptible to large fire occurrence than others.

Our current model emphasizes factors 1 through 2 directly. Factor 3, resource capability, is often considered in a subjective manner.

Burn Environment and fuel Dryness Level (DL)

Our daily assessment of large fire potential begins with an assessment of the *burn environment*, one of our two primary predictors of large fire potential. By burn environment we mean the underlying environmental fuel and weather conditions that will either aid or inhibit significant fire spread. The burn environment is an indispensable ingredient for the occurrence of either a new large fire or for significant growth on existing large fires. Data shows that without a favorable burn environment, large fire growth is rare. On the other hand, a critical burn environment far from ensures large fire activity. We often remain in an elevated burn state for days without the occurrence of new large fires. Therein lies a dilemma, attempting to warn of each and every critical condition while being careful not to over-warn with the inevitable loss of credibility. Such is the pitfall inherent in 'rare event' forecasting.

The burn environment does not start fires, it only provides conditions that either aid or inhibit large fire growth. If conditions are critical enough it is possible for fires to either spread with such rapidity or burn with such energy that **Initial Attack (IA)** resources will be overwhelmed and large fire growth will occur. Without a significant ignition event (i.e. *Ignition Trigger*), data in the northwest has shown that a typical day results in between 0 and 3 fires for any particular PSA. It is evident that IA resources normally, but not always, can prevent large fires from occurring under this scenario even with critical or near-critical burn conditions.

In the northwest, we define the burn environment in terms of three ingredients, either alone or in combination – fuel dryness, low/mid level atmospheric instability and wind. Data shows a definite relationship between the probability of large fire activity and combinations of these three conditions. Our analysis shows that fuel dryness appears to be the most influential of the three but when combined with either instability or strong wind, large fire potential can be elevated further. The effects of instability and wind will be documented in separate papers as will the very important topic of Ignition trigger events. The remainder of this document will be devoted to a discussion of fuel dryness and development of our **Dryness Level**.

Fuel Dryness

It is a well known fact among the fire fighting community that the drier the fuels the more prone we are to large fire occurrence. The **National Fire Danger Rating System (NFDRS)** computes 7 separate indicators of fuel moisture listed below.

1. 1-hour fuel moisture (F1)
2. 10-hour fuel moisture (F10)
3. 100-hr fuel moisture (F100)
4. 1000-hr fuel moisture (F1000)

5. Live Herbaceous fuel moisture (FMH)
6. Live Wood fuel moisture (FMW)
7. **Energy Release Component (ERC)**

To lay the groundwork for a large fire potential model we first needed to *objectively* establish the relationship that we knew existed between fuel dryness and large fire potential. It started with a simple analysis of the correlations between the different NFDRS fuel moisture elements and the occurrence of large fires. Results are shown in table 1.

Table 1. – Absolute value of correlation coefficient between fuel moisture and large fire occurrence

PSA	F1	F10	F100	F1000	FMH	FMW	ERC
W1	.048	.055	.111	.090	.105	.107	.118
W2	.052	.052	.069	.099	.082	.116	.115
W3	.081	.072	.085	.073	.061	.077	.101
W4	.085	.094	.145	.096	.055	.101	.137
C1	.103	.101	.118	.085	.017	.074	.118
C2	.087	.107	.144	.043	.032	.042	.091
C3	.034	.038	.075	.032	.013	.035	.051
E1	.102	.109	.199	.102	.117	.106	.156
E2	.062	.063	.124	.106	.085	.106	.131
E3	.008	.003	.047	.044	.001	.033	.037
E4	.127	.134	.186	.151	.080	.143	.197
E5	.079	.082	.156	.059	.091	.057	.115

* data sample: July-September 1994-2006

A couple of things are noteworthy from the table 1. First, the correlations are fairly low. Hopefully, other predictors can be found that, when combined with fuel moisture, elevates these correlations. Such is indeed the case and will be discussed in future documentation. It should always be remembered that fuel dryness is a necessary ingredient for large fires but, working alone, merely sets the stage. To elevate the large fire threat to more critical levels normally takes another ingredient working in conjunction with fuel dryness, most often a significant ignition trigger event (lightning) or sometimes another component of the burn environment such as atmospheric instability or wind. Also apparent from the table is that large fire occurrence tends to correlate best with either the 100-hr fuel moisture (F100) or the ERC with a slight edge toward F100 for most PSAs. Further analysis in the northwest showed that when a combination of both the F100 and ERC was used as a fuel moisture index, the correlations with large fire occurrence improved a slight bit and this finding is what drove our development of our **Dryness Level index (DL)**.

Dryness Level Development (DL)

Our intent was to establish thresholds of fuel dryness above which the probability of large fires showed marked increases.

Historically, the fire community has defined fuel dryness in terms of percentile ranks of various NFDRS fuel moisture elements. One commonly used threshold has been either the 90th or the 97th percentile value of the ERC. Using simple percentile thresholds is indeed a legitimate way of assessing the relative fuel dryness. However, significant percentile threshold values should be chosen that actually relate to fire activity. Thresholds should be determined that actually relate to increased probability of large fires.

From our correlation analysis between NFDRS fuel moisture elements and large fire occurrence we decided to define our DL in terms of combinations of F100 and ERC for fuel model G (ERC-G). We could have proceeded in various ways including regression analysis. However, a more intuitive approach was to establish a simple and unique matrix of F100 versus ERC-G for each PSA and then partition the matrix into 3 separate areas each corresponding to significantly different probabilities of large fire occurrence. Following are the steps for this process.

1. For each PSA a matrix was developed showing ERC-G, in 5-unit increments, along the x-axis and F100, in 1-unit increments, along the y-axis. For each cell division within the matrix the total number of fire days (i.e. days with at least 1 fire reported) was recorded. For development of our most current matrices the months of July-September were used for the years 2000-2006. This is referred to as our 'Fire Day Matrix'. An example for one of our PSAs is shown below.

FDs	40	45	50	55	60	65	70	75	80	85	
4										1	1
5							1	4	10	4	19
6						4	12	21	11	2	50
7					5	19	28	23	3		78
8			2	4	12	13	26	9			66
9			9	8	15	11	5				48
10		1	4	6	2	7					20
11		1	4	5	7	4					21
12	1	3	7	6	1						18
13	1	1	1		1						4
>13	1	2	1								4
	3	8	28	29	43	58	72	57	24	7	329

We see that in our 7 year sample, there was a total of 329 fire days for the months of July thru September broken down by F100 vs ERC-G combinations within the matrix.

- Next another matrix was developed identical to the 'Fire Day Matrix' except instead of all fire days, only large fire days were recorded within the matrix. This is referred to as our 'Large Fire Day Matrix'. An example is shown below.

LFDs	40	45	50	55	60	65	70	75	80	85		
4	Green			Yellow		Orange					0	
5	Green			Yellow		Orange					1	
6	Green			Yellow		2	2	4	1		9	
7	Green			Yellow		1	2	1	1		5	
8	Green			1	1	1	1	1			4	
9	Green			1	1	1	1				2	
10	Green											0
11	Green											0
12	Green											0
13	Green											0
>13	Green											0
	0	0	0	1	3	6	4	6	1	0	21	

We see that of the 329 'Fire Days' 21 of them were also 'Large Fire Days'. Their breakdown with relation to the F100 and ERC-G are shown within the matrix.

- The next task was to partition the matrix into 3 separate divisions each showing a significantly different probability of a large fire than the other. This is accomplished quite simply by dividing the number of large fire day occurrences for a particular F100/ERC combination (cell) from the 'Large Fire Day Matrix' by the number of fire day occurrences for the corresponding cell in the 'fire day matrix'. This represents the historic probability that given a fire day having a particular ERC/F100 combination a large fire would occur. For example, when the ERC was between 70 and 74 and the F100 was 6 there was a total of 12 'fire days' (from fire day matrix). For that same ERC/F100 combination, of those 12 'fire days', 2 of them were 'large fire days' (from the large fire day matrix). Dividing 2 by 12 results in an historic probability of 17% that given at least 1 ignition with that particular combination of ERC/F100, a large fire would result.

Once probabilities for all matrix cells are computed the matrix can be divided into three distinct divisions, each having a significantly different conditional probability for a large fire than the other.

Table 2, below, shows statistics generated from the two matrices above.

DL	Conditional Probability For a 'Large Fire'	Percent of all 'Fire Days'	Percent of all 'Large fire Days'
Moist	0%	26%	0%
Dry	6%	53%	52%
Very Dry	14%	21%	48%

Table 2 shows that for this 7 year sample, given at least 1 ignition, there were no 'large fires' when the ERC/F100 combination fell within the moist (green) area of our matrix (i.e. 0%). Furthermore 26% of all fire days occurred under this condition. On the other end of the spectrum, 21% of all 'fire days' occurred when conditions were Very Dry (brown) and on these 21% of days, nearly half (48%) of all large fire days occurred. The conditional Probability column shows the significantly different probabilities for large fires associated with each of the 3 fuel moisture regimes.

Fire Day and Large Fire day matrices have been developed for each of our 12 PSAs and are updated every year after the previous year's fire occurrence data is available and is the basis of our DLs.

Operational Use of our DLs

Each day during the fire season we make a forecast of the DL for each PSA for each of the next 7 days. This is posted to the NWCC web page as part of the **7-Day Significant Fire Potential** product. The DL is portrayed as green, yellow or brown representing moist, dry or very dry conditions, respectively. The forecasts are objectively generated by NWCC developed regression equations that use predictors derived from weather models as well as the previous days observed NFDRS fuel moistures.

Thoughts Regarding Fuel Dryness

Those of you who are statistically inclined may question the use of ERC and F100 used in conjunction with one another because F100 is already part of the ERC computation within NFDRS and therefore the two are rather highly correlated. While this is true, correlation coefficient around .86, the relationship to large fire occurrence is nevertheless better when used together. Essentially, we are adding additional weight to the F100 than would be present by simply using the ERC by itself. This makes some sense. The ERC is a composite of fuel moisture from all size classes of fuel, both living and dead, but is heavily weighted toward fuel moistures of large fuels (F1000) and hence is a relatively conservative measure, acting more slowly to daily fluctuations in air mass

moisture. On the other hand, F100 is much more responsive to daily moisture fluctuations. By using both measures together a better representation of both the longer term moisture levels (ERC) and the more volatile daily moisture levels (F100) is achieved.

Another very important point that should be recognized about our DLs is that they were developed with no regard given to other factors that influence large fire occurrence such as whether or not lightning was present or whether conditions were windy or unstable. In other words, factors such as lightning events were not extracted from the sample before the analysis to determine the DL was conducted. Therefore you don't know for certain how much of the correlation between our DL and large fire occurrence was truly due to the fuel dryness and how much may be attributable to other confounding predictors. My present feeling is that in the grand scheme of things it will not present a significant problem because the DL is not the final step in the large fire assessment process. Ultimately, the other potentially significant factors will be considered and incorporated into our final large fire potential assessment model.