1 WEATHER

Contents

1.1 Fire Weather Observations (http://www.nwccweb.us/content/pdfs/TakingGoodWxObs.pdf)

1.1.1 Who is responsible for regular weather observations and forecast updates,

Take time to review forecasts and make good fireline observations to ensure effective forecasts and briefings. Each Single Resource (crew, squad, and individual) is responsible for insuring that they *"keep informed of fire weather conditions and forecasts"* so that they may *"base all actions on current and expected behavior of the fire."* ***The process involves obtaining and reviewing latest forecasts, taking observations to validate them through the assignment, reporting what is learned to those who need the information, and requesting forecast updates.***

1.1.2 Location & Timing of Fireline Weather Observation

1.1.2.1 When to take observations:

Four times during a 24 hour day stand out as valuable for assessing forecasts and evaluating thresholds associated with fire behavior transitions.

- An early morning observation that represents time and conditions when the minimum temperature and maximum humidity occur.
- A late afternoon observation that represents the time and conditions when the maximum temperature and minimum humidity occur.
- At the times when active fire behavior seems to increase and diminish during the burn period.

Other times, for example hourly throughout the afternoon or when changes occur, may be called for by fireline supervisors or dictated by changing conditions to ensure situational awareness.

1.1.2.2 Where to take observations:

Regardless of whether the fire is a prescribed fire project or a wildfire, the weather observer should strive to pick observation sites that most accurately reflect environmental conditions around the fire's location.

- Decide whether a ridgetop, midslope, or drainage bottom location is most representative.
- If on a slope, the aspect and slope steepness is an important consideration.
- Consider what is a representative fuelbed for the fire.
- Attempt to find a safe site upwind or on the flank of the fire. Generally, well ventilated areas in the shade are desirable locations for the observation.
- Minimize the fire's influence on your observation. Avoid taking observations in the black. Avoid observations affected by gusty indraft breezes and radiant heat from the fireline

1.1.2.3 Note the type of Instruments Used

It's a good idea to remark whether the observations were made with an electronic weather sensor or traditional sling psychrometer. Electronic temperature and humidity sensors should regularly be calibrated against weather instruments of reliable accuracy. Check that the batteries are fresh

1.1.2.4 Communicate and Document the weather observation

The most accurate weather observation is of little use unless it is properly communicated in a timely fashion to those who need it. Make sure that current observations are reported verbally over the radio to insure situational awareness.

- Follow instructions for periodic radio reports to fireline supervisors and/or incident communications unit. Ask for report to be repeated for confirmation to reduce errors.
- Report measurements with trends, such as temperature 75 – up 5 degrees from last hour.

Provide written documentation of weather observations to fireline supervisor, situation unit, incident meteorologist, or the local Weather Forecast Office. Retain a copy for your records. Don't assume that weather observations are automatically being received by the proper users. The weather observer may need to take the initiative to verify that the information is being passed up the line. Forms are available.

1.1.3 Wind Observations and Estimations; Calibrating Forecasts & Predictions

Because windspeed and direction is the most variable weather factor over the duration of an assignment, the observer will be concerned with adjusting and validating forecasted winds as much as measuring current windspeed. It is difficult for a meteorologist to produce localized wind forecasts, especially if the wind is influenced by terrain features. Forecasted winds will frequently need adjustment because they are representing a wind other than mid-flame, such as ridgetop or surface winds. See the definitions in section 1.2. It will be important to communicate with the meteorologist the factors that influence the wind measurements that are provided.

Report observation type or height. Identify sheltering and aspect/slope position for the wind observation. And indicate whether local winds are influencing the observation.

1.1.3.1 Obtain forecast from Incident Meteorologist or Fire Weather Forecaste (Section 1.6.3)r

1.1.3.2 Consider possibility of Critical Wind (use worksheet reference in section 1.2.3)

1.1.3.3 Use Worksheet to estimate or validate 20-ft surface windspeed (Section 1.2.3)

If the weather forecast product provides windspeed as “free air or ridgetop” or if winds in the fire area are influenced by local winds, it may be necessary to use the form in section 1.2.3 to estimate the surface/20 ft windspeed.

- ✓ Identify speed and direction of any forecast critical wind.
- ✓ Determine speed and direction of any Local Winds
- ✓ Determine speed and direction of General Winds and whether they will influence the 20-ft wind.
- ✓ Combine factors above into an estimate of local surface (20-ft) windspeed.

1.1.3.4 Estimate or validate Midflame Windspeed (use guide in section 1.2.5)

Eye level windspeed is usually assumed to be the same as mid-flame windspeed. However, as suggested in the Fireline Assessment Method (FLAME) reference, it may be too low for flames in shrub fuels and too high for flames in forest litter. In any case, it may be necessary to make adjustments to forecasted 20 ft winds or observed mid-flame windspeed to make comparisons and validate forecasts.

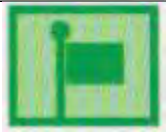
Observing eye level windspeed in the field:

- ✓ The observer should take care to face directly into the wind and closely observe the wind speed indicator fluctuations. Exposure to sunlight is not a concern during the wind observation.
- ✓ An eye level wind speed measurement requires at least one full minute of sampling and preferably more.
- ✓ When using a Dwyer tube, mentally average the wind speed and note the peak gust during the sampling period.
- ✓ Electronic sensors make wind averaging and gust measurement easy. They are more accurate and are preferred for eye level wind speed observations.
- ✓ Remember: The wind direction is defined as the direction the wind is coming from.

1.1.3.5 Estimate Effective Windspeed for slope influence (Use table in section 5.3.5 or 5.4.2

The influence of slope on fire spread is applied as a slope-equivalent “windspeed”. Where slope is significant (generally 20% or more), all the fire behavior assessment tools in section 5 (FLAME, Lookup Tables, Nomograms & Nomographs, and BehavePlus) provide means for estimating “effective windspeed”. This adjusted windspeed should be used instead of the mid-flame windspeed estimate in fire behavior predictions.

1.1.3.6 Visual Surface (20ft) Wind Estimate - Modified Beaufort Scale

Class	Windspeed	Terminology		Visible Effect
0	**Less than 1 mph**	**Calm**		Calm, Smoke rises vertically
1	**1 to 3 mph**	**Very Light Breeze**		Leaves of quaking aspen in constant motion; small branches sway, tall grasses and weeds sway and bend with wind, wind vane barely moves
2	**4 to 7 mph**	**Light Breeze**		Trees of pole size in the open sway gently, Wind felt distinctly on face; leaves rustle; loose scraps of paper move, wind flutters small flag
3	**8 to 12 mph**	**Gentle Breeze**		Leaves, small twigs in constant motion; Tops of trees in dense stands sway; light flags extended
4	**13 to 18 mph**	**Moderate Breeze**		Trees of pole size in the open sway violently; whole trees in dense stands sway noticeably; dust is raised in the road.
5	**19 to 24 mph**	**Fresh Breeze**		Branchlets are broken from trees; inconvenience is felt in walking against wind
6	**25 to 31 mph**	**Strong Breeze**		Tree damage increases with occasional breaking of exposed tops & branches; progress impeded when walking against wind.
7	**32 to 38 mph**	**Moderate Gale**		Severe damage to tree tops; very difficult to walk into wind; significant structural damage occurs.
8	**39 to 46 mph**	**Fresh Gale**		Surfaced strong Santa Ana; intense stress on all exposed objects, vegetation, buildings; canopy offers virtually no protection
9	**47 to 54 mph**	**Strong Gale**		Slight structural damage occurs; slate blown from roofs
10	**55 to 63 mph**	**Whole Gale**		Seldom experienced on land; trees broken; structural damage occurs
11	**64 to 72 mph**	**Storm**		Very rarely experienced on 12land; usually with widespread damage
12	**73 mph or more**	**Hurricane Force**		Violence and destruction

1.1.4 Temperature/Humidity/Dew Point Observation

Estimating temperature, relative humidity and dewpoint can provide insight to critical fire behavior thresholds for ignition and crown fire potential. Even without references, 1-hr moisture content can be estimated from relative humidity. RH (in %) can be divided by 5 to approximate the fine dead fuel moisture content

1.1.4.1 Sling Psychrometer Use

The following are instructions for determining wet and dry bulb temperatures using the sling psychrometer. These instructions are based on those from page 259 of the S-290 Instructors Manual. Several additional comments have been added.

1. If your sling has been in your pack, you may need to hang it in a tree, in the shade, to let it adjust to the outside air temperature. This may be a good time to take the wind observation.
2. Stand in a shaded, open area away from objects that might be struck during whirling. If in open country, use your body shade to shade the psychrometer. If possible, take your weather observations over a fuel bed that is representative of the fuels that the fire is burning in. Stay away from heat sinks.
3. Face the wind to avoid influence of body heat on the thermometers.
4. Saturate the wick of the wet bulb with clean, mineral free water (distilled if available) at air temp.
5. Ventilate the thermometers by whirling at full arm's length. Your arm should be parallel to the ground. Whirl for 1 minute.
6. Note the wet bulb temperature. Whirl for another 40 or 50 times and read again. If the wet bulb is lower than the first reading, continue to whirl and read until it will go no lower. Read and record the lowest point. If the wet bulb is not read at the lowest point, the calculated relative humidity will be too high. Calculate dew point each time. If it is changing significantly it may suggest a bad observation.
7. Read the dry bulb immediately after the lowest wet bulb reading is obtained.
8. Determine the relative humidity from the tables.

Important Tips: Sometimes beginners do not take accurate psychrometer readings because of the following common mistakes:

- Changing psychrometers from one observation to the next. Try and use same one throughout.
- not ventilating the psychrometer long enough to reach equilibrium;
- not getting the wick wet enough, or letting it dry out;
- holding it too close to the body or taking too long to read the thermometers;
- touching the bulb ends with the hands while reading;
- Not facing into the breeze.

1.1.4.2 Adjusting RH for changes in Temperature and Elevation

Under certain circumstances, it may not be possible to estimate relative humidity for a particular elevation. It may also be necessary to make field adjustment to forecasted relative humidity for some time later in the burn period. In both of these cases, given that the air mass is unchanging and fairly neutral, it is possible to use current estimates of dew point and temperature and to make adjustments in both cases:

Case 1: ***Estimate relative humidity for an elevation above or below the observation***; assuming an average lapse rate of approximately 4° F, increase the temperature by 4° F for each 1000 ft drop in elevation or decrease it by 4° F for each 1000 ft increase in elevation. Using the new temperature and the estimated dew point, look up the new relative humidity in the appropriate psychometric table.

Case 2: ***Validate a forecasted relative humidity***; using the estimated dew point and the forecasted temperature, look up the new relative humidity in the appropriate psychometric table.

1.1.5 Sky Observations

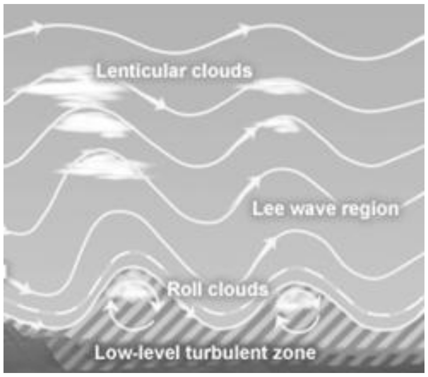
Synoptic (Large Scale) forecasts and representations of current conditions include reference to the relative stability of the atmosphere in the area. In that vein, there are numerous indicators that can be reviewed and interpreted. Several are referenced in section 1.4.

However, these general atmospheric conditions are influenced by the terrain and other local factors to produce more localized effects. The weather observer can provide important information to meteorologists by reporting the visual cues and the timing of changes throughout the day.

These visual cues are generally associated with a weather observation by recording them in the remarks column so that they get a time stamp. Here are some important examples:

Clouds, Fog, & Precipitation

- Cloud Cover, in percent, is an important input for fuel moisture shading.
- Clouds are an important indicator of stability. Flattened (stratus) clouds are an indicator of stable and moist conditions. Cumulus clouds are an indicator of rising air and instability. There are a number of cloud charts available. This link provides one with fire behavior interpretations (http://www.wildfirelessons.net/Additional.aspx?Page=299).
- Altocumulus castellanus clouds indicate instability in the middle level that may affect the surface and fire later in the day.
- Altocumulus Lenticular clouds indicate strong winds aloft that may surface later in the day.
- Building cumulus, towering cumulus, or thunderstorms are all indicators of significant instability that is probably already influencing surface winds.
- Showers or virga may be indicators of instability.



Smoke Column

- Does the smoke continue to rise (indicator of netural or instable conditions) or does it flatten (indicator of inversion at that point)?
- Does the smoke column change direction as it rises (indicator of wind shear or local wind influence)?
- Smoke column developing a pyrocumulus cap cloud (strong instability and impending down drafts)

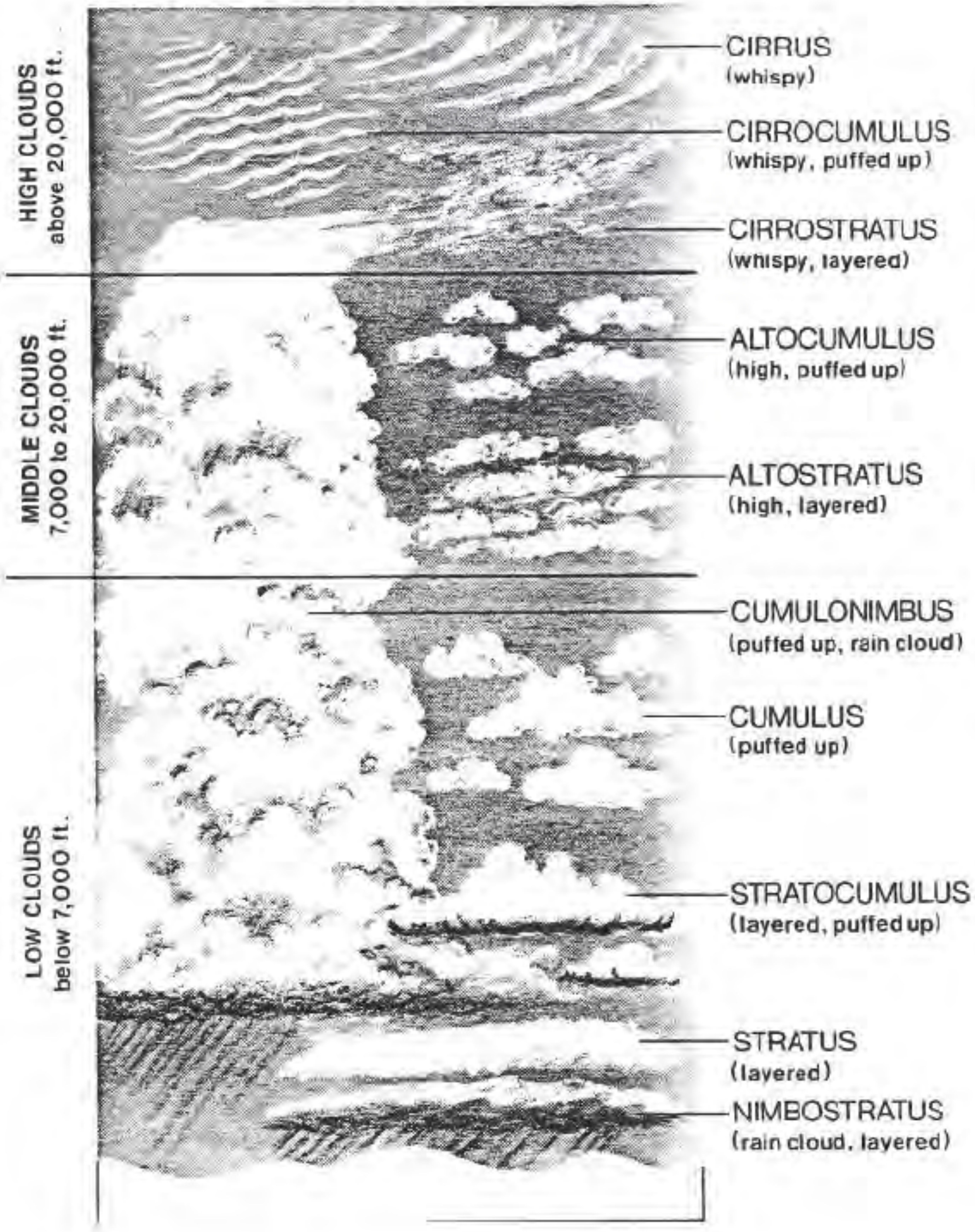
Haze and poor visibility are indicators of inversions. Is this localized (night-time inversion) or more general and persisting throughout the day. Note if and when the haze or poor visibility abates during the burn period.

Lightning should be reported immediately to alert fireline supervisors to take appropriate precautions and to cue meteorologists to review their lightning detection tools.

Wind Variability

- Sudden wind shifts may be important indicators of breaking inversions or frontal passage.
- Dust clouds radiating away from thunderstorms indicate potentially dangerous downdrafts.
- Dust devils and firewhirls are important indicators of surface instability.
- Note time and rapidity of transitions in diurnal winds

Usually, if a visual cue is worth noting with the weather observation, photography can be very valuable supporting documentation. If a photo is taken, use a photo log or reference the photo number with the location date, time and other identifying comments.

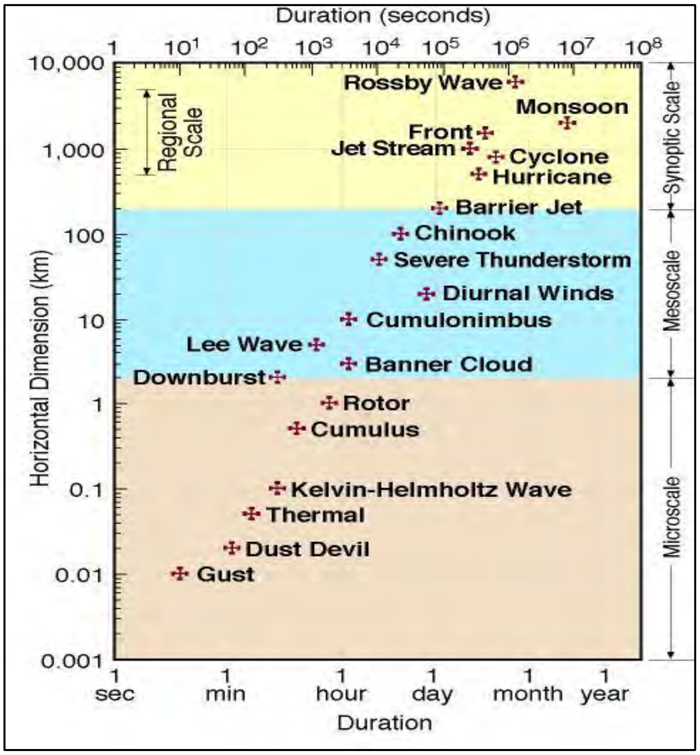

HIGH CLOUDS
above 20,000 ft.
MIDDLE CLOUDS
7,000 to 20,000 ft.
LOW CLOUDS
below 7,000 ft.
CIRRUS
(whispy)
CIRROCUMULUS
(whispy, puffed up)
CIRROSTRATUS
(whispy, layered)
ALTOCUMULUS
(high, puffed up)
ALTOSTRATUS
(high, layered)
CUMULONIMBUS
(puffed up, rain cloud)
CUMULUS
(puffed up)
STRATOCUMULUS
(layered, puffed up)
STRATUS
(layered)
NIMBOSTRATUS
(rain cloud, layered)

1.2 Winds

1.2.1 Definitions

1.2.1.1 General Winds

(Synoptic scale, gradient, free air, ridgetop) are large scale winds produced by broad scale pressure gradients between high- and low-pressure systems. They may be influenced and modified considerably in the lower atmosphere by terrain and vegetative structure.



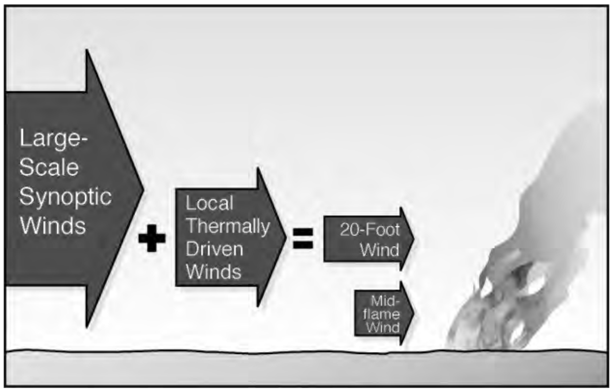
1.2.1.2 Local winds

(Thermal, convective, drainage) are convective winds caused by local temperature differences generated over a comparatively small area by local terrain and weather. They differ from those which would be appropriate to the general pressure pattern in that they are limited to near surface and are controlled by the strength of the daily solar cycle.

- ***Slope Winds*** are driven by heat exchange at the slope surface. The can react quickly to insolation on the slope, with upslope breezes starting within a few minutes. The strength of upslope winds is also influenced by the length and steepness of the slope as well as the exposure. Upslope winds generally range from 3-8 mph. The transition from upslope to downslope wind begins soon after the first slopes go into afternoon shadow and cooling of the surface begins. In individual draws and on slopes going into shadow, the transition period consists of (1) dying of the upslope wind, (2) a period of relative calm, and then (3) gentle laminar flow downslope. Downslope winds are very **shallow** and of a **slower** speed than upslope winds, [generally 2-5 mph]. The cooled denser air is stable and the downslope flow, therefore, tends to be laminar.
- ***Valley Winds*** are similar to and linked with slope winds. Their development each day generally lags 1-3 hours behind that of slope winds. Peak speeds can be as much as double those of slope winds, reaching 10-15 mph at their peak.
- ***Land and Sea Breeze Circulations***: During the day, Sea/Lake breeze can reach 10-15 mph at the peak of solar heating in the afternoon. The corresponding land breeze is lighter, perhaps 5-10 mph

1.2.1.3 ***Surface Winds***

Are measured near the earth's surface, at a surface observing station, customarily at some distance (usually 20 feet or 10 meters) above the average vegetative surface and/or a distance equal to at least 10 times the height of any obstruction to minimize the distorting effects of local obstacles and terrain. Generally, 10 meter windspeed is approximately 1.15 times the 20 ft equivalent.



1.2.1.4 ***Critical Winds*** dominate the fire environment and easily override local wind influences. Examples include frontal winds, Foehn winds, thunderstorm winds, whirlwinds, surfacing or low-level jets (reverse wind profiles), and glacier winds.

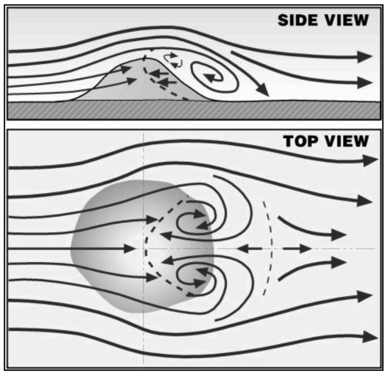
1.2.1.5 ***Wind Gust*** Is a sudden, brief increase in speed of the wind. According to U.S. weather observing practice, gusts are reported when the peak wind speed reaches at least 16 knots and the variation in wind speed between the peaks and lulls is at least 9 knots. The duration of a gust is usually less than 20 seconds. NWCG Definition is based solely on the variation between peaks and lulls, at 11.5 mph.

1.2.1.6 ***Midflame Windspeed*** is the estimated windspeed at a height above the surface fuel equivalent to the height at midflame. This is the wind input required for estimating fire spread using the Rothermel surface fire model. It is generally derived from the Surface (20-ft) Wind based on sheltering from an upper canopy or flame height based on fuel bed depth.

1.2.1.7 ***Eye Level Winds*** are frequently used to represent midflame windspeeds, though that may represent an overestimate for shallow and sparse fuelbeds that have lower flame heights or an underestimate for shrub and crown fuels with deep fuelbeds

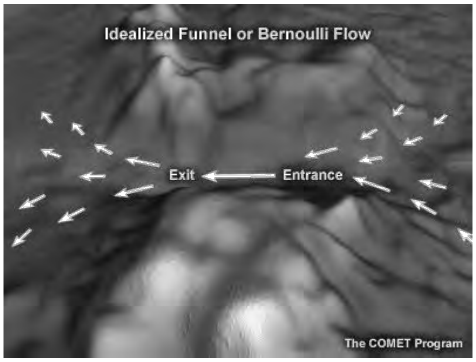
1.2.1.8 ***Effective Windspeed*** is the combined effect of Midflame Wind Speed and the slope equivalent windspeed in the direction of maximum spread (head fire). Effective Wind Speed is used to determine the shape (length-to-width ratio) of a point source fire. See section 5.3.

1.2.2 Factor to Consider when Estimating Surface (20ft) Windspeed in Mountain Terrain (From S490)



For the ***slopes and ridges of Mountains***, consider:

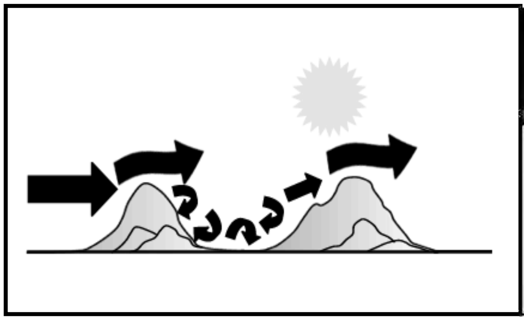
- *Isolated peaks* tend to divert general wind flow horizontally and vertically. Some acceleration of general winds is likely around the flanks and over the top of isolated mountains peaks with gently inclined slopes. On the lee side of the peak, a turbulent reversal (wind eddies) of general wind flow is possible
- Overall, *mesas* tend to decelerate general winds because energy must be expended to create local reversals of wind flow called "separation eddies" that form upwind and downwind of steep sided barriers In the vicinity of separation eddies and on top of the mesa, expect 20 ft winds to be decelerated below what might be expected for the general area. Be aware of the potential for frequent gusts and shifts in wind direction near the eddies.
- For *Continuous Ridges*, when airmass is instable, general winds tend to ride over the ridge. Under stable conditions, weak winds can be blocked and a stagnant zone formed below the ridges. In either case, the atmospheric stability, the strength of the general wind & its angle of incidence, and influence of diurnal winds (which may be opposing) must all be considered on the downwind side of the ridge.

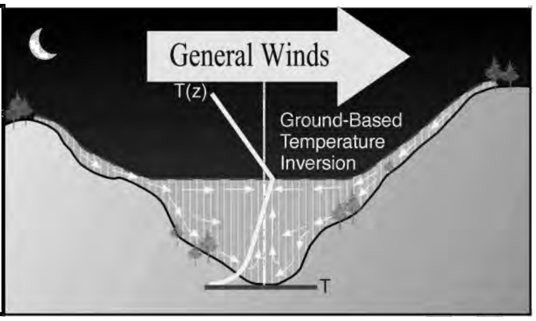


Gaps in Terrain can produce a venturi effect, where winds can be expected to accelerate downwind of the constriction, primarily in the exit region. These gap winds are part of the general wind, because they are based on general winds.

- *Low Level Gorges* frequently facilitate gap flow when upwind airmass is stable and discourages the wind from rising over terrain. These gap winds are fairly shallow, less than a few thousand feet
- *Mountain Passes & Saddles*: upper level winds that impact high terrain tend to flow through the lowest possible spots in a mountain chain rather than climb over it. Local slope and valley winds should be included here.

Valley Influences

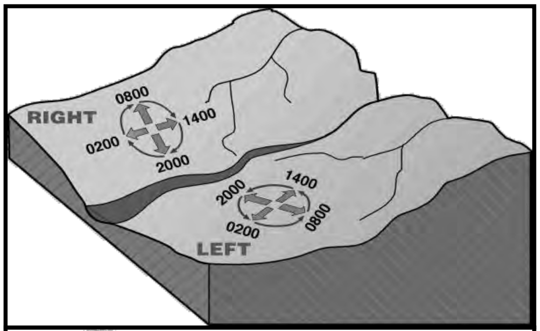


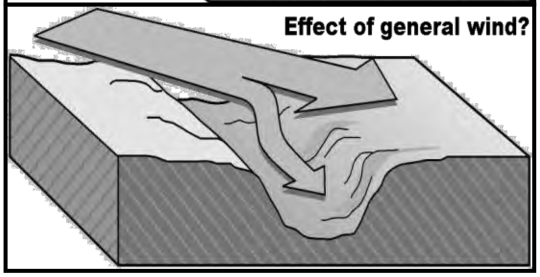


- *Enclosed or Isolated Basins* have generally reduced surface wind low on the slopes and valley bottoms. Inversions may limit even the infrequent gusts.
- *Elongated Valley Winds*
  The Local drainage wind component transitions from upslope as the sun hits the upper slopes, then upvalley as the heating becomes widespread to downslope as the sun sets and down valley during the night

  The general wind influence on surface winds in these valleys depends on its strength, the angle of incidence to the valley axis, the depth of the valley, its aspect alignment, and the time of day.

  - ✓ During the day, general winds that are aligned with the upvalley wind will increase the surface winds. Opposing winds will result in decreased surface winds. And perpendicular general winds will contribute little to the local winds found there.
  - ✓ During the night, general winds are most likely to surface when they are strong and aligned parallel to the valley axis.



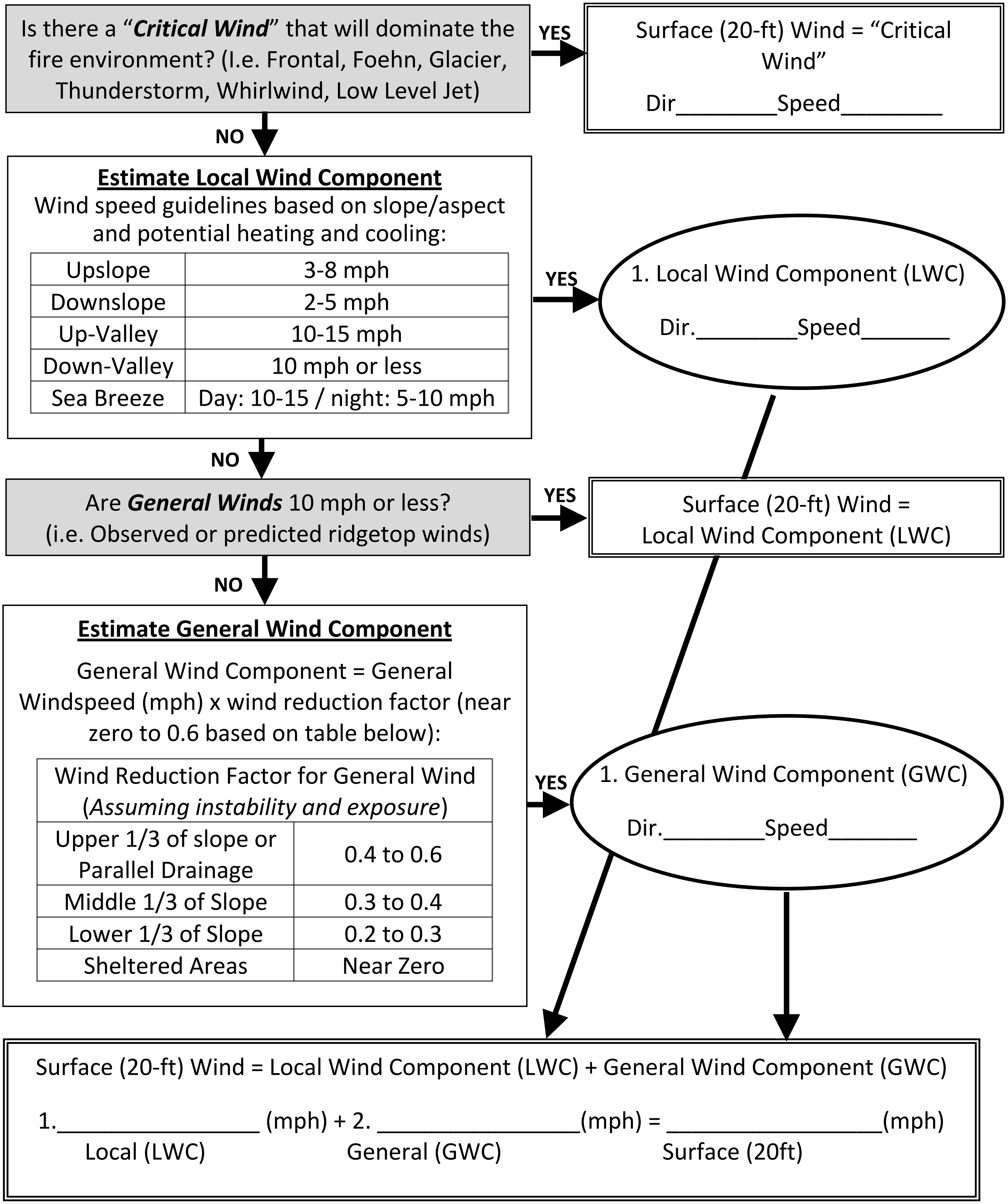


- *Forked or Bent River Drainages* are even more dominated by local winds, though the relationships are even more complex. In the daytime, look for general winds to surface primarily in several exposed stretches, creating a mosaic of stronger and weaker surface winds, depending on alignment. At night, the situation is simplified with predominately local downslope and down valley breezes. Again, beware of strong general winds that are aligned with certain sections.
- *Inversions in valleys* are very effective at preventing general winds from surfacing on the midslopes or valley floor. Light local slope and valley flow will likely be the dominant winds. Expect to adjust the 20 ft wind downward when an inversion is present. They generally form at night, but may persist through daylight hours if sunlight is diminished by smoke, fog, or cloud cover. Beware that strong general winds at night can dissipate and inversion through turbulent mixing

Special Cases

Beware of factors that produce critical winds, such as Foehn winds, barrier jets, downslope windstorms, and cold air avalanches. These may interact locally with the terrain features discussed above and result in even stronger flows.

1.2.3 Worksheet for Estimating 20-ft Surface Winds



Is there a "***Critical Wind***" that will dominate the fire environment? (I.e. Frontal, Foehn, Glacier, Thunderstorm, Whirlwind, Low Level Jet)

Surface (20-ft) Wind = "Critical Wind"

Dir________Speed________

Estimate Local Wind Component

Wind speed guidelines based on slope/aspect and potential heating and cooling:

Upslope	3-8 mph
Downslope	2-5 mph
Up-Valley	10-15 mph
Down-Valley	10 mph or less
Sea Breeze	Day: 10-15 / night: 5-10 mph

1. Local Wind Component (LWC)

Dir.________Speed_______

Are ***General Winds*** 10 mph or less?
(i.e. Observed or predicted ridgetop winds)

Surface (20-ft) Wind =
Local Wind Component (LWC)

Estimate General Wind Component

General Wind Component = General Windspeed (mph) x wind reduction factor (near zero to 0.6 based on table below):

Wind Reduction Factor for General Wind (*Assuming instability and exposure*)	
Upper 1/3 of slope or Parallel Drainage	0.4 to 0.6
Middle 1/3 of Slope	0.3 to 0.4
Lower 1/3 of Slope	0.2 to 0.3
Sheltered Areas	Near Zero

1. General Wind Component (GWC)

Dir.________Speed_______

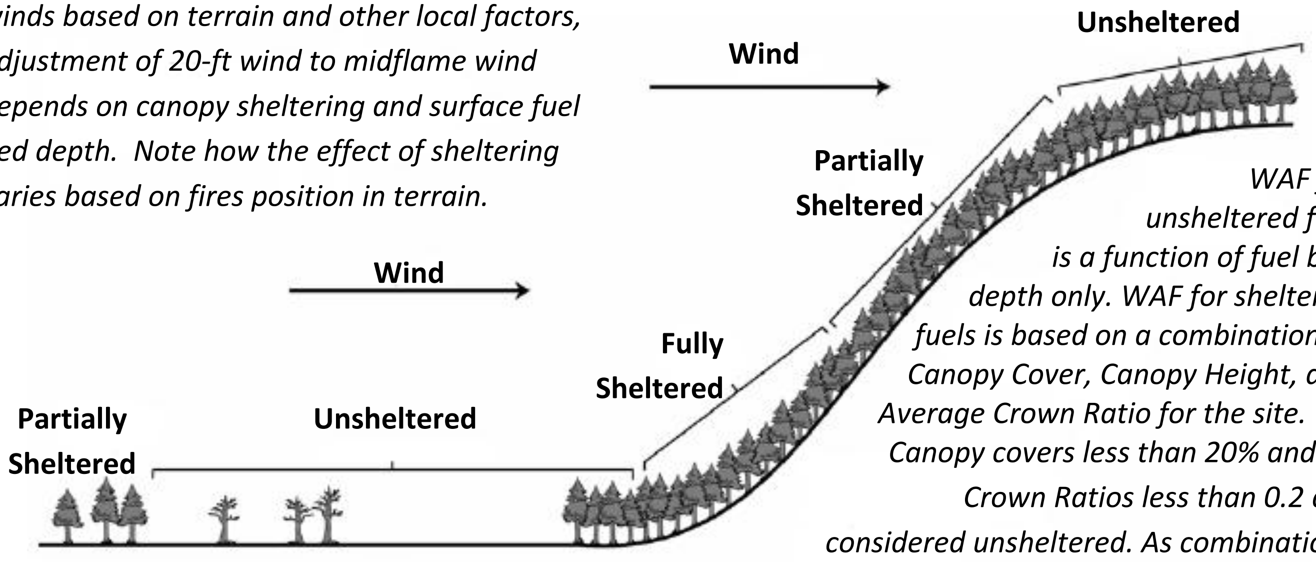
Surface (20-ft) Wind = Local Wind Component (LWC) + General Wind Component (GWC)

1.________________ (mph) + 2. ________________(mph) = _________________(mph)
Local (LWC) General (GWC) Surface (20ft)

1.2.4 Adjusting Surface (20ft) Wind to Midflame Windspeed

Sheltering Description	Wind Adj. Factor (WAF)	Fuel Models	Bed Depth	Interpretation
Unsheltered	**0.5**	Grass (gr7, gr8, gr9) Shr (4, sh4, sh5, sh7, sh8, sh9) Slash (13, sb4)	More than 2.7 ft	• Openings on level ground • On high ridges where trees offer little shelter from wind • Leafless canopy • Surface with average Crown Ratio less than 0.2 (crowns less than 20% of tree height) and Canopy Cover less than 20%
	0.4	Grass & Grass-Shrub (1, 2, 3, gr2, gr3,gr4, gr5, gr6, gs1, gs2, gs3, gs4) Shrub (5, 6, 7, sh1, sh2, sh3, sh6) Tbr-Undrsty (10, tu2, tu3) Slash (11, 12, sb1, sb2, sb3	0.9 ft to 2.7 ft	
	0.3	All Timber Litter Fuels (8, 9, tl1 thru tl9) gr1, tu1, tu4, tu5	Less than 0.9 ft	
Partially Sheltered	**0.3**	All Fuel Models	Any	• Patchy Timber • Beneath canopy at midslope or higher with wind blowing directly at slope
Full Sheltered	**0.2**	Open Canopy		• Standing timber on flat or gentle slope • Standing timber near base of mountain with steep slopes
	0.1	Dense Canopy		

Once general winds are adapted to 20-ft surface winds based on terrain and other local factors, adjustment of 20-ft wind to midflame wind depends on canopy sheltering and surface fuel bed depth. Note how the effect of sheltering varies based on fires position in terrain.



WAF for unsheltered fuel is a function of fuel bed depth only. WAF for sheltered fuels is based on a combination of Canopy Cover, Canopy Height, and Average Crown Ratio for the site. All Canopy covers less than 20% and all Crown Ratios less than 0.2 are considered unsheltered. As combinations of these factors increase, WAF becomes partially sheltered, then fully sheltered.

1.2.5 Windspeed Reduction and Adjustment Calculator

1/¼	¾/¼		¾/½	1/¾	Surface			¾			½			¼		
4.0	3.0	2.0	1.5	1.33	1.0	0.9	0.8	0.75	0.7	0.6	0.5	0.4	0.3	0.25	0.2	0.1
4	3	2	2	1	**1**	1	1	1	1	1	1	0	0	0	0	0
8	6	4	3	3	**2**	2	2	2	1	1	1	1	1	1	0	0
12	9	6	5	4	**3**	3	2	2	2	2	2	1	1	1	1	0
16	12	8	6	5	**4**	4	3	3	3	2	2	2	1	1	1	0
20	15	10	8	7	**5**	5	4	4	4	3	3	2	2	1	1	1
24	18	12	9	8	**6**	5	5	5	4	4	3	2	2	2	1	1
28	21	14	11	9	**7**	6	6	5	5	4	4	3	2	2	1	1
32	24	16	12	10	**8**	7	6	6	6	5	4	3	2	2	2	1
36	27	18	14	12	**9**	8	7	7	6	5	5	4	3	2	2	1
40	30	20	15	13	**10**	9	8	8	7	6	5	4	3	3	2	1
44	33	22	17	14	**11**	10	9	8	8	7	6	4	3	3	2	1
48	36	24	18	16	**12**	11	10	9	8	7	6	5	4	3	2	1
52	39	26	20	17	**13**	12	10	10	9	8	7	5	4	3	3	1
56	42	28	21	18	**14**	13	11	11	10	8	7	6	4	4	3	1
60	45	30	23	20	**15**	14	12	11	11	9	8	6	5	4	3	2
64	48	32	24	21	**16**	14	13	12	11	10	8	6	5	4	3	2
68	51	34	26	22	**17**	15	14	13	12	10	9	7	5	4	3	2
72	54	36	27	23	**18**	16	14	14	13	11	9	7	5	5	4	2
76	57	38	29	25	**19**	17	15	14	13	11	10	8	6	5	4	2
80	60	40	30	26	**20**	18	16	15	14	12	10	8	6	5	4	2
84	63	42	32	27	**21**	19	17	16	15	13	11	8	6	5	4	2
88	66	44	33	29	**22**	20	18	17	15	13	11	9	7	6	4	2
92	69	46	35	30	**23**	21	18	17	16	14	12	9	7	6	5	2
96	72	48	36	31	**24**	22	19	18	17	14	12	10	7	6	5	2
100	75	50	38	33	**25**	23	20	19	18	15	13	10	8	6	5	3
112	84	56	42	36	**28**	25	22	21	20	17	14	11	8	7	6	3
120	90	60	45	39	**30**	27	24	23	21	18	15	12	9	8	6	3
140	105	70	53	46	**35**	32	28	26	25	21	18	14	11	9	7	4
160	120	80	60	52	**40**	36	32	30	28	24	20	16	12	10	8	4
180	135	90	68	59	**45**	41	36	34	32	27	23	18	14	11	9	5
200	150	100	75	65	**50**	45	40	38	35	30	25	20	15	13	10	5

1.3 Temperature, Relative Humidity, and Dew Point Tables

1.3.1

Elevations between 0 and 500 feet

Dry Bulb Temperatures 41 to 60 F (Read Across)

Wet Bulb Temperatures 28 to 59 F (Read Down)

	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59
41	-36 3	-12 10	-1 17	7 24	13 32	18 39	22 44	25 53	29 61	31 68	34 74	37 84	39 92																			
42		-23 5	-7 12	3 19	10 26	15 33	20 40	23 47	27 54	30 62	33 69	35 77	38 84	40 92																		
43		-49 1	-15 8	-2 14	4 21	12 28	17 35	21 41	25 48	28 55	31 62	34 70	36 77	39 85	41 92																	
44			-29 4	-9 10	2 17	9 23	14 29	19 36	23 43	26 49	29 54	32 63	35 70	37 78	40 85	42 92																
45				-18 6	-4 12	5 19	11 25	16 31	21 37	24 44	28 51	31 57	34 64	36 71	39 78	41 85	43 93															
46				-33 2	-11 8	0 14	7 20	13 26	18 32	22 39	26 45	29 52	32 58	35 65	37 72	40 79	42 86	44 91														
47					-22 5	-6 10	3 16	10 22	16 28	20 34	24 40	27 46	31 53	33 59	36 64	38 72	41 79	43 86	45 93													
48					-45 1	-14 7	-2 12	6 18	13 24	18 29	22 35	26 41	29 47	32 54	35 60	37 64	40 71	42 79	44 84	46 93												
49						-27 3	-8 9	2 14	9 20	15 25	20 31	24 37	27 42	30 48	33 54	36 61	39 67	41 73	43 80	45 86	47 93											
50							-17 5	-3 10	5 14	12 21	17 27	21 32	25 38	29 44	32 49	35 55	37 61	40 68	42 74	44 80	46 87	48 93										
51							-33 2	-11 7	1 12	8 17	14 23	19 28	23 34	27 39	30 45	33 52	34 56	39 62	41 68	43 74	45 81	47 87	49 93									
52								-21 4	-5 9	4 14	11 19	17 24	21 29	25 35	29 40	32 44	35 51	37 57	40 63	42 69	44 75	46 81	48 87	50 94								
53								-42 1	-13 6	-1 11	8 16	14 21	19 26	23 31	27 34	30 41	33 47	36 51	39 58	41 64	43 69	45 75	47 81	49 87	51 94							
54									-25 3	-7 8	3 12	11 17	16 22	21 27	25 32	28 37	32 42	35 48	37 53	40 59	42 64	44 70	47 76	49 82	50 88	52 94						
55										-15 5	-2 9	7 14	13 19	18 24	23 28	27 34	30 38	33 41	36 49	39 54	41 59	43 65	46 70	48 76	50 82	51 88	53 94					
56										-29 2	-8 7	3 11	10 16	16 20	21 25	26 30	29 35	32 39	35 44	37 50	40 55	42 60	45 65	47 71	49 77	51 82	53 89	54 94				
57											-17 4	-3 8	6 13	13 17	18 22	23 27	27 31	30 36	33 41	36 45	39 50	41 56	44 61	46 66	48 71	50 77	52 83	54 88	55 94			
58											-33 2	-10 6	2 10	10 14	14 19	21 23	25 28	28 32	32 37	35 42	38 46	40 51	43 56	45 61	47 67	49 72	51 77	53 83	55 88	56 94		
59												-19 3	-4 7	6 12	13 16	18 21	23 24	27 29	30 33	33 38	36 43	39 47	41 52	44 57	46 62	48 67	50 72	52 78	54 83	56 89	57 94	
60												-38 1	-11 5	1 9	9 13	15 17	20 21	25 26	29 30	32 34	35 39	38 44	40 48	43 53	45 58	47 63	49 68	51 73	53 78	55 85	57 89	58 94

DP	**DP**
RH	**RH**

Wet Bulb Temperatures 23 to 40 F

Dry Bulb Temperatures

	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
31	-8 18	1 27	8 37	13 47	18 57	22 68	25 78	28 89										
32	-16 11	-4 20	4 30	10 39	15 49	19 59	23 69	26 79	29 89									
33	-31 5	-12 14	-1 23	4 32	12 41	17 51	21 60	24 70	28 80	30 90								
34		-22 8	-7 16	2 25	9 34	14 43	18 52	22 62	26 71	29 81	32 90							
35		-47 2	-16 10	-4 19	5 27	11 36	16 45	20 54	24 63	27 72	30 81	33 91						
36			-30 5	-11 13	0 21	7 29	13 38	18 47	22 55	25 64	28 73	31 82	34 91					
37				-21 7	-4 15	3 23	9 31	15 40	19 48	23 57	26 65	29 74	32 82	35 91				
38				-42 2	-14 10	-2 18	4 25	12 33	17 42	21 50	25 58	28 66	31 74	33 83	36 91			
39					-27 5	-9 12	1 20	8 28	14 35	19 43	22 51	26 59	29 67	32 75	34 83	37 92		
40						-18 7	-4 15	4 22	11 30	16 37	20 45	24 52	27 60	30 68	33 76	35 84	38 92	

Elevations between 0 and 500 feet

Wet Bulb Temperatures

40 to 79 F

(Read Down)

DP RH	DP RH

Dry Bulb Temperatures

61 to 80 F

(Read Across)

	40	41	42	43	44	45	46	46	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79
61	-21 3	-4 7	5 11	12 15	18 19	23 23	27 27	30 31	34 36	36 40	39 44	42 49	44 54	46 58	48 63	50 68	52 73	54 78	56 84	58 89	59 94																			
62	-44 1	-12 6	1 8	9 12	15 16	20 20	25 24	29 28	32 32	35 37	38 41	41 45	43 50	45 54	48 59	50 64	52 69	54 74	55 79	57 84	59 89	60 95																		
63		-23 2	-7 6	3 10	12 14	18 17	23 21	27 25	31 29	34 33	37 38	39 42	42 46	44 51	47 55	49 60	51 64	53 69	55 74	56 79	58 84	60 89	61 95																	
64		-50 1	-11 4	0 8	9 11	18 15	21 19	25 23	29 26	32 30	35 34	38 39	41 43	43 47	46 51	48 56	50 60	52 65	54 70	56 74	57 79	59 84	61 89	62 95																
65			-23 2	-5 6	5 9	12 11	18 16	23 20	27 24	31 28	34 31	37 35	40 39	42 44	45 48	47 52	49 56	51 61	53 65	55 70	57 75	59 80	60 85	62 90	63 95															
66			-57	-13 4	0 7	9 10	15 14	21 18	25 21	29 25	33 29	36 32	39 36	41 40	44 44	46 49	48 53	50 57	52 62	54 66	56 71	58 75	60 80	61 85	63 90	64 95														
67				-26 2	-6 5	5 8	12 12	18 15	23 19	27 22	31 26	34 30	37 34	40 37	43 41	45 45	47 49	50 54	52 58	54 62	55 66	57 71	59 76	61 80	62 85	64 90	65 95													
68					-14 3	0 7	9 10	16 13	21 17	25 20	29 24	33 27	36 31	39 34	42 38	44 42	47 46	49 50	51 54	53 58	55 63	57 67	58 71	60 76	62 81	63 85	65 91	67 95												
69					-26 2	-6 5	5 8	13 11	19 14	23 18	28 21	31 23	35 28	38 32	41 35	43 39	44 43	48 47	50 51	52 55	54 59	56 63	58 67	60 72	61 76	63 81	64 85	66 90	68 95											
70						-14 3	0 6	9 9	16 12	21 16	26 19	30 22	33 26	36 29	39 33	42 36	45 40	47 44	49 48	51 51	53 55	55 60	57 64	59 68	61 72	62 77	64 81	66 86	67 90	69 95										
71						-26 2	-5 5	5 8	13 11	19 14	24 17	28 20	32 23	35 27	38 30	41 34	44 37	46 41	48 45	51 48	53 52	55 54	56 60	58 64	60 68	62 73	63 77	65 81	67 86	68 90	70 95									
72							-13 3	1 6	10 9	16 12	22 15	26 18	30 21	34 24	37 29	40 31	43 35	45 38	47 42	50 45	52 49	54 53	56 57	58 61	59 65	61 69	63 73	64 77	66 82	68 85	69 91	71 95								
73							-26 2	-5 4	6 7	13 10	19 13	24 16	29 19	32 22	36 25	39 29	41 32	44 35	47 39	49 42	51 44	53 50	55 53	57 57	59 61	61 65	62 69	64 73	66 77	67 82	69 84	70 91	72 95							
74								-13 1	1 6	10 8	17 11	22 14	27 17	31 20	34 23	37 24	40 30	43 33	46 34	48 40	50 43	52 47	54 50	56 54	58 58	60 62	62 66	63 70	65 74	67 78	68 82	70 84	71 91	73 95						
75								-25 2	-4 4	6 7	14 10	20 12	25 15	29 18	33 21	34 24	39 27	42 31	45 34	47 37	49 40	52 44	54 47	56 51	58 55	59 58	61 62	63 66	65 70	66 74	68 78	69 82	71 87	72 91	74 95					
76								-57	-12 3	2 5	11 8	17 11	23 14	27 16	31 19	35 22	38 25	41 28	44 31	46 35	49 38	51 41	53 45	55 48	57 52	59 55	61 59	62 63	64 64	66 70	67 74	69 78	70 82	72 87	73 91	75 95				
77									-23 2	-3 4	7 7	15 9	21 12	25 15	30 18	33 20	37 23	40 24	43 29	45 32	48 35	50 39	52 42	54 45	56 49	58 52	60 54	62 59	63 63	65 67	67 71	68 75	70 79	71 83	73 87	74 91	76 94			
78									-49	-11 3	3 5	12 8	18 10	23 13	28 16	32 19	35 21	39 24	41 27	44 30	47 33	49 36	51 39	53 43	56 46	57 49	59 53	61 56	63 60	65 63	66 67	68 71	69 75	71 79	72 83	74 87	75 91	77 94		
79										-21 2	-2 4	8 6	15 9	21 12	26 14	30 17	34 20	37 22	40 25	43 28	44 31	48 34	51 37	53 40	55 43	57 47	59 50	61 53	62 57	64 60	66 64	67 68	69 71	70 75	72 79	73 83	75 87	76 91	78 94	
80										-43	-9 3	4 5	12 8	19 10	24 13	29 15	33 18	36 21	39 23	42 26	45 29	47 32	50 35	52 38	54 41	56 44	58 47	60 50	62 54	64 57	65 61	67 64	68 68	70 72	72 75	73 79	74 83	76 87	77 91	79 94

Elevations between 0 and 500 feet

Wet Bulb Temperatures

50 to 90 F

(Read Down)

	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
81	-19 2	-1 4	9 6	16 9	22 11	27 14	31 16	35 19	38 21	41 24	44 27	46 30	49 33	51 35	53 38	55 42	57 45	59 48	61 51	63 54	65 58	66 61	68 65	70 68	71 72	73 76	74 80	76 83	77 87	78 92	80 96															
82	-37 1	-7 3	5 5	13 7	20 10	25 12	29 15	33 17	37 20	40 22	43 25	45 28	48 31	50 33	53 36	55 39	57 42	59 45	61 48	62 52	64 55	66 58	68 62	69 65	71 69	72 72	74 76	75 80	77 84	78 88	79 95	81 94														
83		-16 2	0 4	10 6	17 9	23 11	28 13	32 16	35 18	39 21	42 23	44 26	47 29	50 31	52 34	54 37	56 40	58 43	60 46	62 49	64 52	65 55	67 59	69 62	70 65	72 69	73 73	75 76	76 80	78 84	79 88	80 92	82 96													
84		-31 1	-6 3	6 5	14 7	21 10	26 12	30 14	34 17	37 19	41 22	43 24	46 27	49 29	51 32	53 35	55 38	57 41	59 43	61 46	63 50	65 53	67 56	68 59	70 62	71 66	73 69	74 73	76 76	77 80	79 84	80 88	81 92	83 96												
85			-14 2	2 4	11 6	18 8	24 11	28 13	33 15	36 18	39 20	42 22	45 25	48 28	50 30	53 33	55 34	57 38	59 41	61 44	63 47	64 50	66 53	68 56	69 60	71 63	72 66	74 70	75 73	77 77	78 80	80 84	81 88	82 92	84 96											
86			-26 1	-4 3	8 5	15 7	22 9	27 12	31 14	35 16	38 18	41 21	44 23	47 26	49 28	52 31	54 34	56 36	58 39	60 42	62 45	64 48	66 51	67 54	69 57	70 60	72 63	74 67	75 70	77 73	78 77	79 81	81 84	82 88	83 92	85 96										
87				-11 2	3 4	12 6	19 8	25 10	29 13	33 15	37 17	40 19	43 22	44 24	49 27	51 29	53 32	55 34	58 37	59 40	61 42	63 45	65 48	67 51	68 54	70 57	72 60	73 64	75 67	76 70	78 74	79 77	80 81	82 84	83 88	84 92	86 94									
88				-22 1	-2 3	9 5	17 7	23 9	28 11	32 13	36 16	39 18	42 20	45 22	48 25	50 27	53 30	55 32	57 35	59 38	61 40	63 43	64 46	66 49	68 52	70 55	71 58	73 61	74 64	76 67	77 71	79 74	80 77	81 81	83 85	84 88	85 92	87 94								
89				-45 1	-8 2	5 4	14 6	20 8	26 10	30 12	34 14	38 17	41 19	44 21	47 23	49 26	52 28	54 30	56 33	58 36	60 38	62 41	64 44	66 46	67 49	69 52	71 55	72 58	74 61	75 64	77 68	78 71	80 74	81 78	82 81	84 85	85 88	86 92	88 94							
90					-17 1	0 3	11 5	18 7	24 9	29 11	33 13	37 15	40 17	43 20	44 22	48 24	51 26	53 29	55 31	58 34	60 36	62 39	63 41	65 44	67 47	69 50	70 53	72 55	73 58	75 62	76 65	78 68	79 71	81 74	82 78	84 81	85 85	86 89	87 92	89 96						
91					-34 1	-5 2	7 4	15 6	22 8	27 10	31 12	35 14	39 16	42 18	45 20	48 23	50 25	53 27	55 29	57 32	59 34	61 37	63 39	65 42	66 45	68 47	70 50	71 53	73 56	75 59	76 62	78 65	79 68	80 71	82 75	83 78	85 82	86 85	87 89	88 92	90 96					
92						-13 2	3 3	12 5	19 7	25 9	30 11	34 13	37 15	41 17	44 19	47 21	49 23	52 26	54 28	56 30	58 33	60 35	62 37	64 40	66 43	68 45	69 48	71 51	73 53	74 56	76 59	77 62	79 65	80 68	82 72	83 75	84 78	86 82	87 85	88 89	89 92	91 96				
93						-26 1	-3 3	9 4	17 6	23 8	28 10	32 12	36 14	40 16	43 18	46 20	48 22	51 24	53 26	56 28	58 31	60 33	62 36	64 38	65 41	67 43	69 46	71 48	72 51	74 54	75 57	77 60	78 63	80 66	81 69	83 72	84 75	85 78	87 82	88 85	89 89	91 93	92 96			
94							-10 2	5 3	14 5	21 7	26 9	31 11	35 13	38 14	42 16	45 18	48 21	50 23	53 25	55 27	57 29	59 31	61 34	63 36	65 39	67 41	68 44	70 46	72 49	73 52	75 54	76 57	78 60	79 63	81 66	82 69	84 72	85 75	86 79	88 82	89 85	90 89	92 93	93 96		
95							-20 1	0 3	11 4	18 6	24 8	29 10	33 11	37 13	41 15	44 17	47 19	49 21	52 23	54 25	56 28	59 30	61 32	63 34	64 37	66 39	68 42	70 44	71 47	73 49	75 52	76 55	78 57	79 60	81 63	82 66	83 69	85 72	86 76	87 79	89 82	90 86	91 89	93 91	94 96	
96							-39 1	-6 2	7 4	15 5	22 7	27 9	32 10	36 12	39 14	43 16	46 18	48 20	51 22	53 24	56 26	58 28	60 30	62 33	64 35	66 37	68 40	69 42	71 45	73 47	74 50	76 52	77 55	79 58	80 61	82 64	83 67	84 70	86 73	87 74	88 79	90 82	91 86	92 89	94 93	95 96
97								-14 1	2 3	12 4	20 6	25 8	30 10	35 11	38 13	42 15	45 17	48 19	50 21	53 23	55 25	57 27	59 29	61 31	63 33	65 36	67 38	69 40	71 43	72 45	74 48	75 50	77 53	78 55	80 58	81 61	83 64	84 67	85 70	87 73	88 76	89 79	91 83	92 86	93 89	95 93
98								-28 1	-3 2	9 4	17 5	23 7	29 9	33 10	37 12	40 14	44 16	47 18	49 19	52 21	54 23	57 25	59 27	61 30	63 32	65 34	67 36	68 38	70 41	72 43	73 46	75 48	77 51	78 53	80 56	81 59	82 61	84 64	85 67	87 70	88 73	89 76	91 79	92 83	93 86	94 89
99									-10 1	5 3	14 5	21 6	27 8	32 9	36 11	39 13	43 15	46 16	48 18	51 20	54 22	56 24	58 26	60 28	62 30	64 32	66 34	68 37	70 39	71 41	73 44	75 46	76 48	78 51	79 54	81 56	82 59	84 62	85 65	86 67	88 70	89 73	90 76	92 80	93 83	94 86
100									-20 1	0 2	11 4	19 5	25 7	30 9	34 10	38 12	42 14	45 15	48 17	50 19	53 21	55 23	57 25	60 27	62 29	64 31	66 33	67 35	69 37	71 39	73 42	74 44	76 46	77 49	79 51	80 54	82 57	83 59	85 62	86 65	87 68	89 71	90 74	91 77	93 80	94 83

DP	DP
RH	RH

Dry Bulb Temperatures

81 to 100 F

(Read Across)

Elevations between 0 and 500 feet

Wet Bulb Temperatures, 58 to 95 F

(Read Down)

	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
101	-40	-6 2	8 3	16 5	23 6	28 8	33 9	37 11	40 13	44 14	47 16	49 18	52 20	54 21	57 23	59 25	61 27	63 29	65 31	67 33	69 36	70 38	72 40	74 42	75 45	77 47	79 49	80 52	81 54	83 57	84 60	86 62	87 65	88 68	90 71	91 74	92 77	94 80
102		-14 1	3 3	13 4	21 5	26 7	31 9	36 10	39 12	43 13	46 15	49 17	51 18	54 20	56 22	58 24	61 26	63 28	65 30	66 32	68 34	70 36	72 38	73 40	75 43	77 45	78 47	80 50	81 52	83 55	84 57	86 60	87 63	88 65	90 68	91 71	92 74	93 77
103		-26 1	-2 2	10 3	18 5	24 6	30 8	34 9	38 11	42 12	45 14	48 16	50 17	53 19	55 21	58 23	60 25	62 26	64 28	66 30	68 32	70 34	71 37	73 39	75 41	76 43	78 45	79 48	81 50	82 53	84 55	85 58	87 60	88 63	89 66	91 68	92 71	93 74
104			-8 1	6 3	15 4	22 6	26 7	33 9	37 10	40 12	44 13	47 15	50 16	52 18	55 20	57 22	59 23	61 25	63 27	65 29	67 31	69 33	71 35	73 37	74 39	76 41	77 44	79 46	80 48	82 51	83 53	85 55	86 58	88 61	89 63	90 66	92 69	93 72
105			-18 1	2 2	12 4	20 5	26 6	31 8	35 9	39 11	43 12	46 14	49 15	51 17	55 19	56 20	59 22	61 24	63 26	65 28	67 30	69 31	70 33	72 35	74 38	75 40	77 42	79 44	80 46	82 49	83 51	85 53	86 56	87 58	89 61	90 63	91 66	93 69
106			-34	-4 2	9 3	18 4	24 6	29 7	34 8	38 10	42 11	45 13	48 14	51 16	53 18	56 19	58 21	60 23	62 25	64 26	66 28	68 30	70 32	72 34	73 36	75 38	77 40	78 42	80 44	81 47	83 49	84 51	86 54	87 56	88 59	90 61	91 64	92 66
107				-11 1	5 2	15 4	22 5	28 6	33 8	37 9	41 11	44 12	47 14	50 15	53 17	55 18	57 20	60 22	62 23	64 25	66 27	68 29	70 31	71 32	73 34	75 36	76 38	78 41	79 43	81 45	83 47	84 49	85 52	87 54	88 56	90 59	91 61	92 64
108				-22 1	0 2	12 3	20 4	26 6	31 7	35 8	39 10	43 11	46 13	49 14	52 16	54 17	57 19	59 21	61 22	63 24	65 26	67 27	69 29	71 31	73 33	74 35	76 37	78 39	79 41	81 43	82 45	84 47	85 50	87 52	88 54	89 57	91 59	92 62
109				-46	-6 1	8 3	17 4	24 5	29 6	34 8	38 9	42 11	45 12	48 13	51 15	54 16	56 18	58 20	61 21	63 23	65 24	67 26	69 28	70 30	72 32	74 33	76 35	77 37	79 39	80 41	82 43	83 46	85 48	86 50	88 52	89 55	90 57	92 60
110					-14 1	4 2	14 3	22 5	28 6	33 7	37 8	41 10	44 11	47 13	50 14	53 15	55 17	58 19	60 20	62 22	64 23	66 25	68 27	70 28	72 30	74 32	75 34	77 36	78 38	80 40	82 42	83 44	85 46	86 48	87 50	89 53	90 55	91 57
111					-26	-1 2	11 3	19 4	26 5	31 6	36 8	39 9	43 10	46 12	49 13	52 15	55 16	57 18	59 19	62 21	64 22	66 24	68 26	70 27	71 29	73 31	75 33	76 34	78 36	80 38	81 40	83 42	84 44	86 46	87 49	89 51	90 53	91 55
112						-7 1	8 2	17 3	24 5	29 6	34 7	38 8	42 10	45 11	48 12	51 14	54 15	56 17	59 18	61 20	63 21	65 23	67 24	69 26	71 28	73 29	74 31	76 33	78 35	79 37	81 39	82 41	84 43	85 45	87 47	88 49	90 51	91 53
113						-16 1	3 2	14 3	22 4	28 5	33 7	37 8	41 9	44 10	48 12	50 13	53 14	56 16	58 17	60 19	63 20	65 22	67 23	69 25	70 27	72 28	74 30	76 32	77 33	79 35	81 37	82 39	84 41	85 43	87 45	88 47	89 49	91 51
114						-31	-2 1	11 3	19 4	26 5	31 6	36 7	40 8	43 10	47 11	50 12	52 14	55 15	57 16	60 18	62 19	64 21	66 22	68 24	70 25	72 27	74 29	75 30	77 32	79 34	80 36	82 38	83 39	85 41	86 43	88 45	89 47	91 50
115							-9 1	7 2	17 3	24 4	29 5	34 7	39 8	42 9	46 10	49 12	52 13	54 14	57 16	59 17	61 18	64 20	66 21	68 23	70 24	71 26	73 28	75 29	77 31	78 33	80 34	81 36	83 38	85 40	86 42	87 44	89 46	90 48
116							-18 1	3 2	14 3	22 4	28 5	33 6	37 7	41 8	45 10	48 11	51 12	54 13	56 15	59 16	61 17	63 19	65 20	67 22	69 23	71 25	73 26	75 28	76 30	78 31	80 33	81 35	83 37	84 38	86 40	87 42	89 44	90 46
117							-35	-3 1	11 2	19 3	26 4	31 6	36 7	40 8	44 9	47 10	50 11	53 13	55 14	58 15	60 17	63 18	65 19	67 21	69 22	71 24	72 25	74 27	76 28	78 30	79 32	81 33	82 35	84 37	85 39	87 41	88 43	90 44
118								-9 1	7 2	17 3	24 4	30 5	35 6	39 7	43 8	46 10	49 11	52 12	55 13	57 15	60 16	62 17	64 19	66 20	68 21	70 23	72 24	74 26	76 27	77 29	79 31	80 32	82 34	84 36	85 37	87 39	88 41	89 43
119								-19 1	2 1	14 2	22 4	28 5	33 6	38 7	42 8	45 9	48 10	51 11	54 13	57 14	59 15	61 16	64 18	66 19	68 20	70 22	72 23	73 25	75 26	77 28	79 29	80 31	82 33	83 34	85 36	86 38	88 40	89 41

DP	DP
RH	RH

Dry Bulb Temperatures

101 to 119 F

(Read Across)

1.3.2

Elevations between 501 and 1,900 feet

Wet Bulb Temperatures
28 to 59 F
(Read Down)

Dry Bulb Temperatures
41 to 60 F
(Read Across)

DP	DP
RH	RH

	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59
41	-26 5	-9 11	1 18	8 24	14 33	18 40	22 47	26 54	29 61	32 69	34 77	37 84	39 92																			
42		-18 7	-4 14	5 21	11 28	16 34	20 41	24 48	27 55	30 62	33 70	35 77	38 85	40 92																		
43		-33 3	-11 9	0 16	8 23	13 29	18 36	22 42	25 49	28 54	31 63	34 70	36 78	39 85	41 92																	
44			-21 5	-6 12	3 18	10 24	13 31	20 37	23 44	27 50	30 57	33 64	35 71	38 78	40 85	42 93																
45			-42 2	-13 8	-1 14	6 20	12 26	17 32	21 39	25 45	28 51	31 58	34 65	36 72	39 78	41 86	43 93															
46				-25 4	-7 10	2 16	9 22	14 28	19 34	23 40	26 46	30 52	32 59	35 65	38 72	40 79	42 86	44 93														
47				-36 1	-16 6	-3 12	5 18	11 23	17 29	21 35	25 41	28 47	31 53	34 60	36 66	39 73	41 79	43 86	45 93													
48					-29 3	-10 8	1 14	8 19	14 25	19 31	23 36	26 42	29 48	32 54	35 60	38 67	40 73	42 80	44 86	46 93												
49						-19 5	-5 10	4 16	11 21	16 26	20 32	24 38	28 43	31 49	34 55	36 61	39 67	41 74	43 80	45 87	47 93											
50						-37 2	-12 7	-1 12	7 17	13 22	18 28	22 33	26 39	29 44	32 50	35 56	38 62	40 68	42 74	44 80	46 87	48 93										
51							-23 4	-6 9	3 14	10 19	15 24	20 29	24 35	28 40	31 46	34 51	36 57	39 63	41 69	43 75	45 81	47 87	49 93									
52							-47 1	-14 6	-2 11	6 15	13 20	18 25	22 31	26 36	29 41	32 47	35 52	38 58	40 63	42 69	44 75	46 81	48 87	50 94								
53								-27 3	-8 7	2 12	9 17	15 22	20 27	24 32	27 37	31 42	34 48	36 53	39 58	41 64	43 70	46 76	48 82	49 88	51 96							
54									-17 5	-3 9	6 14	12 19	17 23	22 28	26 33	29 38	32 43	35 49	38 54	40 59	42 65	45 70	47 76	49 82	50 88	52 94						
55									-32 2	-10 6	1 11	9 15	15 20	20 25	24 30	27 34	31 39	34 44	36 49	39 55	41 60	44 65	46 71	48 76	50 82	52 88	53 94					
56										-19 4	-4 8	5 13	12 17	17 21	22 26	26 31	29 36	32 40	35 45	38 50	40 55	43 61	45 66	47 71	49 77	51 82	53 88	54 94				
57										-37 1	-11 4	1 10	8 14	14 18	19 23	24 27	27 32	31 37	34 41	37 46	39 51	42 56	44 61	46 67	48 72	50 77	52 83	54 88	55 94			
58											-21 3	-5 7	5 11	11 16	17 20	22 24	26 29	29 33	32 38	35 42	38 47	40 52	43 57	45 62	47 67	49 72	51 78	53 83	55 89	56 94		
59											-43 1	12 5	0 9	8 13	14 17	19 21	24 25	28 30	31 34	34 39	37 43	39 48	42 53	44 58	46 63	48 68	50 73	52 78	54 83	56 89	57 94	
60												-24 3	-6 7	4 10	11 14	17 18	22 22	26 27	29 31	33 35	36 40	38 44	41 49	43 54	45 58	47 63	49 68	51 73	53 78	55 83	57 88	58 94

Wet Bulb Temperatures

Dry Bulb Temperatures

	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
31	-37 1	-19 10	-8 20	2 29	9 38	14 48	18 58	22 68	25 78	28 89									
32		-34 4	-13 13	-3 22	5 31	11 40	15 50	20 60	23 69	26 79	29 90								
33			-25 7	-9 15	0 24	7 33	13 42	17 52	21 61	25 71	28 80	30 90							
34			-36 1	-18 9	-5 18	3 26	9 35	14 44	19 53	23 62	26 72	29 81	32 91						
35				-34 4	-13 12	-2 20	4 29	11 37	16 46	20 55	24 64	27 73	30 82	33 91					
36					-14 6	-8 14	1 22	8 31	14 39	18 48	22 54	25 65	28 74	31 82	34 91				
37					-50 1	-17 9	-4 17	4 25	10 33	15 41	20 49	24 58	27 66	30 74	32 83	35 91			
38						-31 4	-11 11	0 19	7 27	13 35	17 43	21 51	25 59	28 67	31 75	33 83	34 91		
39							-21 7	-6 14	3 21	9 29	15 37	19 44	23 52	26 60	29 67	32 75	34 83	37 92	
40							-42 2	-14 9	-2 16	6 23	12 31	17 38	21 46	24 53	28 61	30 68	33 76	36 84	38 92

Elevations between 501 and 1,900 feet

Wet Bulb Temperatures
39 to 80 F
(Read Down)

Dry Bulb Temperatures
61 to 80 F
(Read Across)

DP	DP
RH	RH

	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60																				
61	-50 1	-14 4	-1 8	8 12	14 16	19 20	24 24	28 28	31 32	34 34	37 41	40 45	42 50	44 54	47 59	49 64	51 69	53 74	54 79	56 84	58 89	59 95	**61**																			
62		-25 2	-6 6	4 10	11 13	17 17	22 21	26 25	30 29	33 33	34 37	38 42	41 44	43 50	44 55	48 60	50 64	52 69	54 74	55 79	57 84	59 89	60 95	**62**																		
63		-54	-14 4	-1 7	8 11	14 15	20 19	24 22	28 24	31 30	34 34	37 38	40 43	42 47	45 51	47 56	49 60	51 65	53 70	55 74	57 79	58 84	60 89	61 95	**63**																	
64			-27 2	-7 5	4 9	11 12	17 14	22 20	26 24	30 27	33 31	34 35	39 39	41 43	44 48	46 52	48 54	50 61	52 65	54 70	56 75	58 80	59 85	61 90	62 95	**64**																
65				-15 3	-1 7	8 10	14 14	20 17	24 21	28 25	32 29	35 32	38 34	40 40	43 44	45 48	47 53	49 57	51 61	53 64	55 70	57 75	59 80	60 85	62 90	63 95	**65**															
66				-28 2	-7 5	4 8	11 12	17 15	22 19	24 22	30 26	33 30	36 33	39 37	42 41	44 45	46 49	49 53	51 58	53 62	54 64	56 71	58 74	60 80	61 85	63 90	64 95	**66**														
67					-15 3	-1 6	8 10	15 13	20 16	24 20	28 23	32 27	35 31	38 34	41 38	43 42	44 46	48 50	50 54	52 58	54 63	56 67	57 71	59 76	61 80	62 85	64 90	66 95	**67**													
68					-29 2	-7 5	4 8	12 11	18 14	22 18	27 21	30 24	34 28	37 32	40 35	42 39	45 43	47 47	49 51	51 55	53 59	55 63	57 67	59 72	60 76	62 81	63 85	65 90	67 95	**68**												
69						-15 3	-1 4	8 9	15 12	20 16	25 19	29 22	32 24	35 29	38 33	41 34	44 40	46 44	48 47	50 51	52 55	54 59	56 64	58 68	60 72	61 77	63 81	65 84	66 90	68 95	**69**											
70						-29 1	-7 4	4 7	12 10	18 14	23 17	27 20	31 23	34 27	37 30	40 34	43 37	45 41	47 44	50 48	52 52	54 56	55 60	57 64	59 68	60 72	62 77	64 81	66 86	67 90	69 95	**70**										
71							-15 3	0 6	9 9	15 12	21 15	25 18	29 21	33 24	34 28	39 31	42 34	44 38	46 42	49 45	51 49	53 53	55 57	57 60	58 65	60 69	62 73	63 77	65 82	67 86	68 91	70 95	**71**									
72							-28 1	-6 4	5 7	12 10	18 13	23 16	28 19	31 22	35 25	38 29	40 32	43 35	44 39	48 42	50 44	52 50	54 53	56 57	58 61	60 65	61 69	63 73	65 77	66 82	68 86	69 91	71 95	**72**								
73								-14 3	0 5	9 8	16 11	21 14	26 17	30 20	33 23	34 26	39 30	42 33	45 36	47 40	49 43	51 47	53 50	55 55	57 58	59 62	61 65	62 69	64 74	66 78	67 82	69 84	70 91	72 95	**73**							
74								-27 1	-4 4	5 7	13 10	19 12	24 15	28 18	32 21	35 24	38 27	41 30	44 34	46 37	48 40	51 44	53 47	55 51	57 54	58 58	60 62	62 64	64 70	65 74	67 78	68 82	70 87	71 91	73 95	**74**						
75									-13 3	1 5	10 8	16 11	22 13	26 16	30 19	34 22	37 25	40 28	43 31	45 35	48 38	50 41	52 44	54 48	56 51	58 55	60 59	61 62	63 66	65 70	66 74	68 78	69 82	71 87	72 91	74 95	**75**					
76									-25 1	-5 4	4 7	14 9	20 12	24 15	29 17	32 20	34 23	39 26	42 29	44 32	47 35	49 39	51 42	53 45	55 49	57 52	59 56	61 59	62 63	64 67	66 71	67 75	69 79	70 83	72 87	73 91	75 96	**76**				
77									-57	-12 3	2 5	10 8	17 10	22 13	27 16	31 18	34 21	38 24	41 27	43 30	46 33	48 36	50 39	53 43	55 46	57 49	58 53	60 56	62 60	64 63	65 67	67 71	68 75	70 79	71 83	73 87	74 91	76 96	**77**			
78										-23 1	-4 4	7 6	14 9	20 11	25 14	29 17	33 19	36 22	39 25	42 28	45 31	47 34	50 37	52 40	54 43	56 46	58 50	60 53	61 57	63 60	65 64	66 67	68 71	69 75	71 79	72 83	74 87	75 91	77 96	**78**		
79										-48	-11 3	3 5	11 8	18 10	23 13	28 15	32 18	35 20	38 23	41 26	44 29	46 32	49 35	51 38	53 41	55 44	57 47	59 50	61 54	63 57	64 61	66 64	67 68	69 72	71 75	72 79	73 83	75 87	76 91	78 96	**79**	
80											-21 2	-2 4	8 6	15 9	21 11	26 14	30 16	34 19	37 21	40 24	43 27	45 30	48 32	50 35	52 38	54 41	56 45	58 48	60 51	62 54	64 58	65 61	67 65	69 68	70 72	72 76	73 79	75 83	76 87	77 92	79 96	**80**

Elevations between 501 and 1,900 feet

Wet Bulb Temperatures
49 to 91 F
(Read Down)

DP RH	DP RH

Dry Bulb Temperatures
81 to 100 F
(Read Across)

	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80															
81	-40 1	-9 3	4 5	12 7	19 10	24 12	28 15	32 17	34 20	39 22	42 25	45 28	47 30	49 33	52 36	54 39	56 42	58 45	60 48	61 51	63 55	65 58	67 62	68 65	70 69	71 72	73 76	74 80	76 84	77 88	78 92	80 96	**81**														
82		-18 2	-1 4	9 6	16 8	22 10	27 13	31 16	34 18	38 21	41 23	44 26	46 28	49 31	51 34	53 37	55 40	57 43	59 46	61 49	63 52	64 55	66 59	68 62	69 65	71 69	72 73	74 76	75 80	77 84	78 88	79 92	81 96	**82**												
83		-34 1	-7 3	5 5	13 7	20 9	25 12	29 14	33 17	34 19	40 21	43 24	45 27	48 29	50 32	52 35	54 38	56 40	58 43	60 46	62 49	64 53	66 56	67 59	69 62	70 66	72 69	73 73	75 76	76 80	78 84	79 88	80 92	82 96	**83**												
84			-15 2	1 4	10 6	17 8	23 10	27 13	32 15	35 17	38 20	41 22	44 25	47 27	49 30	52 33	54 35	56 38	58 41	60 44	62 47	63 50	65 53	67 56	68 59	70 63	71 66	73 70	74 73	76 77	77 80	79 84	80 88	81 92	83 96	**84**											
85			-29 1	-5 3	7 5	14 7	21 9	26 11	30 14	34 16	37 18	40 21	43 23	46 26	48 28	51 31	53 33	55 36	57 39	59 42	61 45	63 47	65 50	66 54	68 57	69 60	71 63	73 66	74 70	76 73	77 77	78 81	80 84	81 88	82 92	84 96	**85**										
86				-12 2	2 4	11 6	18 8	24 10	28 12	32 15	36 17	39 19	42 22	45 24	48 26	50 29	52 32	54 34	57 37	59 40	60 42	62 45	64 48	66 51	67 54	69 57	71 60	72 64	74 67	75 70	77 74	78 77	79 81	81 84	82 88	83 92	85 96	**86**									
87				-24 1	-3 3	6 5	16 7	22 9	27 11	31 13	35 16	38 18	41 20	44 22	47 25	49 27	52 30	54 32	56 35	58 37	60 40	62 43	64 46	65 49	67 51	69 54	70 58	72 61	73 64	75 67	76 70	78 74	79 77	80 81	82 85	83 88	84 92	86 96	**87**								
88				-50	-10 2	4 4	13 6	16 8	25 10	29 12	33 14	37 16	40 19	43 21	46 23	48 26	51 28	53 30	55 33	57 35	59 38	61 41	63 43	65 46	66 49	68 52	70 55	71 58	73 61	74 64	76 67	77 71	79 74	80 78	81 81	83 85	84 88	85 92	87 96	**88**							
89					-19 1	-1 3	10 5	17 7	23 9	28 11	32 13	36 15	39 17	42 19	45 22	48 24	50 26	52 29	55 31	57 34	59 36	61 39	62 41	64 44	66 47	68 50	69 52	71 55	72 58	74 61	76 65	77 68	78 71	80 74	81 78	83 81	84 85	85 88	86 92	88 96	**89**						
90					-37	-7 2	6 4	14 6	21 8	26 10	30 12	34 14	38 16	41 18	44 20	47 22	49 25	52 27	54 29	56 32	58 34	60 37	62 39	64 42	66 45	67 47	69 50	71 53	72 56	74 59	75 62	77 65	78 68	79 71	81 75	82 78	84 82	85 85	86 89	87 92	89 96	**90**					
91						-15 1	1 3	11 5	18 7	24 9	29 11	33 13	37 15	40 17	43 19	46 21	48 23	51 25	53 28	55 30	57 32	59 35	61 37	63 40	65 42	67 45	68 48	70 51	72 53	73 56	76 59	78 62	79 65	81 68	82 72	83 75	85 78	86 82	87 85	88 89	90 92	90 96	**91**				
92						-28 1	-4 2	8 4	16 6	22 8	27 10	31 12	35 14	39 16	42 18	45 20	47 22	50 24	52 26	55 28	57 31	59 33	61 35	63 38	65 40	66 43	68 46	70 48	71 51	73 54	74 57	76 60	77 63	79 66	80 69	82 72	83 75	84 78	86 82	87 85	88 89	90 92	91 96	**92**			
93							-11 2	4 3	13 5	20 7	25 9	30 11	34 12	38 14	41 16	44 18	47 20	49 23	52 25	54 27	56 29	58 31	60 34	62 36	64 38	66 41	68 43	69 46	71 49	72 51	74 54	76 57	77 60	78 63	80 66	81 69	83 72	84 75	85 79	87 82	88 85	89 89	91 93	92 96	**93**		
94							-21 1	-1 3	10 4	17 6	23 8	28 10	32 11	36 13	40 15	43 17	46 19	48 21	51 23	53 25	55 28	58 30	60 32	62 34	63 37	65 39	67 41	69 44	70 47	72 49	74 52	75 55	77 57	78 60	80 63	81 66	82 69	84 72	85 76	86 79	88 82	89 86	90 89	92 93	93 96	**94**	
95							-43	-7 2	6 4	14 5	21 7	26 9	31 10	35 12	39 14	42 16	45 18	47 20	50 22	52 24	55 26	57 28	59 30	61 33	63 35	65 37	67 40	68 42	70 45	72 47	73 50	75 52	76 55	78 58	79 61	81 64	82 66	83 70	85 73	86 76	87 79	89 82	90 86	91 89	93 93	94 96	**95**
96								-16 1	1 3	11 4	19 6	25 8	29 9	34 11	37 13	41 15	44 17	47 19	49 21	52 23	54 25	56 27	58 29	60 31	62 33	64 35	66 38	68 40	70 43	71 45	73 48	74 50	76 53	77 55	79 58	80 61	82 64	83 67	85 70	86 73	87 76	88 79	90 82	91 86	92 89	94 93	95 96
97								-30 1	-4 2	8 4	16 5	23 7	28 9	32 10	36 12	40 14	43 16	46 17	48 19	51 21	53 23	56 25	58 27	60 29	62 32	64 34	66 36	67 38	69 41	71 43	72 45	74 48	76 51	77 53	79 56	80 59	81 61	83 64	84 67	86 70	87 73	88 76	90 79	91 83	92 86	93 89	95 93
98									-11 1	4 3	13 5	20 6	26 8	31 9	35 11	38 13	42 15	45 16	48 18	50 20	53 22	55 24	57 26	59 28	61 30	63 32	65 34	67 37	69 39	70 41	72 44	74 46	75 48	77 51	78 54	80 56	81 59	83 62	84 64	85 67	87 70	88 73	89 76	91 80	92 83	93 86	94 89
99									-21 1	-1 2	10 4	18 5	24 7	29 9	33 10	37 12	41 14	44 15	47 17	49 19	52 21	54 23	57 25	59 27	61 29	63 31	65 33	66 35	68 37	70 39	72 42	73 44	75 46	76 49	78 51	79 54	81 57	82 59	84 62	85 65	86 68	88 71	89 74	90 77	92 80	93 83	94 86
100									-43	-7 2	4 3	15 5	22 6	27 8	32 9	36 11	40 13	43 14	46 16	49 18	51 20	54 21	56 23	58 25	60 27	62 29	64 31	66 33	68 35	70 38	71 40	73 42	74 44	76 47	78 49	79 52	81 54	82 57	83 60	85 62	86 65	87 68	89 71	90 74	91 77	93 80	94 83

Elevations between 501 and 1,900 feet

Wet Bulb Temperatures, 58 to 95 F

(Read Down)

Dry Bulb Temperatures 101 to 119 F

(Read Across)

DP	DP
RH	RH

	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
101	-15 1	2 3	12 4	20 5	26 7	30 8	35 10	38 12	42 13	45 15	48 17	50 18	53 20	55 22	57 24	60 26	62 28	64 30	65 32	67 34	69 36	71 38	72 40	74 43	76 45	77 47	79 50	80 52	82 55	83 57	84 60	86 63	87 65	89 68	90 71	91 74	92 77	94 80
102	-28 1	-3 2	9 3	17 5	24 6	29 8	33 9	37 11	41 12	44 14	47 16	50 17	52 19	55 21	57 23	59 25	61 26	63 28	65 30	67 32	69 34	70 36	72 39	74 41	75 43	77 45	78 48	80 50	81 53	83 55	84 58	86 60	87 63	88 66	90 68	91 71	92 74	93 77
103		-10 1	5 3	15 4	21 6	27 7	32 8	36 10	40 12	43 13	46 15	49 16	51 18	54 20	56 21	58 23	60 25	63 27	64 29	66 31	68 33	70 35	72 37	73 39	75 41	76 43	78 46	80 48	81 50	82 53	84 55	85 58	87 60	88 63	89 66	91 69	92 71	93 74
104		-19 1	1 2	12 3	19 5	25 6	30 8	35 9	38 11	42 12	45 14	48 15	51 17	53 19	55 20	58 22	60 24	62 26	64 28	66 29	68 31	69 33	71 35	73 37	75 40	76 42	78 44	79 46	81 48	82 51	84 53	85 56	86 58	88 61	89 63	90 66	92 69	93 72
105		-37	-5 2	8 3	17 4	23 6	29 7	33 8	37 10	41 11	44 13	47 14	50 16	52 18	55 9	57 21	59 23	61 24	63 26	65 28	67 30	69 32	71 34	72 36	74 38	76 40	77 42	79 44	80 47	82 49	83 51	85 54	86 56	87 59	89 61	90 64	91 66	93 69
106			-12 1	4 2	14 4	21 5	27 6	32 8	36 9	40 11	43 12	46 14	49 15	52 17	54 18	56 20	59 22	61 23	63 25	65 27	67 29	69 30	70 32	72 34	74 36	75 38	77 40	79 43	80 45	82 47	83 49	84 52	86 54	87 56	89 59	90 61	91 64	93 67
107			-23 1	-1 2	11 3	19 4	25 6	30 7	35 8	38 10	42 11	45 13	48 14	51 16	53 17	56 19	58 20	60 22	62 24	64 26	66 27	68 29	70 31	72 33	73 35	75 37	77 39	78 41	80 43	81 45	83 47	84 50	86 52	87 54	88 57	90 59	91 62	92 64
108			-49	-7 1	7 3	16 4	23 5	29 6	33 8	37 9	41 10	44 12	47 13	50 15	53 16	55 18	57 19	60 21	62 23	64 24	66 26	68 28	70 30	71 31	73 33	75 35	76 37	78 39	79 41	81 43	82 46	84 48	85 50	87 52	88 55	89 57	91 59	92 62
109				-15 1	3 2	13 3	21 5	27 6	32 7	36 8	40 10	43 11	46 13	49 14	52 15	54 17	57 18	59 20	61 22	63 23	65 25	67 27	69 28	71 30	73 32	74 34	76 36	78 38	79 40	81 42	82 44	84 46	85 48	86 50	88 53	89 55	91 57	92 60
110				-28	-2 2	10 3	19 4	25 5	30 6	35 8	39 9	42 10	45 12	48 13	51 15	54 16	56 18	58 19	61 21	63 22	65 24	67 25	69 27	70 29	72 31	74 32	76 34	77 36	79 38	80 40	82 42	83 44	85 46	86 48	88 51	89 53	90 55	92 58
111					-8 1	7 2	16 3	23 5	29 6	33 7	37 8	41 10	44 11	48 12	50 14	53 15	56 17	58 18	60 20	62 21	64 23	66 24	68 26	70 28	72 29	73 31	75 33	77 35	78 37	80 39	81 41	83 43	84 45	86 47	87 49	89 51	90 53	91 56
112					-17 1	2 2	13 3	21 4	27 5	32 7	36 8	40 9	43 10	47 12	50 13	52 14	55 16	57 17	60 19	62 20	64 22	66 23	68 25	70 26	71 28	73 30	75 32	76 33	78 35	80 37	81 39	83 41	84 43	86 45	87 47	88 49	90 51	91 54
113					-32	-3 1	10 2	18 4	25 5	30 6	35 7	39 8	42 10	46 11	49 12	52 14	54 15	57 16	59 18	61 19	63 21	65 22	67 24	69 25	71 27	73 29	74 30	76 32	78 34	79 36	81 37	82 39	84 41	85 43	87 45	88 47	90 50	91 52
114						-10 1	6 2	16 3	23 4	29 5	33 7	38 8	41 9	45 10	48 11	51 13	53 14	56 15	58 17	61 18	63 20	65 21	67 23	69 24	71 26	72 27	74 29	76 31	77 32	79 34	81 36	82 38	84 40	85 42	86 44	88 46	89 48	91 50
115						-19 1	2 2	13 3	21 4	27 5	32 6	36 7	40 8	44 10	47 11	50 12	53 13	55 15	58 16	60 17	62 19	64 20	66 22	68 23	70 25	72 26	74 28	75 30	77 31	79 33	80 35	82 36	83 38	85 40	86 42	88 44	89 46	90 48
116							-3 1	10 2	18 3	25 4	30 6	35 7	39 8	43 9	44 10	49 11	52 13	55 14	57 15	59 17	62 18	64 19	66 21	68 22	70 24	71 25	73 27	75 28	77 30	78 32	80 33	81 35	83 37	84 39	86 41	87 42	89 44	90 46
117							-10 1	6 2	16 3	23 4	29 5	34 6	38 7	42 8	45 10	48 11	51 12	54 13	56 14	59 16	61 17	63 18	65 20	67 21	69 23	71 24	73 26	75 27	76 29	78 30	80 32	81 34	83 36	84 37	86 39	87 41	89 43	90 45
118							-20 1	2 1	13 2	21 3	27 5	32 6	37 7	41 8	44 9	47 10	50 11	53 12	56 14	58 15	60 16	63 18	65 19	67 20	69 22	71 23	72 25	74 26	76 28	78 29	79 31	81 33	82 34	84 36	85 38	87 39	88 41	90 43
119								-40	-4 1	10 2	19 3	25 4	31 5	35 6	40 7	43 8	47 9	50 11	52 12	55 13	58 14	60 15	62 17	64 18	66 19	68 21	70 22	72 24	74 25	76 27	77 28	79 30	80 31	82 33	84 35	85 36	87 38	88 40

1.3.3

Elevations between 1,901 and 3,900 feet

Dry Bulb Temperatures
41 to 60 F
(Read Across)

Wet Bulb Temperatures
27 to 57 F
(Read Down)

DP	DP
RH	RH

	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59
41	-43 2	-15 8	-3 15	5 22	11 28	16 35	20 42	23 49	26 56	29 63	32 70	34 77	37 85	39 92																			
42		-27 4	-9 11	0 17	8 24	13 30	18 37	21 43	25 50	28 57	31 64	33 71	36 78	38 85	40 92																		
43			-18 7	-5 13	4 19	10 26	15 32	19 38	23 45	26 51	29 58	32 64	34 71	37 78	39 85	41 93																	
44			-32 3	-11 9	-1 15	7 21	12 27	17 33	21 39	24 46	28 52	30 59	33 65	36 72	38 79	40 86	42 93																
45				-21 5	-6 11	3 17	9 23	14 29	19 35	23 41	26 47	29 53	32 59	34 66	37 72	39 79	41 86	43 93															
46				-38 2	-13 8	-2 13	6 19	12 25	16 30	21 36	24 42	27 48	30 54	33 60	36 67	38 73	40 80	42 86	44 93														
47					-24 4	-7 10	2 15	9 21	14 26	18 32	22 37	26 43	29 49	32 55	34 61	37 67	39 74	41 80	43 87	45 93													
48					-46 1	-15 6	-3 12	5 17	11 2	16 28	20 33	24 39	27 44	30 50	33 56	36 62	38 68	40 74	42 80	44 87	46 93												
49						-26 3	-9 8	1 13	8 18	13 24	18 29	22 34	26 40	29 45	32 51	34 57	37 63	39 68	41 75	43 81	45 87	47 93											
50						-57 1	-17 5	-4 10	4 15	11 20	16 25	20 30	24 36	32 41	30 46	33 52	36 57	38 63	40 69	42 75	44 81	46 87	48 94										
51							-31 2	-11 7	0 12	7 17	13 22	18 27	22 32	26 37	29 42	32 47	34 53	37 58	39 64	41 70	44 75	46 81	47 88	49 94									
52								-20 4	-5 9	4 14	10 18	15 23	20 28	24 33	27 38	30 43	33 48	36 54	38 59	40 65	43 70	45 76	47 81	48 86	50 94								
53								-36 2	-12 6	-1 11	7 15	13 20	18 24	22 29	25 34	29 39	32 44	34 49	37 54	39 60	42 65	44 71	46 76	48 82	50 88	51 94							
54									-22 4	-6 8	3 12	10 17	15 21	20 26	24 30	27 35	30 40	33 45	36 50	38 55	41 60	43 66	45 71	47 77	49 82	51 88	52 94						
55									-42 1	-14 5	-2 9	6 14	12 18	17 23	22 27	25 32	29 36	32 41	35 46	37 51	40 56	42 61	44 66	46 72	48 77	50 83	52 88	53 94					
56										-25 3	-7 7	2 11	9 15	15 20	20 24	24 28	27 33	30 37	33 42	36 47	39 52	41 57	43 62	45 67	47 73	49 78	51 83	53 89	54 94				
57										-50 1	-15 5	-2 9	6 13	12 17	17 21	22 25	26 30	29 34	32 39	35 43	37 48	40 53	42 57	44 62	46 67	48 73	50 78	52 83	54 89	55 94			
58											-27 2	-8 6	2 10	9 14	15 18	20 22	24 26	27 31	31 35	34 40	36 44	39 49	41 53	43 58	46 63	48 68	49 73	51 78	53 84	55 89	56 94		
59												-16 4	-3 8	6 12	12 16	17 20	22 24	26 28	29 32	32 36	35 41	38 45	40 50	42 54	45 59	47 64	49 69	51 73	52 79	54 84	56 89	57 94	
60												-29 2	-9 6	2 9	9 13	15 17	20 21	24 25	28 29	31 33	34 37	37 41	39 49	41 50	44 55	46 59	48 64	50 69	52 74	53 79	55 84	57 89	58 95

Wet Bulb Temperatures

Dry Bulb Temperatures

	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
31	-13 14	-3 23	5 32	10 41	15 50	19 60	22 69	25 79	28 89										
32	-23 8	-6 17	0 25	7 34	12 43	16 52	20 61	24 71	27 80	29 90									
33	-43 2	-16 11	-5 19	3 27	9 36	14 45	18 54	22 63	25 72	28 81	31 91								
34		-29 5	-12 13	-2 21	5 29	11 38	16 46	20 55	23 64	26 73	29 82	32 91							
35			-21 8	-7 16	1 23	8 31	13 40	17 48	21 57	25 65	28 74	30 83	33 91						
36			-39 3	-15 10	-4 18	4 26	10 33	15 42	19 50	23 58	26 66	29 75	31 83	34 91					
37				-27 5	-10 13	0 20	7 28	12 35	17 43	21 51	24 59	27 67	30 75	32 83	35 91				
38				-57 1	-18 8	-6 15	3 22	9 30	14 37	19 45	22 53	26 60	28 68	31 76	34 84	36 92			
39					-33 3	-12 10	-2 17	4 24	11 32	16 39	20 47	24 54	27 61	30 69	32 76	35 84	37 92		
40						-23 6	-7 13	2 19	8 26	14 34	18 41	22 48	25 55	28 62	31 69	33 77	36 84	38 92	

Elevations between 1,901 and 3,900 feet

Wet Bulb Temperatures
39 to 79 F
(Read Down)

DP	DP
RH	RH

Dry Bulb Temperatures
61 to 80 F
(Read Across)

	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60																			
61	-17	-3	6	12	18	22	26	29	33	35	38	40	43	45	47	49	51	53	55	56	58	59	61																		
	4	7	11	14	18	22	26	30	34	38	42	47	51	56	60	65	69	74	79	84	89	95																			
62	-31	-9	2	9	15	20	24	28	31	34	37	39	42	44	46	48	50	52	54	56	57	59	60	62																	
	2	5	9	12	16	20	23	27	31	35	39	43	48	52	56	61	65	70	75	80	85	90	95																		
63		-18	-3	6	12	18	22	26	30	33	36	38	41	43	45	47	49	51	53	55	57	58	60	61	63																
		3	7	10	14	17	21	25	28	32	36	40	44	48	53	57	61	66	70	75	80	85	90	95																	
64		-32	-9	2	9	15	20	24	28	31	34	37	40	42	45	47	49	51	53	54	56	58	59	61	63	64															
		1	5	8	11	15	18	22	26	29	33	37	41	45	49	53	57	62	66	71	75	80	85	90	95																
65			-18	-3	6	13	18	23	27	30	33	36	39	41	44	46	48	50	52	54	55	57	59	60	62	64	65														
			3	6	9	13	16	20	23	27	30	34	38	42	46	50	54	58	62	67	71	76	80	85	90	95															
66			-32	-9	2	10	16	21	25	29	32	35	38	40	43	45	47	49	51	53	55	57	58	60	61	63	65	66													
			1	4	8	11	14	17	21	24	28	31	35	39	43	47	51	55	59	63	67	72	76	81	85	90	95														
67				-18	-3	6	13	18	23	27	30	34	37	39	42	44	46	48	50	52	54	56	58	59	61	63	64	66	67												
				3	6	9	12	15	19	22	25	29	32	36	40	43	47	51	55	59	63	68	72	76	81	86	90	95													
68				-32	-9	2	10	16	21	25	29	32	35	38	41	43	45	48	50	52	54	55	57	59	60	62	64	65	67	68											
				1	4	7	10	13	17	20	23	26	30	33	37	41	44	48	52	56	60	64	68	72	77	81	86	90	95												
69					-17	-3	7	13	19	23	27	31	34	37	40	42	45	47	49	51	53	55	56	58	60	62	63	65	66	68	69										
					3	6	9	12	15	18	21	24	27	31	34	38	41	45	49	53	56	60	64	69	73	77	81	86	91	95											
70					-31	-9	3	10	16	21	26	29	33	36	39	41	44	46	48	50	52	54	56	58	59	61	63	64	66	67	69	70									
					1	4	7	10	13	16	19	22	25	28	32	35	39	42	46	49	53	57	61	65	69	73	77	82	86	91	95										
71						-17	-2	7	14	19	24	28	31	35	38	40	43	45	47	49	51	53	55	57	59	60	62	64	65	67	68	70	71								
						3	5	8	11	14	17	20	23	26	29	33	36	39	43	46	50	54	58	61	65	69	73	78	82	86	91	95									
72						-30	-8	3	11	17	22	26	30	33	36	39	42	44	46	49	51	53	55	56	58	60	62	63	65	66	68	69	71	72							
						1	4	7	9	12	15	18	21	24	27	30	34	37	40	44	47	51	54	58	62	66	70	74	78	82	86	91	95								
73							-16	-1	8	15	20	24	28	32	35	38	41	43	46	48	50	52	54	56	58	59	61	63	64	66	67	69	70	72	73						
							3	5	8	11	13	16	19	22	25	28	31	34	38	41	44	48	51	55	59	62	66	70	74	78	82	87	91	95							
74							-28	-7	4	12	18	23	27	31	34	37	40	42	45	47	49	51	53	55	57	59	61	62	64	65	67	68	70	71	73	74					
							1	4	6	9	12	14	17	20	23	26	29	32	35	38	42	45	48	52	55	59	63	67	70	74	78	83	87	91	95						
75								-14	0	9	15	21	25	29	33	36	39	41	44	46	48	51	53	55	56	58	60	62	63	65	66	68	69	71	72	74	75				
								3	5	8	10	13	16	18	21	24	27	30	33	36	39	42	46	49	52	56	60	63	67	71	75	79	83	87	91	96					
76								-26	-6	5	13	18	23	27	31	35	38	40	43	45	48	50	52	54	56	58	59	61	63	64	66	68	69	70	72	73	75	76			
								1	4	6	9	11	14	17	19	22	25	28	31	34	37	40	43	46	50	53	57	60	64	67	71	75	79	83	87	91	96				
77								-54	-13	1	9	16	21	26	30	33	36	39	42	45	47	49	51	53	55	57	59*	61	62	64	66	67	69	70	71	73	74	76	77		
									3	5	7	10	12	15	18	20	23	26	29	32	34	37	41	44	47	50	54	57	61	64	68	71	75	79	83	87	91	96			
78									-23	-4	6	13	19	24	28	32	35	38	41	44	46	48	51	53	55	56	58	60	62	63	65	67	68	70	71	73	74	75	77	78	
									1	4	6	9	11	13	16	19	21	24	27	29	32	35	38	41	44	48	51	54	57	61	64	68	72	76	79	83	87	91	96		
79									-45	-11	2	10	17	22	27	30	34	37	40	43	45	48	50	52	54	56	58	60	61	63	65	66	68	69	71	72	74	75	76	78	79
										3	5	7	10	12	14	17	20	22	25	27	30	33	36	39	42	45	46	51	55	58	61	65	68	72	76	80	84	88	92	96	
80										-20	-3	7	14	20	25	29	33	36	39	42	44	47	49	51	53	55	57	59	61	62	64	66	67	69	70	72	73	75	76	77	79
										2	4	6	8	11	13	15	18	20	23	26	28	31	34	37	40	43	46	49	52	55	58	62	65	69	72	76	80	84	88	92	96

Elevations between 1,901 and 3,900 feet

Wet Bulb Temperatures 49 to 89 F

(Read Down)

Dry Bulb Temperatures 81 to 100 F

(Read Across)

	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
81	-9 3	3 5	12 7	18 9	23 12	27 14	31 16	35 19	38 21	41 24	43 26	46 29	48 32	50 35	53 37	55 40	57 43	58 46	60 49	62 52	64 56	65 59	67 62	68 66	70 69	71 73	73 76	74 80	76 84	77 88	78 92	80 96										
82	-17 2	-1 4	8 6	15 8	21 10	26 13	30 15	33 17	37 20	40 22	42 25	45 27	47 30	50 33	52 35	54 38	56 41	58 44	60 47	61 50	63 53	65 56	66 59	68 63	70 66	71 69	72 73	74 77	75 80	77 84	78 88	79 92	81 96									
83	-31 1	-7 3	5 5	13 7	19 9	24 11	28 14	32 16	35 18	39 21	41 23	44 26	47 28	49 31	51 33	53 36	55 39	57 42	59 44	61 47	63 50	64 53	66 57	68 60	69 63	71 66	72 70	74 73	75 77	76 80	78 84	79 88	80 92	82 96								
84		-14 2	1 4	10 6	17 8	22 10	27 12	31 15	34 17	37 19	40 21	43 24	46 26	48 29	50 31	53 34	55 37	57 39	59 42	60 45	62 48	64 51	66 54	67 57	69 60	70 63	72 67	73 70	75 74	76 77	77 81	79 84	80 88	81 92	83 96							
85		-26 1	-5 3	6 5	14 7	20 9	25 11	29 13	33 15	36 18	39 20	42 22	45 25	47 27	50 30	52 32	54 35	56 37	58 40	60 43	62 46	63 48	65 51	67 54	68 57	70 61	71 64	73 67	74 70	76 74	77 77	78 81	80 85	81 88	82 92	84 96						
86			-11 2	2 4	11 6	18 8	23 10	28 12	32 14	35 16	38 19	41 21	44 23	47 25	49 28	51 30	53 33	55 35	57 38	59 41	61 43	63 46	65 49	66 52	68 55	69 58	71 61	72 64	74 67	75 71	77 74	78 78	80 81	81 85	82 88	83 92	85 96					
87			-21 1	-2 3	8 5	15 7	21 9	26 11	30 13	34 15	37 17	40 19	43 22	46 24	48 26	50 29	53 31	55 33	57 36	59 39	61 41	62 44	64 47	66 49	67 52	69 55	71 58	72 61	74 64	75 68	76 71	78 74	79 78	81 81	82 85	83 88	84 92	86 96				
88			-39	-8 2	4 4	13 6	19 8	24 10	29 12	33 14	36 16	39 18	42 20	45 22	47 25	50 27	52 29	54 32	56 34	58 37	60 39	62 42	64 44	65 47	67 50	69 53	70 56	72 59	73 62	75 65	76 68	78 71	79 75	80 78	82 81	83 85	84 89	85 92	87 96			
89				-17 1	0 3	9 5	17 7	22 9	27 11	31 13	35 15	38 17	41 19	44 21	47 23	49 25	51 28	53 30	56 32	58 35	59 37	61 40	63 42	65 45	67 48	68 50	70 53	71 56	73 59	74 62	76 65	77 68	79 71	80 75	81 78	83 82	84 85	85 89	87 92	88 96		
90				-30 1	-6 2	6 4	14 6	20 8	25 10	30 12	34 13	37 15	40 17	43 20	46 22	48 24	51 26	53 28	55 31	57 33	59 35	61 38	63 40	64 43	66 45	68 48	69 51	71 54	72 56	74 59	75 62	77 65	78 69	80 72	81 75	82 78	84 82	85 85	86 89	88 92	89 96	
91					-13 2	2 3	11 5	18 7	23 9	28 11	32 12	36 14	39 16	42 18	45 20	47 22	50 25	52 27	54 29	56 31	58 34	60 36	62 38	64 41	66 43	67 46	69 49	71 51	72 54	74 57	75 60	77 63	78 66	79 69	81 72	82 75	83 79	85 82	86 85	87 89	89 93	90 96
92					-23 1	-3 3	8 4	16 6	22 8	27 10	31 11	35 13	38 15	41 17	44 19	47 21	49 23	51 25	54 27	56 30	58 32	60 34	62 36	63 39	65 41	67 44	69 46	70 49	72 52	73 54	75 57	76 60	78 63	79 66	80 69	82 72	83 75	84 79	86 82	87 86	88 89	90 93
93					-45	-9 2	4 3	13 5	19 7	25 9	29 10	33 12	37 14	40 16	43 18	46 20	48 22	51 24	53 26	55 28	57 30	59 32	61 35	63 37	65 39	66 42	68 44	70 47	71 50	73 52	74 55	76 58	77 60	79 63	80 66	81 69	83 73	84 76	85 79	87 82	88 86	89 89
94						-17 1	0 3	10 4	17 6	23 8	28 9	32 11	36 13	39 15	42 17	45 19	47 20	50 22	52 24	54 27	57 29	59 31	61 33	62 35	64 38	66 40	68 42	69 45	71 47	72 50	74 53	76 55	77 58	78 61	80 64	81 67	83 70	84 73	85 76	87 79	88 82	89 86
95						-31 1	-5 2	6 4	15 5	21 7	26 9	30 10	34 12	38 14	41 16	44 17	47 19	59 21	52 23	54 25	56 27	58 29	60 31	62 34	64 36	66 38	67 40	69 43	71 45	72 48	74 50	75 53	77 56	78 58	80 61	81 64	82 67	84 70	85 73	86 76	88 79	89 83
96							-12 1	3 3	12 4	19 6	24 8	29 9	33 11	37 13	40 14	43 16	46 18	48 20	51 22	53 24	55 26	57 28	59 30	61 32	63 34	65 36	67 39	68 41	70 43	72 46	73 48	75 51	76 53	78 56	79 59	81 61	82 64	83 67	85 70	86 73	87 76	89 79
97							-23 1	-2 2	9 4	16 5	22 7	27 8	32 10	36 12	39 13	42 15	45 17	48 19	50 21	52 23	55 24	57 26	59 28	61 30	63 33	65 35	66 37	68 39	70 41	71 44	73 46	74 49	76 51	77 54	79 56	80 59	82 62	83 65	84 67	86 70	87 73	88 76
98							-44	-8 2	5 3	14 5	20 6	26 8	30 9	34 11	38 13	41 14	44 16	47 18	49 19	52 21	54 23	56 25	58 27	60 29	62 31	64 33	66 35	68 37	69 40	71 42	73 44	74 47	76 49	77 52	79 54	80 57	81 59	83 62	84 65	85 68	87 71	88 74
99								-16 1	1 2	11 4	18 5	24 7	29 8	33 10	37 12	40 13	43 15	46 17	49 18	51 20	53 22	56 24	58 26	60 28	62 30	64 32	65 34	67 36	69 38	71 40	72 42	74 45	75 47	77 50	78 52	80 55	81 57	83 60	84 62	85 65	87 68	88 71
100								-29 1	-4 2	8 3	16 5	22 6	27 8	32 9	35 11	39 12	42 14	45 16	48 17	50 19	53 21	55 23	57 24	59 26	61 28	63 30	65 32	67 34	68 36	70 38	72 41	73 43	75 45	76 48	78 50	79 52	81 55	82 57	84 60	85 63	86 65	88 68

Elevations between 1,901 and 3,900 feet

Wet Bulb Temperatures, 57 to 90 F

(Read Down)

DP	DP
RH	RH

Dry Bulb Temperatures

101 to 119 F

(Read Across)

	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
101	-11 1	4 3	13 4	20 5	25 7	30 8	34 10	38 11	41 13	44 15	47 16	50 18	52 20	54 21	57 23	59 25	61 27	63 29	65 31	66 33	68 35	70 37	71 39	73 41	75 43	76 46	78 48	79 50	81 53	82 55	83 50	85 60	86 63	87 66
102	-20 1	-1 2	10 3	18 5	24 6	29 8	33 9	37 11	40 12	43 14	46 15	49 17	51 19	54 20	56 22	58 24	60 26	62 27	64 29	66 31	68 33	69 35	71 37	73 39	74 42	76 44	77 46	79 48	80 51	82 53	83 56	84 58	86 61	87 63
103	-37	-6 2	7 3	15 4	22 6	27 7	32 8	36 10	39 11	42 13	45 14	48 16	51 18	53 19	55 21	58 23	60 24	62 26	64 28	65 30	67 32	69 34	71 36	72 38	74 40	75 42	77 44	78 48	80 49	81 51	83 53	84 56	86 58	87 61
104		-13 1	3 2	13 4	20 5	25 6	30 8	34 9	38 11	41 12	44 13	47 15	50 17	52 18	55 20	57 21	59 23	61 25	63 27	65 28	67 30	69 32	70 34	72 36	74 38	75 40	77 42	78 45	80 47	81 49	83 51	84 54	85 56	87 59
105		-24 1	-2 2	9 3	17 4	24 6	29 7	33 8	37 10	40 11	43 13	46 14	49 16	52 17	54 19	56 20	58 22	61 24	63 25	64 27	66 29	68 31	70 33	72 35	73 37	75 49	76 41	78 43	79 45	81 47	82 49	84 52	85 54	86 57
106		-48	8 1	6 3	15 4	22 5	27 6	32 8	36 9	39 10	43 12	46 13	48 15	51 16	53 18	56 19	58 21	60 23	62 24	64 26	66 28	68 30	69 31	71 33	73 35	74 37	76 39	78 41	79 43	80 45	82 48	83 50	85 52	86 54
107			-16 1	2 2	12 3	19 4	25 6	30 7	34 8	38 10	42 11	45 12	48 14	50 15	53 17	55 18	57 20	59 22	62 23	64 25	65 27	67 28	69 30	71 32	72 34	74 36	76 38	77 40	79 42	80 44	82 46	83 48	84 50	86 52
108			-28	-3 2	9 3	17 4	23 5	29 6	33 8	37 9	41 10	44 12	47 13	49 14	52 16	54 17	57 19	59 20	61 22	63 24	65 25	67 27	69 29	70 31	72 32	74 34	75 36	77 38	78 40	80 42	81 44	83 46	84 48	86 51
109				-9 1	5 2	15 3	21 5	27 6	32 7	36 8	40 10	43 11	46 12	49 14	51 15	54 17	56 18	58 19	60 21	63 23	64 24	66 26	68 28	70 29	72 31	73 33	75 35	77 36	78 38	80 40	81 42	83 44	84 47	85 49
110				-18 1	1 2	12 3	19 4	25 5	30 6	35 8	38 9	42 10	45 12	48 13	51 14	53 16	56 17	58 19	60 20	62 22	64 23	66 25	68 26	70 28	71 30	73 31	75 33	76 35	78 37	79 39	81 41	82 43	84 45	85 47
111				-32	-4 1	9 2	17 4	24 5	29 6	33 7	37 8	41 10	44 11	47 12	50 13	52 15	55 16	57 18	59 19	61 21	64 22	65 24	67 25	69 27	71 28	73 30	74 32	76 34	77 35	79 37	80 39	82 41	83 43	85 45
112					-10 1	5 2	15 3	22 4	27 5	32 7	36 8	40 9	43 10	46 11	49 13	52 14	54 15	57 17	59 18	61 20	63 21	65 23	67 24	69 26	70 27	72 29	74 31	76 32	77 34	79 36	80 38	82 40	83 42	85 44
113					-19 1	1 2	12 3	19 4	25 5	31 6	35 7	39 8	42 10	45 11	48 12	51 13	54 15	56 16	58 17	60 19	63 20	65 22	66 23	68 25	70 26	72 28	74 29	75 31	77 33	78 35	80 36	81 38	83 40	84 42
114					-35	-4 1	9 2	17 3	24 4	29 5	34 6	38 7	41 8	44 9	47 11	50 13	53 14	55 15	58 16	60 18	62 19	64 21	66 22	68 24	70 25	71 27	73 28	75 30	76 32	78 33	80 35	81 37	83 39	84 40
115						-11 1	5 2	15 3	22 4	27 5	32 6	36 7	40 8	44 9	47 11	50 12	52 13	55 14	57 16	59 17	61 18	64 20	66 21	67 23	69 24	71 26	73 27	74 29	76 30	78 32	79 34	81 35	82 37	84 39
116						-20 1	1 2	12 2	20 4	26 5	31 6	35 7	39 8	43 9	46 10	49 11	51 12	54 14	56 15	59 16	61 18	63 19	65 20	67 22	69 23	71 25	72 26	74 28	76 29	77 31	79 32	81 34	82 36	84 38
117						-38	-4 1	9 2	17 3	24 4	29 5	34 6	38 7	42 8	45 9	48 11	51 12	53 13	56 14	58 15	60 17	63 18	65 19	67 21	68 22	70 24	72 25	74 26	75 28	77 30	79 31	80 33	82 34	83 36
118							-11 1	5 2	15 3	22 4	28 5	33 6	37 7	41 8	46 9	47 10	50 11	53 12	55 13	58 15	60 16	62 17	64 18	66 20	68 21	70 23	72 24	73 25	75 27	77 28	78 30	80 32	81 33	83 35
119							-21	1 1	12 2	20 3	26 4	31 5	36 6	40 7	43 8	46 9	49 11	52 12	55 13	57 14	59 15	62 16	64 18	66 19	68 20	69 22	71 23	73 24	75 26	76 27	78 29	80 30	81 32	83 34

1.3.4 Elevations between 3,901 and 6,100 feet

Dry Bulb Temperatures
41 to 60 F
(Read Across)

Wet Bulb Temperatures
27 to 56 F
(Read Down)

DP	DP
RH	RH

	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59
41	-22 6	-8 12	1 18	8 25	13 31	17 38	21 44	24 51	27 58	30 64	32 71	35 78	37 85	39 93																			
42	-39 2	-15 8	-3 14	4 20	10 27	15 33	19 39	23 46	26 52	29 58	31 64	34 71	36 78	38 85	40 93																		
43		-25 5	-9 10	0 16	7 22	13 29	17 35	21 41	24 47	27 53	30 59	32 66	35 72	37 79	39 86	41 93																	
44		-48 1	-17 7	-4 13	4 18	10 24	15 30	19 36	22 42	25 48	28 54	31 60	34 66	36 73	38 80	40 86	42 93																
45			-29 4	-10 9	0 15	7 20	12 26	17 31	20 37	24 43	27 49	30 55	32 61	35 67	37 73	39 80	41 86	43 93															
46				-19 6	-5 11	3 17	9 22	14 27	18 33	22 38	25 44	28 50	31 56	34 62	36 68	38 74	40 80	42 87	44 93														
47				-32 3	-12 8	-1 13	6 18	12 23	16 29	20 34	24 40	27 45	30 51	32 57	35 62	37 68	39 74	41 81	43 87	45 93													
48					-20 5	-6 10	2 15	9 20	14 25	18 30	22 35	25 41	28 46	31 52	34 57	36 63	38 69	40 75	42 81	44 87	46 94												
49					-35 2	-13 7	-2 12	5 17	11 21	16 26	20 31	24 37	27 42	30 47	32 53	35 58	37 64	39 70	42 75	44 81	45 87	47 94											
50						-22 4	-7 9	2 13	8 18	14 23	18 28	22 33	25 38	28 43	31 48	34 53	36 59	39 64	41 70	43 76	45 82	46 88	48 94										
51						-39 2	-14 6	-3 10	5 15	11 20	16 24	20 29	24 34	27 39	30 44	33 49	35 54	37 60	40 65	42 71	44 76	46 82	48 88	49 94									
52							-24 3	-8 8	1 12	8 17	13 21	18 26	22 30	25 35	28 40	31 45	34 50	36 55	39 60	41 66	43 71	45 77	47 82	49 88	50 94								
53							-45 1	-16 5	-3 9	5 14	11 18	16 22	20 27	24 32	27 36	30 41	33 46	35 51	38 56	40 61	42 66	44 72	46 77	48 83	50 88	51 94							
54								-27 3	-9 7	1 11	8 15	13 19	18 24	22 28	25 33	29 37	31 42	34 47	37 52	39 57	41 62	43 67	45 72	47 77	49 83	51 89	52 94						
55								-53 1	-17 5	-4 8	4 13	11 17	16 21	20 25	24 29	27 34	30 38	33 41	36 48	38 52	40 57	42 62	44 67	46 73	48 78	50 83	52 89	53 94					
56									-29 2	-10 6	0 10	8 14	13 18	18 22	22 26	26 31	29 35	32 39	34 44	37 49	39 53	41 58	44 63	46 68	47 73	49 78	51 83	52 89	54 94				
57										-18 4	-4 8	4 12	11 15	16 19	20 23	24 28	27 32	30 36	33 40	36 45	38 49	41 54	43 59	45 64	47 68	49 73	50 79	52 84	54 89	55 94			
58										-31 2	-10 6	0 9	7 13	13 17	18 21	22 25	26 29	29 33	32 37	35 41	37 46	40 50	42 55	44 59	46 64	48 69	50 74	51 79	53 84	55 89	56 95		
59											-19 4	-5 7	4 11	11 14	16 18	20 22	24 26	28 30	31 34	34 38	36 42	39 47	41 51	43 55	45 60	47 65	49 69	51 74	53 79	54 84	56 89	57 95	
60											-32 2	-11 5	0 9	8 12	13 16	18 19	22 23	26 27	29 31	32 35	35 39	38 43	40 47	42 52	44 56	46 61	48 65	50 70	52 75	54 79	55 84	57 90	58 95

Wet Bulb Temperatures

Dry Bulb Temperatures

	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
31	-20 10	-8 18	0 26	6 35	11 44	16 52	19 61	23 71	26 80	28 90									
32	-35 4	-15 12	-4 20	3 28	9 37	13 45	17 54	21 63	24 73	27 81	30 90								
33		-25 7	-10 15	-1 22	5 30	11 39	15 47	19 56	22 64	25 73	28 82	31 91							
34		-48 2	-18 9	-6 17	2 25	8 32	12 40	17 49	20 57	24 65	27 74	29 83	32 91						
35			-31 4	-13 12	-3 19	4 27	10 34	14 42	18 50	22 58	25 67	28 75	30 83	33 92					
36				-22 7	-9 14	0 21	7 29	12 36	16 44	20 52	23 60	26 68	29 76	32 84	34 92				
37				-40 3	-16 9	-5 16	3 23	9 31	14 38	18 46	22 53	25 61	28 69	30 76	33 84	35 92			
38					-27 5	-11 12	-1 19	6 26	11 33	16 40	20 47	23 55	26 62	29 69	31 77	34 84	36 92		
39					-55 1	-19 7	-6 14	2 21	8 27	13 34	18 42	21 49	25 56	27 63	30 70	33 77	35 85	37 92	
40						-32 3	-13 10	-2 16	5 23	11 29	15 36	19 43	23 50	26 57	29 64	31 71	34 78	36 85	38 92

Elevations between 3,901 and 6,100 feet

Wet Bulb Temperatures

38 to 79 F

(Read Down)

DP	DP
RH	RH

Dry Bulb Temperatures

61 to 80 F

(Read Across)

	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79
61	-19 3	-5 7	4 10	11 14	16 17	21 21	24 24	28 28	31 32	34 36	37 40	39 44	41 48	43 52	46 57	48 61	49 66	51 70	53 75	55 80	56 85	58 90	59 95																			
62	-33 1	-11 5	0 8	8 11	14 15	19 18	23 22	26 26	30 29	33 33	35 37	38 41	40 45	43 49	45 53	47 57	49 62	51 66	52 71	54 75	56 80	57 85	59 90	61 95																		
63		-19 3	-5 6	4 9	11 13	16 16	21 20	25 23	28 27	31 30	34 34	37 38	39 42	42 46	44 50	46 54	48 58	50 62	52 67	54 71	55 76	57 80	58 85	60 90	62 95																	
64		-34 1	-11 4	0 8	8 11	14 14	19 17	23 21	27 24	30 28	33 31	36 35	38 39	41 43	43 46	45 50	47 54	49 59	51 63	53 67	55 72	56 76	58 81	60 85	61 90	63 95																
65			-19 3	-4 6	5 9	11 12	17 15	21 19	25 22	29 25	32 29	35 32	37 36	40 40	42 43	44 47	47 51	49 55	50 59	52 63	54 68	56 72	57 76	59 81	61 86	62 90	64 95															
66			-33 1	-10 4	1 7	8 10	14 13	19 16	23 20	27 23	31 26	34 30	36 33	39 37	41 40	44 44	46 48	48 52	50 56	52 60	53 64	55 68	57 72	58 77	60 81	62 86	63 90	65 95														
67				-19 3	-4 6	5 8	12 11	17 15	22 18	26 21	29 24	32 27	35 31	38 34	40 38	43 41	45 45	47 49	49 52	51 56	53 60	55 64	56 68	58 73	60 77	61 81	63 86	64 90	66 95													
68				-32 1	-10 4	1 7	9 10	15 13	20 16	24 19	28 22	31 25	34 28	37 32	39 35	42 39	44 42	46 46	48 49	50 53	52 57	54 61	56 65	57 69	59 73	61 77	62 82	64 86	65 91	67 95												
69					-18 3	-3 5	6 8	12 11	18 14	22 17	26 20	30 23	33 26	36 29	38 33	41 36	43 39	45 43	48 46	50 50	52 54	53 57	55 61	57 65	59 69	60 73	62 78	63 82	65 86	66 91	68 95											
70					-31 1	-9 4	2 7	10 9	15 12	20 15	25 18	28 21	32 24	35 27	37 30	40 33	42 37	45 40	47 44	49 47	51 51	53 54	55 58	56 62	58 66	60 70	61 74	63 78	64 82	66 86	67 91	69 95										
71						-17 3	-3 5	6 8	13 11	18 13	23 16	27 19	30 22	33 25	36 28	39 31	41 34	44 38	46 41	48 44	50 48	52 51	54 55	56 58	57 62	59 66	61 70	62 74	64 78	65 82	67 87	68 91	70 95									
72						-29 1	-8 4	3 6	10 9	16 12	21 14	25 17	29 20	32 23	35 26	38 29	41 32	43 35	45 38	47 42	49 45	51 48	53 52	55 55	57 59	59 63	60 66	62 70	63 74	65 78	66 83	68 87	69 91	71 95								
73							-15 3	-2 5	7 8	14 10	19 13	23 16	27 18	31 21	34 24	37 27	40 30	42 33	44 36	47 39	49 42	51 46	53 49	55 52	56 56	58 59	60 63	61 67	63 71	64 75	66 79	67 83	69 87	70 91	72 96							
74							-26 1	-7 4	4 6	11 9	17 11	22 14	26 17	30 19	33 22	36 25	39 28	41 31	44 34	46 37	48 40	50 43	52 46	54 50	56 53	58 56	59 60	61 64	62 67	64 71	66 75	67 79	68 83	70 87	71 91	73 96						
75							-52	-14 3	0 5	8 7	15 10	20 12	24 15	28 18	32 20	35 23	38 26	40 29	43 31	45 34	47 37	49 41	51 44	53 47	55 50	57 53	59 57	60 60	62 64	64 68	65 71	67 75	68 79	70 83	71 87	72 91	74 96					
76								-24 2	5 4	5 6	12 9	18 11	22 13	27 16	30 19	33 21	36 24	39 27	42 29	44 32	47 35	49 38	51 41	53 44	55 47	56 51	58 54	60 57	62 61	63 64	65 68	66 72	68 75	69 79	71 83	72 87	73 91	75 96				
77								-43	-12 3	1 5	9 7	15 10	21 12	25 14	29 17	32 19	35 22	38 25	41 27	43 30	46 33	48 36	50 39	52 42	54 45	56 48	58 51	59 55	61 58	63 61	64 65	66 68	67 72	69 76	70 80	72 83	73 87	74 92	76 96			
78									-21 2	-4 4	6 6	13 8	19 11	23 13	27 15	31 18	34 20	37 23	40 26	43 28	45 31	47 34	49 37	51 40	53 42	55 46	57 49	59 52	61 55	62 58	64 62	65 65	67 69	68 72	70 76	71 80	73 84	74 88	75 92	77 96		
79									-36 1	-10 3	2 5	10 7	16 9	21 12	26 14	30 16	33 19	36 21	39 24	42 26	44 29	46 32	49 35	51 37	53 40	55 43	57 46	58 49	60 52	62 6	63 59	65 62	66 66	68 69	69 73	71 76	72 80	74 84	75 88	76 92	78 96	
80										-18 2	-2 4	7 6	14 8	20 10	24 13	28 15	32 17	35 20	38 22	41 25	43 27	46 30	48 32	50 35	52 38	54 41	56 44	58 47	60 50	61 53	63 56	65 59	66 63	68 66	69 69	71 73	72 77	73 80	75 84	76 88	77 92	79 96

Elevations between 3,901 and 6,100 feet

Wet Bulb Temperatures 48 to 89 F
(Read Down)

DP	DP
RH	RH

Dry Bulb Temperatures 81 to 100 F
(Read Across)

	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
81	-8 3	4 5	11 7	17 9	22 11	27 14	30 16	34 18	37 21	40 23	42 25	45 28	47 31	49 33	51 36	53 39	55 41	57 44	59 47	61 50	62 53	64 56	66 60	67 63	69 66	70 70	72 73	73 77	74 80	76 84	77 88	78 92	80 96										
82	-15 2	-1 4	8 6	15 8	21 10	25 12	29 15	33 17	36 19	39 21	41 24	44 26	46 29	49 31	51 34	53 37	55 39	57 42	59 45	60 48	62 51	64 54	65 57	67 60	68 63	70 67	71 70	73 73	74 77	75 81	77 84	78 88	80 92	80 96									
83	-26 1	-6 3	5 5	13 7	19 9	23 11	28 13	31 15	35 18	38 20	41 22	43 25	46 27	48 29	50 32	52 35	54 37	56 40	58 43	60 45	61 48	63 51	65 54	66 57	68 60	69 64	71 67	72 70	74 74	75 77	76 81	78 84	79 88	80 92	82 96								
84	-49	-12 2	1 4	10 6	16 8	22 10	26 12	30 14	34 16	37 18	40 21	42 23	45 25	47 28	49 30	52 33	54 35	56 38	57 41	59 43	61 46	63 49	64 52	66 55	68 58	69 61	71 64	72 67	73 71	75 74	76 77	78 81	79 85	80 88	81 92	83 96							
85		-21 1	-3 3	7 5	14 7	20 9	24 11	29 13	32 15	36 17	39 19	41 22	44 24	46 26	49 28	51 31	53 33	55 36	57 38	59 41	61 44	62 47	64 49	66 52	67 55	69 58	70 61	72 64	73 68	74 71	76 74	77 78	79 81	80 82	81 88	82 92	84 96						
86		-37 1	-9 2	3 4	11 6	18 8	23 10	27 12	31 14	34 16	38 18	40 20	43 22	46 25	48 27	50 29	52 32	54 34	56 36	58 39	60 42	62 44	63 47	65 50	67 53	68 56	70 59	71 62	73 65	74 68	76 71	77 74	78 78	80 81	81 85	82 89	83 92	85 96					
87			-17 2	-1 3	8 5	15 7	21 9	26 11	30 13	33 15	36 17	39 19	42 21	45 23	47 25	50 28	52 30	54 32	56 35	58 37	60 40	61 42	63 45	65 48	66 50	68 53	69 56	71 59	72 62	74 65	75 68	77 71	78 75	79 78	81 82	82 85	83 89	85 92	86 96				
88			-29 1	-6 2	5 4	13 6	19 8	24 10	28 12	32 13	35 15	38 17	41 20	44 22	46 24	49 26	51 28	53 31	55 33	57 35	59 38	61 40	63 43	64 45	66 48	67 51	69 54	71 56	72 59	73 62	75 65	76 68	78 72	79 75	80 78	82 82	83 85	84 89	86 92	87 96			
89				-13 2	1 3	10 5	17 7	22 9	27 11	31 12	34 14	37 16	40 18	43 20	46 22	48 24	50 27	53 29	55 31	57 33	58 36	60 38	62 41	64 43	65 46	67 49	69 51	70 54	72 57	73 60	7 63	76 66	77 69	79 72	80 75	81 78	83 82	84 85	85 89	87 93	88 96		
90				-22 1	-3 3	7 4	14 6	20 8	25 10	29 11	33 13	36 15	39 17	42 19	45 21	47 23	50 25	52 27	54 30	56 32	58 34	60 36	62 39	63 41	65 44	67 46	68 49	70 52	71 54	73 57	74 60	76 63	77 66	78 69	80 72	81 75	82 79	84 82	85 85	86 89	88 93	89 96	
91				-40	-9 2	3 4	12 5	18 7	23 9	28 10	32 12	35 14	38 16	41 18	44 20	47 22	49 24	51 26	53 28	55 30	57 32	59 35	61 37	63 39	65 42	66 44	68 47	69 49	71 52	72 55	74 58	75 60	77 63	78 66	80 69	81 72	82 76	84 79	85 82	86 86	87 89	89 93	90 96
92					-17 1	-1 3	9 4	16 6	22 8	26 9	30 11	34 13	37 15	40 17	43 19	46 20	48 22	51 24	53 27	55 29	57 31	59 33	61 35	62 38	64 40	66 42	67 45	69 47	71 50	72 52	74 55	75 58	76 61	78 64	79 67	81 70	82 73	83 76	85 79	86 82	87 86	88 89	90 93
93					-29 1	-6 2	6 4	14 5	20 7	25 9	29 10	33 12	36 14	39 16	42 17	45 19	48 21	50 23	52 25	54 27	56 29	58 31	60 34	62 36	64 38	65 40	67 43	69 45	70 48	72 50	73 53	75 56	76 58	78 61	79 64	80 67	82 70	83 73	84 76	86 79	87 82	88 86	89 89
94						-12 2	2 3	11 5	18 6	23 8	28 9	32 11	35 13	38 14	41 16	44 18	47 20	49 22	51 24	54 26	56 28	58 30	60 32	61 34	63 36	65 39	67 41	68 43	70 46	71 48	73 51	74 53	76 56	77 59	79 61	80 64	81 67	83 70	84 73	85 76	87 79	88 83	89 86
95						-22 1	-3 2	8 4	15 5	21 7	26 9	30 10	34 12	37 13	40 15	43 17	46 19	48 21	51 22	53 24	55 26	57 28	59 30	61 33	63 35	65 37	66 39	68 41	69 44	71 46	73 49	74 51	76 54	77 56	78 59	80 62	81 65	82 67	84 70	85 73	86 76	88 80	89 83
96						-39	-8 2	4 3	13 5	19 6	24 8	29 9	33 11	36 13	40 14	42 16	45 18	48 19	50 21	52 23	55 25	57 27	59 29	60 31	62 33	64 35	66 37	67 40	69 42	71 44	72 47	74 49	75 51	77 54	78 57	80 59	81 62	82 65	84 68	85 71	86 74	87 77	89 80
97							-16 1	0 3	10 4	17 5	23 7	27 8	32 10	35 12	39 13	42 15	44 17	47 18	49 20	52 22	54 24	56 26	58 28	60 30	62 32	64 34	65 36	67 38	69 40	70 42	72 45	73 47	75 49	76 52	78 54	79 57	81 60	82 62	83 65	85 68	86 71	87 74	88 77
98							-27 1	-4 2	7 3	15 5	21 6	26 8	30 9	34 11	37 12	41 14	44 16	46 17	49 19	51 21	53 23	55 24	58 26	59 28	61 30	63 32	65 34	67 36	68 38	70 41	72 43	73 45	75 47	76 50	78 52	79 55	80 57	82 60	83 63	84 65	86 68	87 71	88 74
99							-54	-10 1	3 3	12 4	19 6	24 7	29 8	33 10	36 11	40 13	43 15	45 16	48 18	50 20	53 21	55 23	57 25	59 27	61 29	63 31	65 33	66 35	68 ##	70 39	71 41	73 43	74 46	76 48	77 50	79 53	80 55	81 58	83 60	84 63	85 66	87 68	88 71
100								-19 1	-1 2	9 4	17 5	22 6	27 8	32 9	35 11	39 12	42 14	45 15	47 17	50 19	52 20	54 22	56 24	58 26	60 27	62 29	64 31	66 33	68 35	69 37	71 39	72 41	74 44	75 46	77 48	78 51	80 53	81 55	83 58	84 61	85 63	87 66	88 69

Elevations between 3,901 and 6,100 feet

Wet Bulb Temperatures, 55 to 90 F

(Read Down)

	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
101	-33	-6 2	6 3	14 4	21 6	26 7	30 8	34 10	38 11	41 13	44 14	46 16	49 18	51 19	54 21	56 23	58 24	60 26	62 28	64 30	65 32	67 34	69 36	70 38	72 40	74 42	75 44	77 46	78 49	79 51	81 53	82 56	84 58	85 61	86 63	88 66
102		-13 1	2 2	12 4	19 5	24 6	29 8	33 9	37 11	40 12	43 13	46 15	48 17	51 18	53 20	55 21	57 23	59 25	61 27	63 28	65 30	67 32	68 34	70 36	72 38	73 40	75 42	76 44	78 47	79 49	81 51	82 54	83 56	85 59	86 61	87 64
103		-22 1	-2 2	9 3	16 4	22 6	27 7	32 8	35 10	39 11	42 13	45 14	48 16	50 17	52 19	55 20	57 22	59 24	61 25	63 27	65 29	66 31	68 33	70 35	71 37	73 39	74 41	76 43	77 45	79 47	80 49	82 52	83 54	84 56	86 59	87 61
104		-39	-7 1	5 3	14 4	20 5	26 6	30 8	34 9	38 10	41 12	44 13	47 15	49 16	52 18	54 19	56 21	58 23	60 24	62 26	64 28	66 29	68 31	69 33	71 35	73 37	74 39	76 41	77 43	79 45	80 47	81 50	83 52	84 54	86 57	87 59
105			-14 1	2 2	11 3	18 5	24 6	29 7	33 8	37 10	40 11	43 12	46 14	49 15	51 17	53 18	56 20	58 21	60 23	62 25	64 26	65 28	67 30	69 32	71 34	72 36	74 37	75 39	77 41	78 44	80 46	81 48	83 50	84 52	85 55	87 57
106			-25 1	-3 2	8 3	16 4	22 5	27 6	32 8	36 9	39 10	42 12	45 13	48 14	50 16	53 17	55 19	57 20	59 22	61 24	63 25	65 27	67 29	69 30	70 32	72 34	73 36	75 38	77 40	78 42	80 44	81 46	82 48	84 50	85 53	86 55
107			-47	-8 1	5 2	14 4	20 5	26 6	30 7	35 8	38 10	41 11	44 12	47 14	50 15	52 17	54 18	57 19	59 21	61 23	63 24	65 26	66 27	68 29	70 31	72 33	73 35	75 36	76 38	78 40	79 42	81 44	82 46	83 49	85 51	86 55
108				-16 1	1 2	11 3	18 4	24 5	29 7	33 8	37 9	40 10	44 12	46 13	49 14	52 16	54 17	56 19	58 20	60 22	62 23	64 25	66 26	68 28	69 30	71 31	73 33	74 35	76 37	77 39	79 41	80 43	82 45	83 47	85 49	86 51
109				-27	-3 2	8 3	16 4	23 5	28 6	32 7	36 8	39 10	43 11	46 12	48 13	51 15	53 16	56 18	58 19	60 21	62 22	64 24	66 25	67 27	69 28	71 30	72 32	74 34	76 35	77 37	79 39	80 41	82 43	83 45	84 47	86 49
110				-58	-9 1	5 2	14 3	21 4	26 5	31 7	35 8	38 9	42 10	45 11	48 13	50 14	53 15	55 17	57 18	59 20	61 21	63 23	65 24	67 26	69 27	70 29	72 31	74 32	75 34	77 36	78 38	80 40	81 41	83 43	84 45	85 47
111					-17 1	1 2	11 3	19 4	24 5	29 6	34 7	37 8	41 10	44 11	47 12	49 13	52 15	54 16	57 17	59 19	61 20	63 22	65 23	67 25	68 26	70 28	72 29	73 31	75 33	77 34	78 36	80 38	81 40	82 42	84 44	85 46
112					-29	-4 1	8 2	16 3	23 4	28 6	32 7	36 8	40 9	43 10	46 11	49 13	51 14	54 15	56 16	58 18	60 19	62 21	64 22	66 24	68 25	70 27	71 28	73 30	75 31	76 33	78 35	79 37	81 38	82 39	84 42	85 44
113						-10 1	5 2	14 3	21 4	26 5	31 6	35 7	39 8	42 10	45 11	48 12	51 13	53 14	55 16	58 17	60 18	62 20	64 21	66 23	68 24	69 26	71 27	73 29	74 30	76 32	77 34	79 35	80 37	82 39	83 41	85 43
114						-18 1	1 2	11 3	19 4	25 5	30 6	34 7	38 8	41 9	44 10	47 11	50 12	53 14	55 15	57 16	59 17	61 19	63 20	65 22	67 23	69 24	71 26	72 27	74 29	76 31	77 32	79 34	80 36	82 37	83 39	85 41
115						-31	-4 1	8 2	17 3	23 4	28 5	33 6	37 7	40 8	44 9	47 11	49 12	52 13	54 14	57 15	59 17	61 18	63 19	65 21	67 22	69 23	70 25	72 26	74 28	75 29	77 31	78 33	80 34	81 36	83 38	84 40
116							-10 1	5 2	14 3	21 4	27 5	32 6	36 7	39 8	43 9	46 10	49 11	51 12	54 13	56 15	58 16	60 17	62 18	64 20	66 21	68 23	70 24	72 25	73 27	75 28	77 30	78 31	80 33	81 35	83 36	84 38
117							-18 1	1 1	12 2	19 3	25 4	30 5	35 6	38 7	42 8	45 9	48 11	51 12	53 13	55 14	58 15	60 16	62 18	64 19	66 20	68 22	70 23	71 24	73 26	75 27	76 29	78 30	79 32	81 33	82 35	84 37
118							-31	-3 1	9 2	17 3	24 4	29 5	33 6	37 7	41 8	44 9	47 10	50 11	52 12	55 13	57 14	59 16	62 17	64 18	65 19	67 21	69 22	71 23	73 25	74 26	76 28	78 29	79 31	81 32	82 34	84 35
119								-9 1	6 2	15 3	22 4	27 4	32 5	36 6	40 7	43 8	46 9	49 10	52 12	54 13	57 14	59 15	61 16	63 17	65 19	67 20	69 21	71 22	72 24	74 25	76 27	77 28	79 30	80 31	82 33	83 34

DP	**DP**
RH	**RH**

Dry Bulb Temperatures 101 to 119 F

(Read Across)

1.3.5 Elevations between 6,101 and 8,500 feet

Wet Bulb Temperatures

20 to 50 F

(Read Down)

Dry Bulb Temperatures

31 to 50 F

(Read Across)

DP	DP
RH	RH

	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
31	-29 6	-13 14	-4 22	3 30	8 38	13 46	17 55	20 63	23 72	26 81	28 90																				
32	-57 1	-21 9	-9 16	-1 24	5 32	10 40	14 48	18 56	21 64	24 73	27 82	30 91																			
33		-36 4	-16 11	-5 18	2 26	7 34	12 41	16 49	20 57	23 66	36 74	28 83	31 92																		
34			-26 6	-11 13	-2 21	4 28	10 35	14 43	18 51	21 59	24 67	27 75	30 84	32 92																	
35			-44 2	-19 9	-7 16	1 23	7 30	12 37	16 45	19 52	23 60	26 68	28 76	31 84	33 92																
36				-31 4	-13 11	-4 18	3 25	9 32	13 39	17 46	21 54	24 61	27 69	29 77	32 84	34 92															
37					-22 7	-9 13	0 20	6 27	11 34	15 41	19 48	22 55	25 63	28 70	31 77	33 85	35 92														
38					-37 3	-16 9	-5 16	3 22	8 29	13 35	17 42	21 49	24 57	27 64	29 71	32 78	24 85	36 92													
39						-25 5	-10 11	-1 18	4 24	11 31	15 37	19 44	22 51	25 58	28 64	30 71	33 78	35 85	37 93												
40						-45 2	-18 8	-6 14	2 20	8 26	13 32	17 39	21 46	24 52	27 58	29 65	32 72	34 79	36 86	38 93											
41							-29 4	-12 10	-2 16	5 22	10 28	15 34	19 41	22 47	25 53	28 59	30 66	33 72	35 79	37 86	39 93										
42							-57 1	-20 6	-7 12	1 18	8 24	13 30	17 36	20 42	24 48	27 54	29 60	32 66	34 73	36 80	38 86	40 93									
43								-33 3	-13 9	-3 14	4 20	10 26	15 31	19 37	22 43	25 49	28 55	30 61	33 67	35 73	37 80	39 86	41 93								
44									-22 5	-8 11	1 16	7 22	12 27	17 33	20 38	24 44	26 50	29 56	32 62	34 68	36 74	38 80	40 87	42 93							
45									-37 2	-14 7	-3 13	4 18	10 24	15 29	18 34	22 40	25 45	28 51	31 57	33 62	35 68	37 74	39 81	41 87	43 93						
46										-24 4	-9 9	0 15	7 20	12 25	16 30	20 35	23 41	26 46	29 52	32 57	34 63	36 69	39 75	41 81	42 87	44 94					
47										-41 2	-15 7	-4 12	4 17	10 21	14 26	18 31	22 37	25 42	28 47	31 53	33 58	35 64	38 70	40 75	42 81	43 87	45 94				
48											-25 4	-9 9	0 13	7 18	12 23	16 28	20 33	23 38	27 43	29 48	32 53	34 59	37 64	39 70	41 76	43 82	45 88	46 94			
49											-45 1	-16 6	-4 11	3 15	9 20	14 24	18 29	22 34	25 39	28 44	31 49	33 54	36 60	38 65	40 71	42 76	44 82	46 88	47 94		
50												-26 3	-9 8	0 12	6 17	12 21	16 26	20 30	24 35	27 40	29 45	32 50	35 55	37 60	39 66	41 71	43 77	45 82	47 88	48 94	

Elevations between 6,101 and 8,500 feet

Wet Bulb Temperatures

31 to 70 F

(Read Down)

Dry Bulb Temperatures

51 to 70 F

(Read Across)

DP	DP
RH	RH

	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70
51	-44 1	-16 5	-5 10	3 14	9 18	14 23	18 27	22 32	25 36	28 41	31 46	33 51	36 56	38 61	40 66	42 72	44 77	46 83	48 88	49 94																				
52		-27 3	-10 7	-1 11	6 15	12 20	16 24	20 28	24 33	27 37	30 42	32 47	35 52	37 57	39 62	41 67	43 72	45 77	47 83	49 88	50 94																			
53		-50 1	-18 5	-5 9	3 13	9 17	14 21	18 25	22 30	25 34	28 38	31 43	34 48	36 52	38 57	40 62	42 67	44 73	46 78	48 83	50 89	51 94																		
54			-29 2	-11 6	-1 10	4 14	12 18	16 22	20 26	24 31	27 35	30 39	33 44	35 49	37 53	40 58	42 63	44 68	46 73	47 78	49 83	51 89	52 94																	
55			-57	-19 4	-6 8	3 12	9 16	14 20	18 24	22 28	26 32	39 36	31 40	34 45	36 49	39 54	41 59	43 64	45 68	47 73	48 79	50 84	52 89	53 94																
56				-30 2	-11 6	-1 9	4 13	12 17	16 21	21 25	24 29	27 33	30 37	33 41	35 46	38 50	40 55	42 59	44 64	46 69	48 74	50 79	51 84	53 89	54 95															
57					-19 4	-6 7	3 11	9 15	14 18	19 22	22 26	26 30	29 34	32 38	34 42	37 47	39 51	41 55	43 60	45 65	47 69	49 74	51 79	52 84	54 89	55 95														
58					-22 2	-12 5	-1 9	6 12	12 16	17 20	21 23	24 27	28 31	31 35	33 39	36 43	38 47	40 52	42 56	44 61	46 65	48 70	50 75	52 79	53 84	55 90	56 95													
59						-20 3	-6 7	3 10	9 14	15 17	19 21	23 25	26 28	29 32	32 36	35 40	37 44	39 48	42 52	44 57	46 61	48 66	49 70	51 75	53 80	54 85	56 90	58 95												
60						-32 2	-12 5	-1 8	6 12	12 15	17 18	21 22	25 26	28 29	31 33	34 37	36 41	39 45	41 49	43 53	45 57	47 62	49 66	50 71	52 75	54 80	55 85	57 89	59 95											
61							-20 3	-4 6	3 10	10 13	15 16	19 20	23 23	27 27	30 30	33 34	35 38	38 42	40 46	42 50	44 54	46 58	48 62	50 67	52 71	53 76	55 80	56 85	58 90	60 95										
62							-32 2	-11 5	-1 8	7 11	13 14	17 17	21 21	25 24	28 28	31 31	34 35	37 39	39 43	41 46	43 50	45 54	47 59	49 63	51 67	52 72	54 76	56 81	58 85	59 90	61 95									
63								-19 3	-5 6	4 9	10 12	15 15	20 19	24 22	27 25	30 29	33 32	36 36	38 40	40 43	43 47	45 51	47 55	49 59	50 63	52 68	54 72	55 76	57 81	59 85	60 90	62 95								
64								-32 1	-11 4	0 7	7 10	13 13	18 17	22 20	26 23	29 26	32 30	35 33	37 37	40 40	42 44	44 48	46 52	48 56	50 60	52 64	53 68	55 72	57 77	58 81	60 86	61 90	63 95							
65									-19 3	-5 6	4 9	11 12	16 15	20 18	24 21	28 24	31 27	34 31	36 34	39 38	41 41	43 45	45 49	47 52	49 56	51 60	53 64	54 68	56 73	58 77	59 81	61 86	62 90	64 95						
66									-31 1	-10 4	0 7	8 10	14 13	18 16	22 19	26 22	29 25	32 28	35 32	38 35	40 39	42 42	44 44	46 49	48 53	50 57	52 61	54 65	55 69	57 73	59 77	60 82	62 86	63 91	65 95					
67										-18 3	-44 4	5 8	11 11	16 14	21 17	25 20	28 23	31 26	34 29	37 33	39 34	41 39	44 43	46 46	48 50	50 54	51 57	53 61	55 65	57 69	58 73	60 78	61 82	63 86	64 91	66 95				
68										-29 1	-9 4	1 7	8 10	14 12	19 15	23 18	27 21	30 24	33 27	34 30	38 33	41 37	43 40	45 44	47 47	49 51	51 54	53 58	54 62	54 66	58 70	59 74	61 78	62 82	64 86	65 91	67 95			
69										-54	-16 3	-3 5	5 8	12 11	17 13	21 16	25 19	29 22	32 25	35 28	37 31	40 34	42 38	44 41	46 44	48 48	50 51	52 55	54 58	56 62	57 66	59 70	60 74	62 78	63 82	65 87	66 91	68 95		
70											-27 2	-8 4	2 7	9 9	5 12	20 15	24 17	27 20	31 23	34 26	36 29	39 32	41 35	43 38	46 42	48 45	50 48	51 52	53 55	55 59	57 63	58 66	60 70	61 74	63 78	64 82	66 87	67 91	69 95	

Elevations between 6,101 and 8,500 feet

Wet Bulb Temperatures

42 to 81 F

(Read Down)

	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85
71	-15 3	-2 5	4 8	13 10	18 13	22 16	26 18	29 21	32 24	35 27	38 30	40 33	43 34	45 39	47 42	49 46	51 49	53 52	54 56	56 59	58 63	59 67	61 71	63 75	64 79	65 83	67 87	68 91	70 96															
72	-25 2	-7 4	3 6	10 9	16 11	20 14	24 17	28 19	31 22	34 25	37 28	39 31	42 34	44 37	46 40	48 43	50 46	52 50	54 53	56 56	57 60	59 64	61 67	62 71	64 75	65 7*9	67 83	68 87	69 91	71 96														
73	-43 1	-13 3	-1 5	7 8	13 10	18 13	23 15	27 18	30 20	33 23	36 26	39 29	41 32	43 34	46 37	48 41	50 44	52 47	53 50	55 53	56 57	58 60	60 64	62 68	63 71	65 75	66 79	68 83	69 87	70 91	72 96													
74		-22 2	-6 4	4 6	11 9	16 11	21 14	25 16	29 19	32 21	35 24	38 27	40 29	43 32	45 35	47 38	49 41	81 44	53 47	55 51	56 54	58 57	60 61	61 64	63 68	64 72	66 75	67 79	69 83	70 87	71 91	73 96												
75		-37 1	-12 3	0 5	8 7	14 10	19 12	24 15	27 17	31 20	34 22	37 25	39 28	42 30	44 33	46 36	48 39	50 42	52 45	54 48	56 51	58 55	59 58	61 61	62 65	64 68	65 72	67 76	## 80	70 83	71 87	72 92	74 96											
76			-19 2	-4 4	5 6	12 9	17 11	22 13	26 16	30 18	33 21	36 23	38 26	41 28	43 31	45 34	48 37	50 40	52 43	53 46	55 49	57 52	59 55	60 58	62 62	63 65	65 69	66 72	68 76	69 80	71 84	72 88	73 92	75 96										
77			-32 1	-10 3	2 5	9 7	15 10	20 12	24 14	28 17	32 19	35 21	37 24	40 26	42 29	45 32	47 35	49 37	51 40	53 43	55 46	56 49	58 52	60 55	61 59	63 62	65 66	66 69	68 73	69 76	70 80	72 84	73 88	74 92	76 96									
78				-17 2	-3 4	4 6	13 8	18 11	23 13	27 15	30 17	33 20	34 22	39 25	42 27	44 30	46 33	48 35	50 38	52 41	54 44	56 47	58 50	59 53	61 56	63 59	64 63	66 66	67 69	69 73	70 76	71 80	73 84	74 88	75 92	77 96								
79				-27 1	-8 3	3 5	11 7	16 9	21 12	25 14	29 16	32 18	35 21	38 23	41 26	43 28	45 31	48 33	50 36	52 39	54 41	55 44	57 47	59 50	61 53	62 56	64 60	65 63	67 66	68 70	70 73	71 77	72 80	74 84	75 88	76 92	78 96							
80				-52	-14 2	-1 4	8 6	14 8	19 10	24 12	28 15	31 17	34 19	37 22	40 24	42 26	45 29	47 31	49 34	51 37	53 39	55 42	57 45	58 48	60 51	62 54	63 57	65 60	66 63	68 67	69 70	71 73	72 77	73 81	75 84	76 88	77 92	79 96						
81					-21 1	-3 3	5 5	12 7	17 9	22 11	26 13	30 16	33 18	36 20	39 22	42 25	44 27	46 30	48 32	50 35	52 37	54 40	56 43	58 45	60 48	61 51	63 54	64 57	66 60	68 64	69 67	70 70	72 74	73 77	75 81	76 84	77 88	78 92	80 96					
82					-40 1	-11 2	1 4	9 6	15 8	20 10	25 12	29 14	32 16	35 19	38 21	41 23	43 25	46 28	48 30	50 33	52 35	54 38	56 41	57 43	59 46	61 49	62 52	64 55	66 58	67 61	69 64	70 67	71 71	73 74	74 77	76 81	77 85	78 88	79 92	81 96				
83						-19 2	-3 3	4 5	13 7	19 9	23 11	27 13	31 15	34 17	37 19	40 22	42 24	45 26	47 29	49 31	51 33	53 36	55 38	57 41	59 44	60 47	62 49	64 52	65 55	67 58	68 61	70 64	71 68	73 71	74 74	75 78	77 81	78 85	79 88	80 92	82 96			
84						-31 1	-8 3	3 4	11 6	17 8	22 10	26 12	30 14	33 16	36 18	39 20	42 22	44 25	46 27	49 29	51 32	53 34	55 37	56 39	58 42	60 44	62 47	63 50	65 53	66 56	68 59	69 62	71 65	72 68	74 71	75 74	76 78	78 81	79 85	80 89	82 92	83 96		
85							-15 2	-1 4	8 5	14 7	20 9	24 11	28 13	32 15	35 17	38 19	41 21	43 23	46 25	48 28	50 30	52 32	54 35	56 37	58 40	59 42	61 45	63 48	64 50	66 53	68 56	69 59	70 62	72 65	73 68	75 71	76 75	77 78	79 81	80 85	81 89	83 92	84 96	
86							-25 1	-6 3	5 4	12 6	18 8	23 10	27 12	31 14	34 16	37 18	40 20	42 22	43 24	47 26	49 28	51 31	53 33	55 35	57 38	59 40	61 43	62 45	64 48	66 51	67 54	69 56	70 59	72 62	73 65	74 68	76 72	77 75	78 78	80 82	81 85	82 89	84 92	85 96
87							-44	-12 2	1 4	9 5	16 7	21 9	26 11	29 13	33 14	36 16	39 18	42 20	44 22	46 25	49 27	51 29	53 31	55 33	57 36	59 38	60 41	62 43	64 46	65 48	67 51	68 54	70 57	71 60	73 63	74 66	75 69	77 72	78 75	79 78	81 82	82 85	83 89	85 92
88								-20 1	-3 3	7 5	14 6	19 8	24 10	28 12	32 13	35 15	38 17	41 19	43 21	46 23	48 25	50 27	52 30	54 32	56 34	58 36	60 39	62 41	63 44	65 46	66 49	68 52	69 54	71 57	72 60	74 63	75 66	77 69	78 72	79 75	81 79	82 82	83 85	84 89
89								-33 1	-8 2	3 4	11 5	17 7	21 9	27 11	30 12	34 14	37 16	40 18	43 20	45 22	47 24	50 26	52 28	54 30	56 32	58 35	59 37	61 39	63 42	64 44	66 47	68 49	69 52	71 55	72 58	73 60	75 63	76 66	78 69	79 72	80 76	81 79	83 82	84 86
90									-15 2	-1 3	8 5	15 6	21 8	25 10	29 11	33 13	36 15	39 17	42 19	44 21	47 22	49 25	51 27	53 29	55 31	57 33	59 35	61 38	62 40	64 42	66 45	67 47	69 50	70 52	72 55	73 58	75 61	76 64	77 67	79 70	80 73	81 76	83 79	84 82

DP	DP
RH	RH

Dry Bulb Temperatures

71 to 90 F

(Read Across)

Elevations between 6,101 and 8,500 feet

Wet Bulb Temperatures, 50 to 85 F

(Read Down)

	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85
91	-25 1	-5 2	5 4	13 5	19 7	24 9	28 10	32 12	35 14	38 16	41 17	43 19	46 21	48 23	50 25	53 27	55 29	57 31	58 34	60 36	62 38	64 40	65 43	67 45	68 48	70 50	71 53	73 56	74 58	76 61	77 64	78 67	80 70	81 73	82 76	84 79
92	-44	-11 2	2 3	10 5	17 6	22 8	27 10	30 11	34 13	37 15	40 16	43 18	45 20	48 22	50 24	52 26	54 28	56 30	58 32	60 34	61 36	63 39	65 41	66 43	68 46	70 48	71 51	73 53	74 56	75 59	77 61	78 64	79 67	81 70	82 73	83 76
93		-18 1	-2 3	6 4	15 6	20 7	25 9	29 10	33 12	36 14	39 15	42 17	44 19	47 21	49 23	51 24	53 26	55 28	57 30	59 33	61 35	63 37	64 39	66 41	69 44	69 46	71 49	72 51	74 54	75 56	76 59	78 62	79 64	81 67	82 70	83 73
94		-31 1	-7 2	4 3	12 5	18 6	23 8	28 9	32 11	35 13	38 14	41 16	44 18	46 20	49 21	51 23	53 25	55 27	57 29	59 31	61 33	62 35	64 37	66 40	67 42	69 44	70 47	72 49	73 51	75 54	76 57	78 59	79 62	80 65	82 68	83 71
95			-13 1	1 3	10 4	16 6	22 7	26 9	30 10	34 12	37 13	40 15	43 17	45 18	48 20	50 22	52 24	54 26	56 28	58 30	60 32	62 34	64 36	65 38	67 40	69 42	70 45	72 47	73 49	75 52	76 54	77 57	79 60	80 62	81 65	83 68
96			-22 1	-3 2	7 4	14 5	20 6	25 8	29 9	33 11	36 12	39 14	42 16	45 17	47 19	50 21	52 23	54 24	56 26	58 28	60 30	61 32	63 34	65 36	67 38	68 41	70 43	71 45	73 47	74 50	76 52	77 55	78 57	80 60	81 63	82 65
97			-38	-9 2	4 3	12 4	18 6	23 7	28 9	32 10	35 12	38 13	41 15	44 16	46 18	49 20	51 21	53 23	55 25	57 27	59 29	61 31	63 33	64 35	66 37	68 39	69 41	71 43	72 45	74 48	75 50	77 53	78 55	80 58	81 60	82 63
98				-16 1	0 2	3 4	16 5	22 6	26 8	30 9	34 11	37 12	40 14	43 15	46 17	48 19	50 20	53 22	55 24	57 26	59 27	61 29	62 31	64 33	66 35	67 37	69 39	71 41	75 44	74 46	75 48	76 51	78 53	79 55	81 58	82 60
99				-26 1	-5 2	4 3	14 4	20 6	25 7	29 9	33 10	36 11	39 13	42 14	45 16	48 18	50 19	52 21	54 23	56 24	58 26	60 28	62 30	64 32	65 34	67 36	69 38	70 40	72 42	73 44	75 46	76 49	78 51	79 53	80 56	81 58
100				-47	-10 1	3 3	11 4	18 5	23 7	28 8	32 9	35 11	39 12	42 14	44 15	47 17	49 18	51 20	54 21	56 23	58 25	60 27	61 28	63 30	65 32	67 34	68 36	70 38	71 40	73 42	74 44	76 47	77 49	79 51	80 54	81 56
101					-18 1	-1 2	9 3	16 5	22 6	26 7	31 9	34 10	38 11	41 13	43 14	46 16	49 17	51 19	53 20	55 22	57 24	59 25	61 27	63 29	65 31	66 33	68 35	70 37	71 39	73 41	74 43	75 45	77 47	78 49	80 52	81 54
102					-29	-4 2	6 3	14 4	20 5	25 7	29 8	33 9	37 11	40 12	43 13	45 15	48 16	50 18	53 19	55 21	57 23	59 24	61 26	62 28	64 29	66 31	68 33	69 35	71 37	72 39	74 41	75 43	77 45	78 47	80 50	81 52
103						-12 1	2 2	11 4	18 5	23 6	28 7	32 9	36 10	39 11	42 13	45 14	47 15	50 17	52 18	54 20	56 22	58 23	60 25	62 26	64 28	66 30	67 32	69 34	70 35	72 37	74 39	75 41	76 43	78 46	79 48	81 50
104						-20 1	-2 2	9 3	16 4	22 5	27 7	31 8	35 9	38 10	41 12	44 13	46 15	49 16	51 17	54 19	56 20	58 22	60 24	62 25	63 27	65 29	67 30	68 32	70 34	72 36	73 38	75 40	76 42	78 44	79 46	80 48
105						-33	-6 1	6 3	14 4	20 5	25 6	30 7	33 9	37 10	40 11	43 12	44 14	48 15	51 17	53 18	55 20	57 21	59 23	61 24	63 26	65 27	66 29	68 31	70 33	71 34	73 36	74 38	76 40	77 42	79 44	80 46
106							-13 1	2 2	11 3	18 4	24 6	28 7	32 8	36 9	39 10	42 12	45 13	48 14	50 16	52 17	55 19	57 20	59 22	61 23	63 25	64 26	66 28	68 30	69 31	71 33	73 35	74 37	76 39	77 41	79 43	80 45
107							-21 1	-2 2	9 3	16 4	22 5	27 6	31 7	35 9	38 10	41 11	44 12	47 14	49 15	52 16	54 18	56 19	58 21	60 22	62 24	64 25	66 27	67 28	69 30	71 32	72 34	74 35	75 37	77 39	78 41	80 43
108							-35	-7 1	5 2	14 3	20 5	25 6	30 7	34 8	37 9	41 10	43 12	44 13	49 14	51 15	53 17	56 18	58 20	60 21	62 23	63 24	65 26	67 27	69 29	70 31	72 32	74 34	75 36	77 38	78 39	79 41
109								-13 1	2 2	11 3	18 4	24 5	29 6	33 7	36 9	40 10	43 11	45 12	48 13	51 15	53 16	55 17	57 19	59 20	61 22	63 23	65 25	67 26	68 28	70 29	72 31	73 33	75 34	76 36	78 38	79 40

DP	DP
RH	RH

Dry Bulb Temperatures

91 to 109 F

(Read Across)

1.3.6 Elevations between 8,501 and 11,000 feet

Wet Bulb Temperatures
19 to 50 F
(Read Down)

Dry Bulb Temperatures
31 to 50 F
(Read Across)

DP	DP
RH	RH

	19	20	21	22	23	24	25	26	27	28	29	30																				
31	-38 4	-18 11	-8 18	-1 25	5 33	10 41	14 49	17 57	21 65	23 73	26 82	28 90	31																			
32		-28 6	-13 13	-5 20	2 27	7 35	11 42	15 50	19 58	22 66	25 74	27 82	30 91	32																		
33		-49 2	-21 9	-9 15	-2 22	4 29	9 37	13 44	17 52	20 59	23 67	26 75	28 83	31 92	33																	
34			-33 4	-15 11	-6 17	1 24	6 31	11 38	15 46	19 53	22 61	25 68	27 76	30 84	32 92	34																
35				-24 7	-11 13	-3 20	4 26	9 33	13 40	17 47	20 54	23 62	26 69	29 77	31 95	33 92	35															
36				-39 3	-18 9	-7 15	0 22	6 28	11 35	15 42	19 49	22 56	25 63	27 71	30 78	32 85	34 92	36														
37					-27 5	-13 11	-3 17	3 24	8 30	13 37	17 43	20 50	23 57	26 64	29 71	31 78	33 85	35 93	37													
38					-47 2	-20 7	-8 13	0 19	6 25	10 32	15 38	18 45	22 52	25 59	27 65	30 72	32 79	34 86	36 93	38												
39						-31 4	-14 10	-4 15	3 21	8 27	12 34	16 40	20 46	23 53	26 59	29 66	31 72	33 79	35 86	37 93	39											
40						-60 1	-22 6	-9 12	-1 17	5 23	10 29	14 35	18 41	22 48	25 54	27 60	30 67	32 73	34 80	36 86	38 93	40										
41							-35 3	-15 8	-5 14	2 19	8 25	12 31	16 37	20 43	23 49	26 55	29 61	31 67	33 74	35 80	37 87	39 93	41									
42								-24 5	-10 10	-1 16	5 21	10 27	14 33	18 39	22 44	25 50	27 56	30 62	32 68	34 74	36 80	38 87	40 93	42								
43								-39 2	-16 7	-6 12	2 18	8 23	12 29	17 34	20 40	23 45	26 51	29 57	31 63	33 68	36 75	37 81	39 87	41 93	43							
44									-25 4	-11 9	-2 14	5 20	10 25	15 30	18 36	22 41	25 46	27 52	30 57	32 63	35 69	37 75	39 81	40 87	42 94	44						
45									-43 2	-17 6	-6 11	2 16	8 21	13 27	16 32	20 37	23 42	26 47	29 53	31 58	34 64	36 70	38 75	40 81	41 87	43 94	45					
46										-27 4	-11 8	-2 13	5 18	10 23	15 28	18 33	22 38	25 43	28 48	30 54	33 59	35 65	37 70	39 76	41 82	43 88	44 94	46				
47										-46 1	-18 6	-6 10	2 15	8 20	13 25	16 29	20 34	23 39	26 44	29 49	31 54	34 60	36 65	38 71	40 76	42 82	44 88	45 94	47			
48											-28 3	-11 8	-2 12	5 17	10 21	15 26	18 31	22 35	25 40	28 45	30 50	33 55	35 60	37 66	39 71	41 77	43 82	45 88	46 94	48		
49											-49 1	-18 5	-6 10	2 14	8 18	13 23	17 27	20 32	23 37	26 41	29 46	32 51	34 56	36 61	38 66	40 72	42 77	44 83	46 88	47 94	49	
50												-29 3	-11 7	-2 12	5 16	10 20	15 24	18 29	22 33	25 38	28 42	30 47	33 52	35 57	38 62	40 67	41 72	43 77	45 86	47 89	48 94	50

Elevations between 8,501 and 11,000 feet

Wet Bulb Temperatures
31 to 70 F
(Read Down)

DP RH	DP RH

Dry Bulb Temperatures
51 to 70 F
(Read Across)

	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70
51	-18 5	-6 9	2 13	8 17	13 21	17 26	20 30	24 34	27 39	29 43	32 48	34 53	37 57	39 62	41 67	43 73	44 78	46 83	48 89	49 94	51																			
52	-29 3	-11 7	-2 11	5 15	10 19	15 23	19 27	22 31	25 35	28 40	31 44	33 49	36 53	38 58	40 63	42 68	44 73	45 78	47 83	49 89	50 94	52																		
53	-51 1	-18 5	-6 8	2 12	8 16	13 20	17 24	21 28	24 32	27 36	30 41	32 45	35 50	37 54	39 59	41 64	43 68	45 73	47 79	48 84	50 89	51 94	53																	
54		-28 3	-11 6	-2 10	5 14	11 17	15 21	19 25	22 29	25 33	28 37	31 42	34 46	36 50	38 55	40 59	42 64	44 69	46 74	48 79	49 84	51 89	52 95	54																
55		-50 1	-18 4	-6 8	2 11	8 15	13 19	17 22	21 26	24 30	27 34	30 38	32 43	35 47	37 51	39 56	42 60	43 65	45 69	47 74	49 79	50 84	52 89	53 95	55															
56			-29 2	-11 6	-2 9	5 13	11 16	15 20	19 24	23 27	26 31	29 35	31 39	34 43	37 48	39 52	41 56	43 61	45 65	46 70	48 75	50 80	51 84	53 90	54 95	56														
57			-52 1	-19 4	-6 7	2 11	8 14	13 18	18 21	21 25	24 29	27 32	30 36	33 40	35 44	38 48	40 53	42 57	44 61	46 66	48 70	49 75	51 80	52 85	54 90	55 95	57													
58				-29 2	-11 5	-2 9	5 12	11 15	16 19	20 22	23 26	26 30	29 33	32 37	34 41	37 45	39 49	41 53	43 58	45 62	47 66	49 71	50 75	52 80	53 85	55 90	56 95	58												
59				-53 1	-18 4	-6 7	2 10	9 13	14 17	18 20	22 24	25 27	28 31	31 34	33 38	36 42	38 46	40 50	42 54	44 58	46 62	48 67	50 71	51 76	53 80	55 85	56 90	58 95	59											
60					-29 2	-11 5	-1 8	6 11	11 15	16 18	20 21	24 25	27 28	30 32	32 35	35 39	37 43	39 47	42 51	44 55	46 59	47 63	49 67	51 72	53 76	54 81	56 85	57 90	59 95	60										
61						-18 3	-5 6	3 10	9 13	14 16	18 19	22 22	25 26	28 29	31 33	34 36	36 40	39 44	41 47	43 51	45 55	47 59	49 63	50 68	52 72	54 76	55 81	57 86	58 90	60 95	61									
62						-28 2	-11 5	-1 8	6 11	12 14	17 17	21 20	24 23	27 27	30 30	33 34	35 37	38 41	40 44	42 48	44 52	46 56	48 60	50 64	51 68	53 72	55 77	56 81	58 86	59 90	61 95	62								
63							-17 3	-5 6	3 9	9 12	15 15	19 18	23 21	26 24	29 28	32 31	34 34	37 38	39 41	41 45	43 49	45 53	47 56	49 60	51 64	53 68	54 73	56 77	57 81	59 86	60 90	62 95	63							
64							-27 2	-10 5	0 8	7 10	12 13	17 16	21 19	25 22	28 25	31 29	33 32	36 35	38 39	40 42	43 46	45 49	47 53	49 57	50 61	52 65	54 69	55 73	57 77	58 82	60 86	61 91	63 95	64						
65							-47 1	-16 3	-4 6	4 9	10 12	15 14	20 17	23 20	27 23	30 26	32 30	35 33	37 36	40 40	42 43	44 46	46 50	48 54	50 58	52 61	53 65	55 69	56 73	58 78	59 82	61 86	62 91	64 95	65					
66								-26 2	-9 5	1 7	7 10	13 13	18 16	22 18	25 21	28 24	31 27	34 31	36 34	39 37	41 40	43 44	45 47	47 51	49 54	51 58	53 62	54 66	56 70	58 74	59 78	60 82	62 86	63 91	65 95	66				
67								-43 1	-15 3	-3 6	5 8	11 11	16 14	20 17	24 19	27 22	30 25	33 28	35 31	38 35	40 38	42 41	45 44	47 48	49 51	50 55	52 59	54 62	55 66	57 70	59 74	60 78	61 82	63 87	64 91	66 95	67			
68									-24 2	-8 4	2 7	8 10	14 12	18 15	22 18	26 20	29 23	32 26	35 29	37 32	39 35	42 39	44 42	46 45	48 48	50 52	52 55	53 59	55 63	57 67	58 70	60 74	61 78	63 83	64 87	65 91	67 95	68		
69									-39 1	-14 3	-2 6	5 8	12 11	17 13	21 16	25 19	28 21	31 24	34 27	36 30	39 33	41 36	43 39	45 42	47 46	49 49	51 52	53 56	54 60	56 63	58 67	59 71	61 75	62 79	64 83	65 87	66 91	68 96	69	
70										-22 2	-7 4	3 7	9 9	15 12	19 14	23 17	27 20	30 22	33 25	35 28	38 31	40 34	42 37	44 40	46 43	48 46	50 50	52 53	54 56	56 60	57 64	59 67	60 71	62 75	63 79	65 83	66 87	67 91	69 95	70

Elevations between 8,501 and 11,000 feet

Wet Bulb Temperatures
41 to 82 F
(Read Down)

	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70																			
71	-12 3	-1 6	6 8	12 10	17 13	22 15	25 18	29 21	32 23	34 26	37 29	39 32	42 35	44 38	46 41	48 44	50 47	52 50	53 54	55 57	57 60	58 64	60 68	61 71	63 75	64 79	66 83	67 87	68 91	70 96	**71**																		
72	-19 2	-5 4	4 7	10 9	15 11	20 14	24 16	27 19	30 22	33 24	36 27	38 30	41 32	43 35	45 38	47 41	49 44	51 48	53 51	55 54	56 57	58 61	60 64	61 68	63 72	64 75	65 79	67 83	68 88	69 91	71 96	**72**																	
73	-31 1	-10 3	0 6	7 8	13 10	18 13	22 15	26 17	29 20	32 22	35 25	38 28	40 30	42 33	44 36	46 39	48 42	50 45	52 48	54 51	56 55	57 58	59 61	61 66	62 68	64 72	65 76	66 80	68 83	69 87	70 92	72 96	**73**																
74		-17 2	-4 4	5 7	11 9	16 11	21 14	25 16	28 18	31 21	34 23	37 26	39 29	41 31	44 34	46 37	48 40	50 43	52 46	54 49	55 52	57 55	59 58	60 62	62 65	63 69	65 72	66 76	67 80	69 84	70 88	71 92	73 96	**74**															
75		-27 1	-9 3	2 6	9 8	14 10	19 12	23 14	27 17	30 19	33 22	36 24	38 27	41 29	43 32	45 35	47 37	49 40	51 43	53 46	55 49	57 52	58 56	60 59	61 62	63 66	64 69	66 73	67 76	69 80	70 84	71 88	72 92	74 96	**75**														
76			-15 2	-2 4	6 7	12 9	17 11	22 13	26 15	29 18	32 20	35 23	37 25	40 27	42 30	44 33	47 35	49 38	50 41	52 44	54 47	56 50	58 53	59 56	61 59	63 63	64 66	65 69	67 73	68 76	70 80	71 84	72 88	73 92	75 96	**76**													
77			-23 2	-7 3	3 6	10 8	15 10	20 12	24 14	28 16	31 19	34 21	37 23	39 26	41 28	44 31	46 33	48 36	50 39	52 42	54 44	55 47	57 50	59 53	61 56	62 60	64 63	65 66	67 70	68 73	69 77	71 80	72 84	73 88	74 92	76 96	**77**												
78			-37 1	-12 3	0 5	7 7	13 9	18 11	23 13	26 15	30 17	33 19	36 22	38 24	41 27	43 29	45 32	47 34	49 37	51 39	53 42	55 45	57 48	58 51	60 54	62 57	63 60	65 63	66 67	68 70	69 73	70 77	72 81	73 84	74 88	75 92	77 96	**78**											
79				-19 2	-5 4	5 6	11 7	16 10	21 12	25 14	29 16	32 18	35 20	37 23	40 25	42 27	45 30	47 32	49 35	51 37	53 40	54 43	56 46	58 48	60 51	61 54	63 57	64 60	66 64	67 67	69 70	70 74	71 77	73 81	74 84	75 88	76 92	78 96	**79**										
80				-31 1	-10 3	1 5	9 7	14 9	19 10	24 13	27 15	31 17	34 19	37 21	39 23	42 26	44 28	46 30	48 33	50 35	52 38	54 41	56 43	57 46	59 49	61 52	62 55	64 58	66 61	67 64	68 67	70 71	71 74	72 77	74 81	75 85	76 88	77 92	79 96	**80**									
81					-16 2	-2 4	6 6	13 7	18 9	22 11	26 13	30 15	33 18	36 20	38 22	41 24	43 26	45 29	47 31	49 34	51 36	53 39	55 41	57 44	59 47	60 49	62 52	64 55	65 58	67 61	68 64	69 68	71 71	72 74	73 78	75 81	76 85	77 88	79 92	80 96	**81**								
82					-25 1	-7 3	3 5	10 6	16 8	20 10	25 12	28 14	32 16	35 18	37 20	40 23	42 25	45 27	47 29	49 32	51 34	53 37	55 39	56 42	58 44	60 47	62 50	63 53	65 56	66 59	68 62	69 65	71 68	72 71	73 74	75 78	76 81	77 85	78 89	80 92	81 96	**82**							
83						-13 2	0 4	8 6	14 7	19 9	23 11	27 13	31 15	34 17	37 19	39 21	42 23	44 26	46 28	48 30	50 32	52 35	54 37	56 40	58 42	59 45	61 48	63 50	64 53	66 56	67 59	69 62	70 65	72 68	73 71	74 75	76 78	77 81	78 85	79 89	81 92	82 96	**83**						
84						-20 1	-5 3	5 5	12 7	17 8	22 10	26 12	29 14	33 16	36 18	38 20	41 22	43 24	46 26	48 28	50 31	52 33	54 35	55 38	57 40	59 43	61 45	62 48	64 51	66 54	67 56	69 59	70 62	71 65	73 68	74 72	75 75	77 78	78 82	79 85	80 89	82 92	83 96	**84**					
85						-32 1	-10 2	2 4	9 6	15 7	20 9	24 11	28 13	32 15	35 17	38 19	40 21	43 23	45 25	47 27	49 29	51 31	53 34	55 36	57 38	58 41	60 43	62 46	64 48	65 51	67 54	68 57	70 60	71 63	72 66	74 69	75 72	76 75	78 78	79 82	80 85	81 89	83 92	84 96	**85**				
86							-16 2	-2 3	7 5	13 7	18 8	23 10	27 12	30 14	34 15	37 17	39 19	42 21	44 23	46 25	49 28	51 30	53 32	54 34	56 37	58 38	60 41	61 44	63 46	65 49	66 52	68 54	69 57	71 60	72 63	74 66	75 69	76 72	77 75	79 79	80 82	81 85	82 89	84 93	85 96	**86**			
87							-25 1	-7 3	4 4	11 6	17 7	21 9	25 11	29 13	33 14	36 16	39 18	41 20	44 22	46 24	48 26	50 28	52 30	54 33	56 35	58 37	59 39	61 42	63 44	64 47	66 49	67 52	69 55	70 57	72 60	73 63	75 66	76 69	77 72	79 76	80 79	81 82	82 86	83 89	85 93	86 96	**87**		
88								-12 2	0 3	8 5	15 7	20 8	24 10	28 12	32 13	35 15	38 17	40 19	43 21	45 23	47 25	49 27	51 29	53 31	55 33	57 35	59 38	61 40	62 42	64 45	66 47	67 50	69 52	70 55	72 58	73 61	74 64	76 66	77 69	78 73	80 76	81 79	82 82	83 86	84 89	86 93	87 96	**88**	
89								-20 1	-4 3	6 4	13 6	18 7	23 9	27 11	30 12	34 14	37 16	40 18	42 20	44 21	47 23	49 25	51 27	53 29	55 31	57 34	58 36	60 38	62 40	63 43	65 45	67 48	68 50	70 53	71 55	73 58	74 61	75 64	77 67	78 70	79 73	81 76	82 79	83 82	84 86	85 89	87 93	88 96	**89**
90								-31 1	-9 2	3 4	10 5	16 7	21 8	25 10	29 11	33 13	36 15	39 17	41 18	44 20	46 22	48 24	50 26	52 28	54 30	56 32	58 34	60 36	61 39	63 41	65 43	66 46	68 48	69 51	71 53	72 56	74 59	75 61	77 64	78 67	79 70	80 73	82 76	83 79	84 83	85 86	86 89	88 93	89 96

DP	DP
RH	RH

Dry Bulb
Temperatures
71 to 90 F
(Read Across)

1.4 Stability

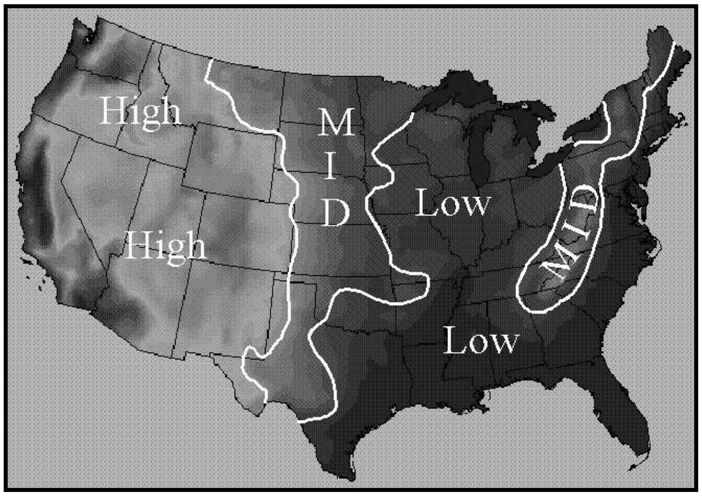
1.4.1 Measures of Stability

Index	Major Factors	Primary Utility	Application
Davis Stability Index	Lapse rate	Basic measure of stability	Southeast US
Ventilation Index	Mixing height and transport wind	Smoke dispersion	
Haines (Lower Atmospheric Stability) Index	Lapse rate and relative humidity	Large fire growth potential	United States
Pasquill Stability Index	Solar radiation, cloud cover and surface wind speed (surface based stability)	Smoke dispersion	SASEM
Lavdas Atmospheric Dispersion Index	Pasquill, mixing height, transport wind	Smoke dispersion and fire growth potential.	Florida

1.4.2 Lower Atmospheric Stability (Haines) Index

The Lower Atmospheric Severity Index (commonly known as the Haines Index) was developed during the 1980s as a fire weather tool to estimate the effect of atmospheric dryness and stability on the growth potential of a wildfire. The goal was to identify typical combinations of humidity and stability and contrast them with combinations of stability and humidity prevalent during problem fire outbreaks.

Stability Term (A)	Moisture Term (B)
LOW ELEVATION	
950 – 850 mb °C	**950 mb T° C – 950 DP° C**
A = 1 when 3°C or less	B = 1 when 5° C or less
A = 2 when 4-7°C	B = 2 when 6-9° C
A = 3 when 8°C or more	B = 3 when 10° C or more
MID ELEVATION	
850 – 700 mb °C	**850 mb T° C – 850 DP° C**
A = 1 when 5°C or less	B = 1 when 5° C or less
A = 2 when 6-10°C	B = 2 when 6-12° C
A = 3 when 11°C or more	B = 3 when 13° C or more
HIGH ELEVATION	
700 – 500 mb °C	**700 mb T° C – 700 DP° C**
A = 1 when 17°C or less	B = 1 when 14° C or less
A = 2 when 18-21°C	B = 2 when 15-20° C
A = 3 when 22°C or more	B = 3 when 21° C or more



Haines Index (A + B)	Potential for Large Fire
2 or 3	Very Low
4	Low
5	Moderate
6	High

1.4.2.1 Haines Index Climatology

- 40 Year (1961-2000) Climatology of Haines Index for North America, http://info.airfire.org/haines/map/
- NWS Western Regional Tech Attachment,http://www.wrh.noaa.gov/wrh/97TAs/TA9717/TA97-17.html

1.5 Fire Weather Data

1.5.1 Digital Weather Data

1.5.1.1 Sources of Digital Weather and Fire Records

FAMWEB Fire & Weather Data (http://fam.nwcg.gov/fam-web/weatherfirecd/) provides access to all archived daily fire weather records for NFDRS stations in the United States, both manual and automated. It also is the source of fire occurrence data for all federal agencies and some state agencies. These files are formatted for easy import into Firefamily Plus.

The ***Kansas City Fire Access Software(KCFast)*** interface (https://fam.nwcg.gov/fam-web/kcfast/mnmenu.htm) provides user requested access to archived and current weather records from NFDRS stations in the United States. Hourly records are stored for the most recent years and all daily records archived in the Weather Information Management System (WIMS) are available. Fire occurrence records are available as well. File formats are compatible with Firefamily Plus import.

The ***Western Region Climate Center*** provides an archive (http://www.wrcc.dri.edu/wraws/) to all Satellite (GOES) enabled RAWS stations. It is the most complete archive of hourly observations for the RAWS network. The interface provides many display alternatives (wind rose, summary tables, frequency distributions and station metadata). The data lister provides for data download of archived data with a user password.

Mesowest (http://mesowest.utah.edu/index.html) provides access to hourly data for a wide variety of weather stations across the United States. With a free user login, up to 365 days of observations may be downloaded at a time, in either excel spreadsheet, comma delimited text, or XML format.

1.5.1.2 Critique and Edit in Firefamily Plus

Firefamily Plus is fire and weather analysis software that is freely available at http://www.firemodels.org and can be used effectively to review and edit archived weather records obtained from the sites listed above. Here are several steps that can help evaluate the weather record for time span, accuracy, and completeness. Once the records are imported:

1. Evaluate the Active Working Set for the archive to determine if the record has a *sufficient time span* (15+ years) for climatological analyses
2. Evaluate the *completeness* of the record by evaluating the data count for the archive. Does the station collect records year round? If not, what period of the year appears to have a relatively complete record?
3. Evaluate individual data elements to determine the archive's *accuracy*. Look for outliers among the basic data observations (Temp, RH, windspeed, precipitation, max & min values) by sorting records in ascending and descending order to locate erroneous values.
4. Evaluate data elements and calculated components and indices by displaying climatology graphs (max, min) and individual years to find erroneous trends and outliers.
5. Evaluate the wind rose to determine whether the station's wind observations (speeds and directions) are representative of the fire situation being analyzed.

It may be appropriate to edit the records, which can be done in the "View Observations" table. Before changing archived observation, the record in question should be compared to those of surrounding stations. Any changes made, should be documented for the local fire management agency.

1.5.2 FARSITE & FlamMap Weather Inputs

1.5.2.1 Wind (WND) and Weather (WTR) Files

Like the Initial Fuel Moisture File, WND and WTR files are simple space delimited text files that may be edited with a simple text editor. Typically these files include both conditions from the recent past (several days to a week or more) and for forecasted weather (2 days to 1 week input manually from narrative forecasts or formatted files obtained from the National Weather Service at http://www.weather.gov/fire).

In FlamMap and Short Term Fire Behavior (STFB), these files are used to apply a conditioning period of varying weather conditions that will result in adjusted fuel moisture conditions for each location in the landscape (LCP) file at the end of the conditioning period. **In FARSITE and Near Term Fire Behavior (NTFB)** these files are used in both the fuel moisture conditioning process and as input weather conditions throughout the analysis period.

For the desktop systems, formatted files of weather observations are generally created in Firefamily Plus data for a selected weather station using ***Weather/Hourly Data Analysis/FARSITE Exports***. These files are generally appended with forecast data from one of a variety of sources. One primary source of forecast data is provided by NWS National Digital Forecast Database (NDFD).

The user is responsible for verifying the quality of these weather inputs:

- Ensure the source of the forecast information. In addition to the NWS, other systems of forecast models produce files in these formats. Evaluate the source model(s) and the resolution (grid cell size used to produce them. In areas with local influences, such as elevation and aspect, weather forecast elements may not be sufficiently resolved by a forecast grid of 2.5 or 5 kilometers
- Contents of these files should be reviewed by the incident meteorologist or local fire weather forecaster and/or compared to narrative forecasts and known conditions over the fire area.
- **Do not assume that forecast WND/WTR files (or WFDSS weather inputs) are accurate or applicable for the fire analysis area**.

1.5.2.2 Gridded Winds

For many fire managers, visualizing the variability of wind in complex terrain can be difficult. Simplified rules and guidelines have been outlined in Section 1.2, however, WindNinja is a freely available wind modeling software tool that is available for download at http://www.firemodels.org/index.php/research-systems/windninja. Though not as sophisticated as other models that incorporate "fluid dynamics", it is fast, simple to use, requires relatively few inputs, and produces a variety of graphic outputs.

In addition to the software, the user needs:

- Elevation Data, in the form of an ASCII Raster file. Readily available fire modeling landscape (lcp) flies are accepted by the program as source of this information.
- One (or several) "domain-mean" initial windspeed(s), either forecast or retrospective, that represents an average for the area being analyzed. This may be provided by NWS NDFD gridded winds.
- General characterization of the dominant vegetation or surface roughness.

The program provides outputs in three formats, a ***Google Earth kmz*** file format, a ***FARSITE/FlamMap ascii grid (asc)*** file format, and an ***ArcGIS shapefile*** format.

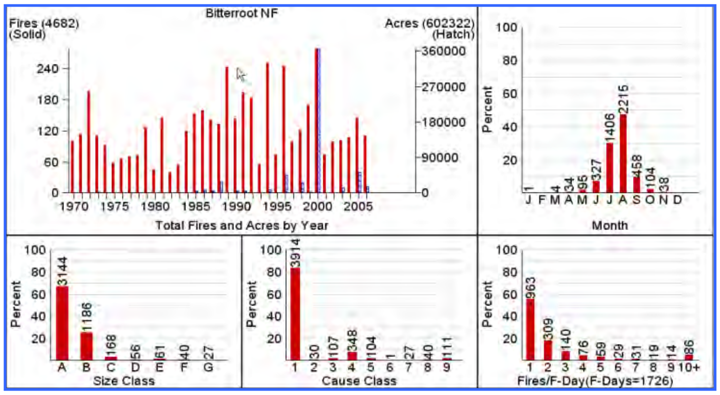
The user should verify the appropriateness for each grid file output. In complex terrain, one way would be to compare ridgetop winds produced in the grid with forecast or observed ridgetop winds for the fire area.

1.6 Fire Season Climatology

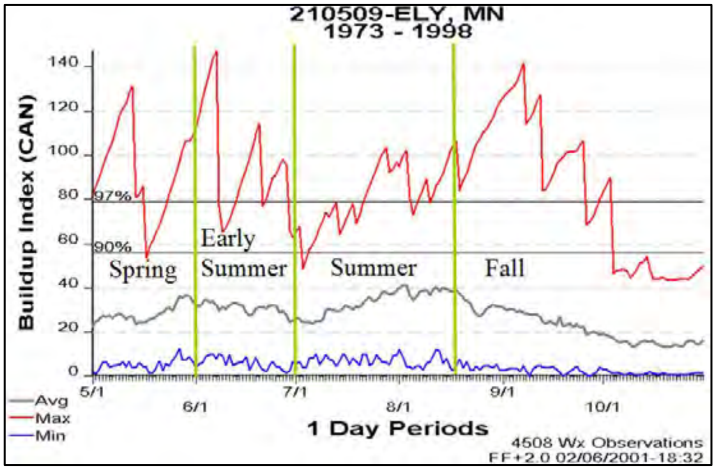
1.6.1 Seasonal Trends

Local Fire Season Climatology

- Evaluate **Fire Occurrence** Patterns

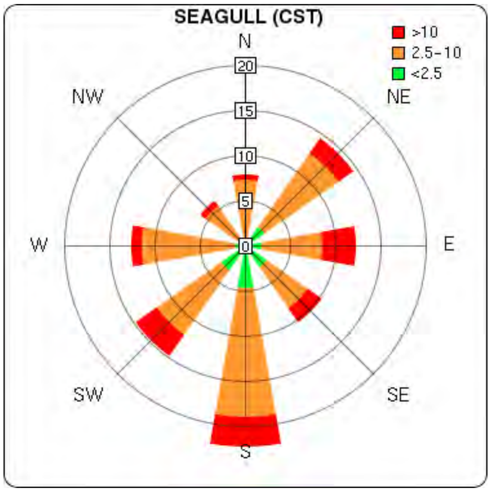


- Use Appropriate **Fire Potential Indicators**- ERC, BUI
- **Identify Seasonal Trend** – Season Start, Peak Period(s), shoulder Seasons, Season End



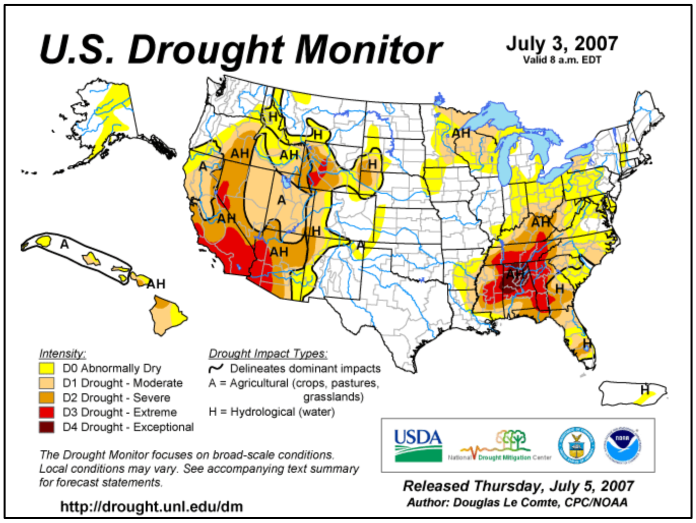
- **Winds Climatology**

Wind roses are available in Firefamily Plus, wrcc.dri.edu, and in other tools. Insure it includes only relevant winds (for example – exclude other seasons, night time winds, etc.)

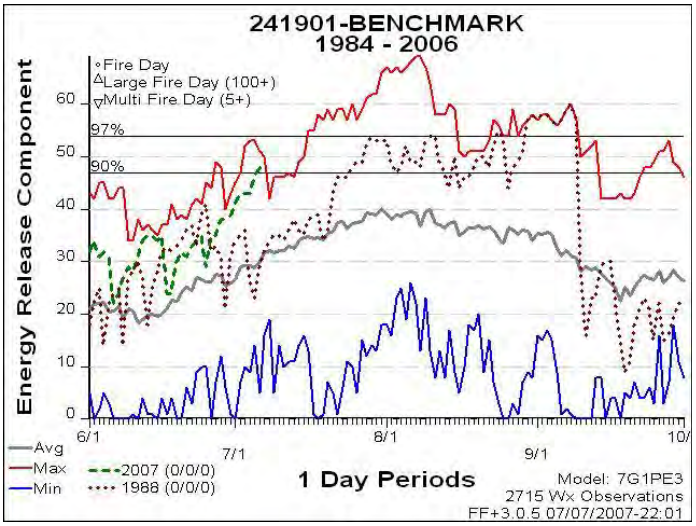


Compare current trends to historic normal/extremes

- **General Trends**, such as the US Drought Monitor depict current conditions spatially, using a combination of indices and human interpretation



- **Current local conditions** can be displayed in the context of historic trends



This Firefamily Plus graphic includes historic maximum (red), average (gray), current year (2007, dash), & analog (1988, dot).

- **Consult with local managers** and experts to evaluate the objective analysis and to identify any local anomalies that may not be apparent.

1.6.2 Climatology of Weather that Slows or Stops Fire Growth

Fire Stopping Events:

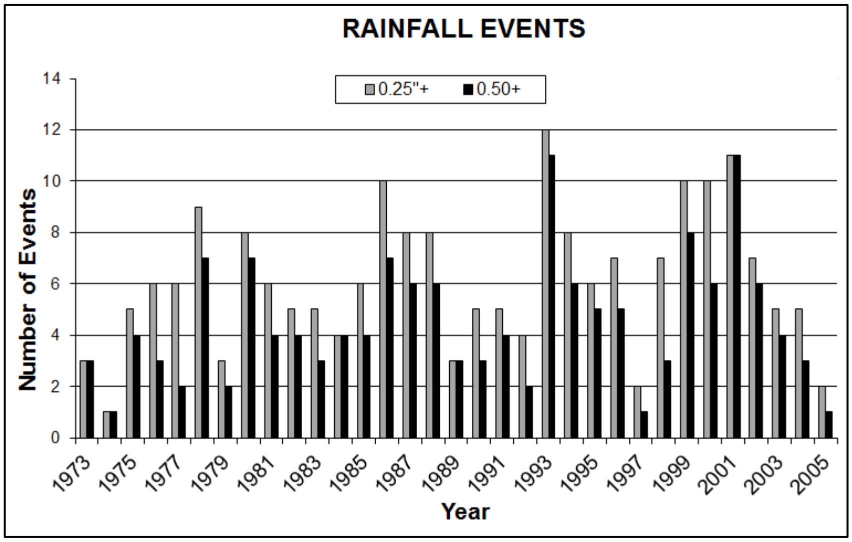
Originally reported by Latham and Rothermel (1993) from opinions of persons familiar with fire and fire weather in the Northern Rockies, example criteria was suggested as 0.5 inches of rain accumulated in 5 days or less. However, other fire potential indicators, such as cloud cover and relative humidity, can help identify periods of continuous low- or no-spread days during a fire season in a locality. These discrete events may not signal the end of the fire or the season. As such, it may be just as important to identify the **frequency** with which they occur and the **duration** of their influence as it is to predict a **waiting time** for the next event.

Fire/Season Ending Date

It is possible to identify the date in a fire season when fire growth is no longer likely or possible. This is generally understood to be the season end. If a fire's threat to values of concern is more imminent or it is early in the fire season, a prediction of the season end may be less important than suggesting if and when a weather event will put the fire out. In bimodal seasons, such as the spring seasons in the southwest and the lake states, weather criteria can suggest fire ending dates in the early "season", even though fire potential is expected to rise again in subsequent periods. Anticipating this date may be critical to strategic decisions as the season end approaches.

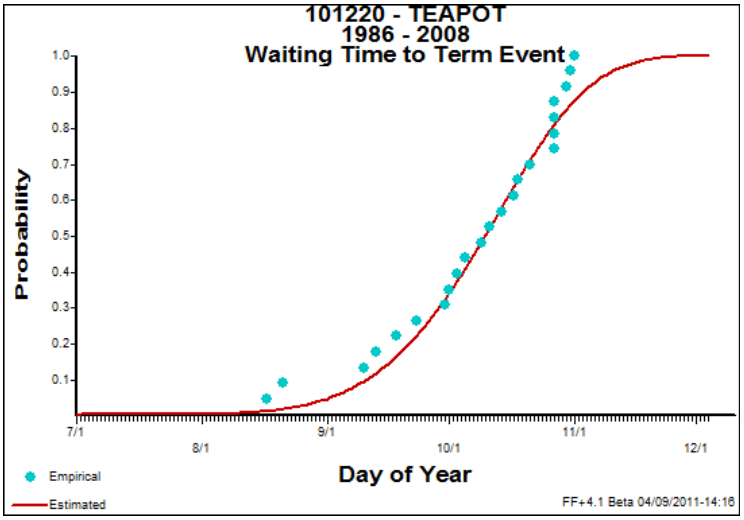
1.6.2.1 Event Frequency and Duration

As suggested above and depicted here, it may be valuable to identify the frequency of fire slowing or stopping events, especially if they are more common, such as in the eastern US. Firefamily Plus Event Locator can be used to evaluate data from a local RAWS station. It is also possible to graph precipitation event probability by duration or quantity for the NWS Cooperative Observer Network at the Western Region Climate Center (http://www.wrcc.dri.edu/sod/arch/index.html)



1.6.2.2 TERM Waiting Time Distribution

Firefamily Plus (version 4.1) includes a "TERM" tool (in the Weather menu) to produce a waiting time distribution of historic fire- or season-ending dates. For each year evaluated, a single date is selected as the ending date based on established criteria. These dates are recorded and the distribution plotted to estimate the probability that the fire or season will end by a specific date.



1.6.3 Forecast and Outlook Products

1.6.3.1 National Weather Service Fire Weather Page (http://www.weather.gov/fire)

1.6.3.2 NOAA NWS Weather Forecast Office

- National Digital Forecast Database is the basis for all Weather Forecast Office (WFO) forecast products. With forecasts for each hour over the 36 hour period, graphs, tables, and narrative products are all derived automatically and reviewed by on-duty forecasters.
- Fire Weather Planning Forecast (http://www.nws.noaa.gov/view/validProds.php?prod=FWF) is produced by the local WFO and includes detailed forecast for the next 36 hours and more general outlook for days 3-8. The format is somewhat standardized across the United States
- Fire Weather Watch / Red Flag Warning (http://www.nws.noaa.gov/view/validProds.php?prod=RFW) are produced to identify extreme fire weather conditions (according to operating plan definition) that are expected in the next 24 hours (Watch) or are expected in the current forecast period (Warning).
- Spot Weather Forecasts are produced by WFO fire weather forecasters based on requests and information for specific locations provided by fire managers. These forecasts are generally limited to today, tonight, & tomorrow.
- Incident Fire Weather Forecasts are produced by incident meteorologists for each operational period.
- NFDRS Point Forecast (http://www.nws.noaa.gov/view/validProds.php?prod=FWM) is produced for an active RAWS location after the current daily (1300 LST) observation is received at the WFO. It is based on the NDFD grid forecast for the corresponding grid cell and calibrated to the reported RAWS observation.
- Activity Planner is a tool that allows the user to specify weather parameters from which future forecast periods can be identified that meet those parameters.

1.6.3.3 Predictive Services Outlooks (http://www.predictiveservices.nifc.gov/outlooks/outlooks.htm)

- The National Incident Coordination Center (NICC) and all regional predictive service offices produce both seasonal (issue date varies) and monthly (issued at the beginning of each month) fire potential forecasts.
- Daily Fire Weather and/or Fire Behavior Outlooks are generally include information and are formatted to the specific needs of responsible fire management agencies within the predictive service region.
- 7 Day Fire Potential products provide forecast assessments of fuel dryness, high risk days, and ignition triggers for climatological/fire management units within the predictive service region. It generally includes supporting narrative and calls to action.
- Multi-Media Briefings are available on a regular basis from each predictive service office.

1.6.3.4 NOAA NWS Storm Prediction Center (http://www.spc.noaa.gov/)

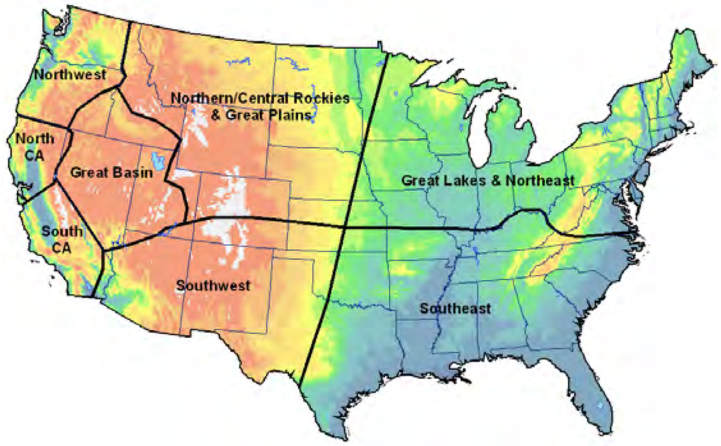
- Fire Weather Outlooks are produced for day 1, day 2, and day 3-8. They identify critical and extremely critical areas for wind and RH, and critical areas for dry thunderstorms
- Convective and Thunderstorm Outlooks are produced for day 1, day 2, and day 3-8. Three separate risk areas (slight, moderate, and high) are used to describe the expected coverage and intensity for the categorical severe weather threat on days 1-3 along with severe weather probabilities for the potential threat.

1.6.3.5 NOAA NWS Climate Prediction Center (http://www.cpc.ncep.noaa.gov/)

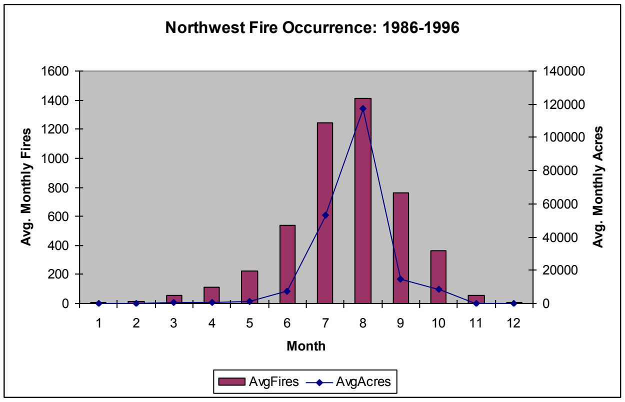
- Probabilistic Temperature and Precipitation Outlooks are produced for Day 6-10 (updated daily), Day 8-14 (updated daily), the next month (produced mid-month) and upcoming 3 month (updated mid-month) periods.
- Drought Monitor and Associated Forecasts (http://droughtmonitor.unl.edu/) are updated and released each Thursday at 0700 Eastern Time.

1.6.4 Regional Fire Seasonality (Fire Occurrence by Month)

The basic climate/weather factors that define fire season are temperature (hot vs. cold), atmospheric moisture (dry vs. moist), and wind patterns. All of these factors affect the fuels conditions and the tendency for fires to start and spread. Climatologic fire season characteristics are driven by seasonal and continental-scale weather patterns, their movement, and variation. In essence, seasonal air mass and jet stream changes affect various regions at different times and in different ways. The 'fire season' shifts around the country with these changes

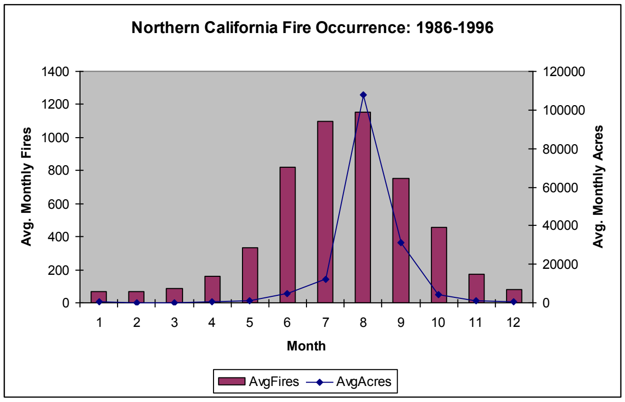


Northwest



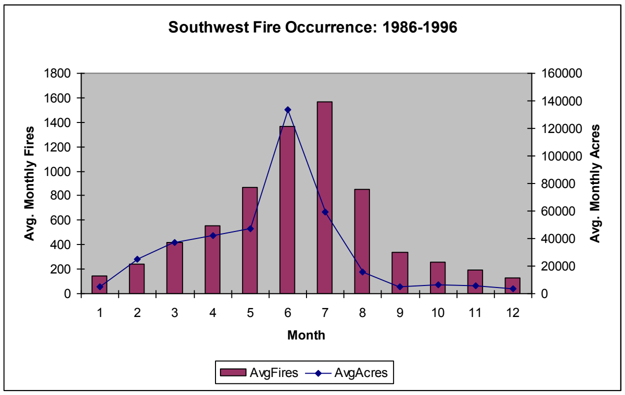
- Fire activity peaks in summer due to increasingly warm & dry conditions and potential for wind and lightning with dry cold frontal passages.
- Rapid decrease in activity in fall with Pacific moisture on the increase, though this the peak period for dry offshore wind events and a few dry cold front passages are still possible.

Northern California



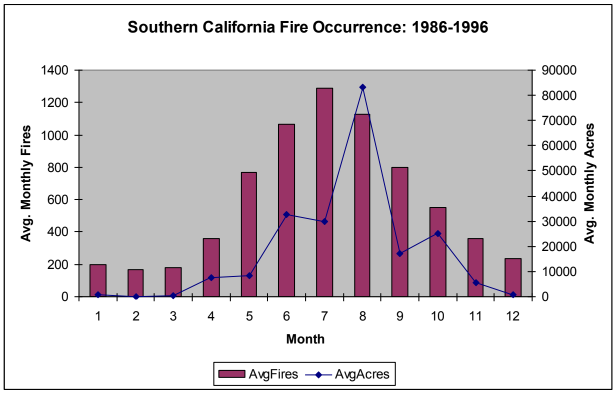
- Fire activity peaks in summer due to increasingly warm & dry conditions and potential for wind and lightning with infrequent dry cold frontal passages.
- Rapid decrease in activity by late fall with Pacific moisture on the increase, though peak period for dry northeast wind events.

Southwest



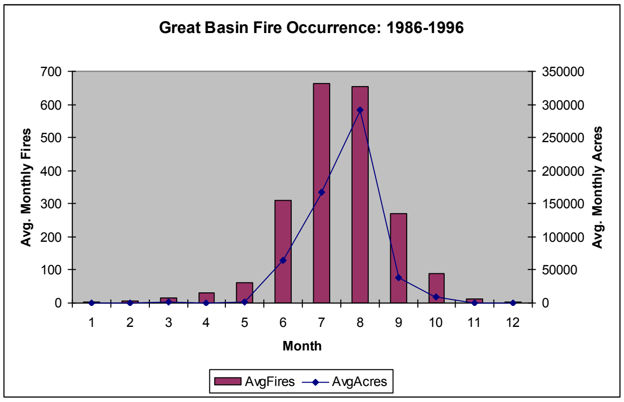
- Fire activity increases in spring as it transitions from windy & dry to hot & dry
- Peak from May – mid-July, with monsoon thereafter
- Rare secondary fall season as moisture exits and jet drops south & wind event potential returns

Southern California



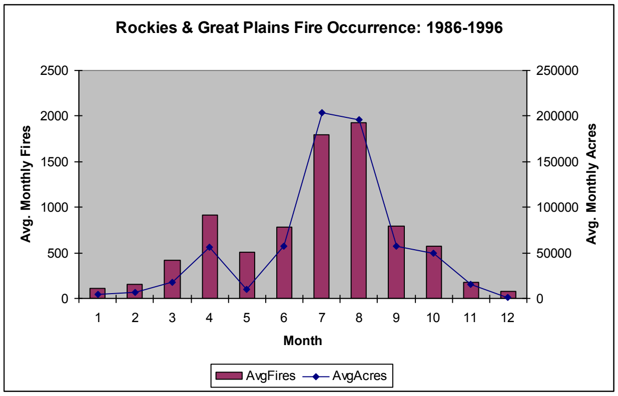
- Fire activity peaks late spring through fall, when influence of maritime air is diminished.
- Greatest potential for offshore wind events in the fall, when fuels are often driest.
- Fires possible any time with offshore wind events.

Great Basin



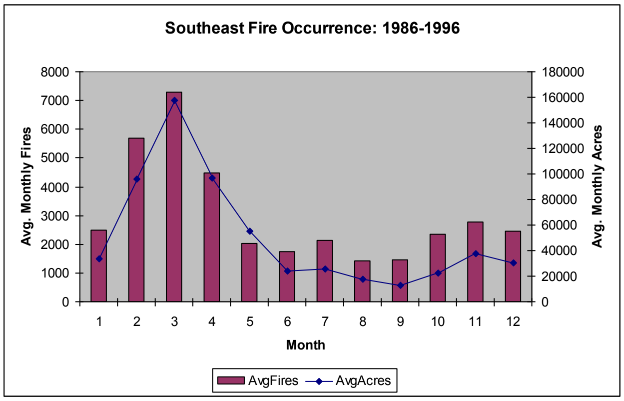
- Almost exclusively in the summer, fire season is dependent on cured fine fuels and windy/dry conditions

Rockies & Great Plains



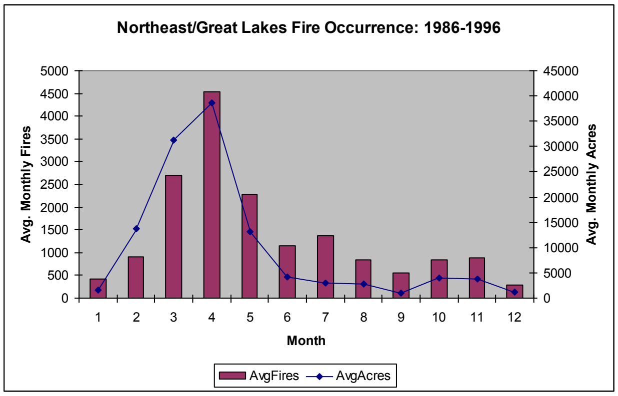
- Fire activity on the plains peaks in spring and fall when windy/dry periods are coincident with dormant or cured fine fuels.
- Fire activity in the mountains peaks in the summer, when it's warmest and driest and some dry cold frontal passages are possible.

Southeast



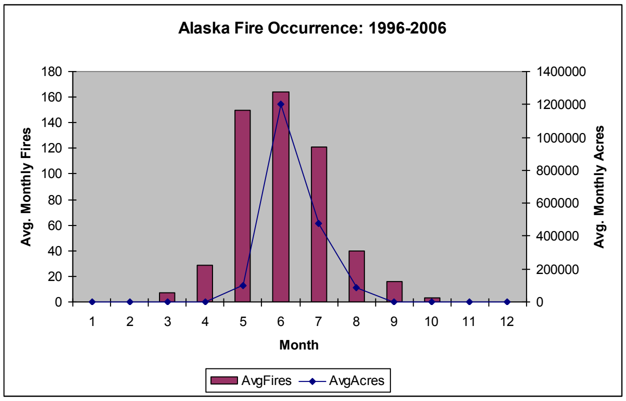
- Fire activity maxima in late winter / early spring and fall, coincident with greatest potential for windy/dry conditions behind passing storm systems
- Dormant fine fuels with low live fuel moisture in winter & spring, leaf-off in fall in northern portion of region
- Season can extend year round anytime warm/moist air becomes suppressed south & east

Northeast/Great Lakes



- Fire activity maxima in spring and fall, coincident with windy periods near jet stream
- Building warmth and dormant fine fuels in spring, leaf-off in fall
- Season can extend well into summer far north if jet remains active and brings windy/dry events that are preceded by prolonged dry conditions

Alaska



Alaska

- Peak fire activity late spring & summer coincident with warmest/driest conditions, and wind event & dry lightning potential
- Vast majority of activity in interior between Alaska and Brooks ranges
- Season ramps up fairly quickly after melt-off and strongly relates to length of day
- Season ends quickly with late summer/early fall moisture increase

1.6.5 Critical Fire Weather Patterns (from www.fs.fed.us/pnw/pubs/pnw_gtr854.pdf)

The four critical weather elements that produce extreme fire behavior are low relative humidity, strong surface wind, unstable air, and drought. [The] *Critical fire weather patterns* [that support these conditions] *can be separated into two primary categories; those that produce strong surface winds and those that produce atmospheric instability. In both cases, an unusually dry airmass, for the region and season, must also occur. In brush and timber fuels, drought becomes an important precursor, by increasing fuel availability.*

Most periods of critical fire weather occur in transition zones between high- and low-pressure systems, both at the surface and in the upper air. The surface pressure patterns of most concern are those associated with cold fronts and terrain-induced foehn winds. Cold front passages are important to firefighters because of strong, shifting winds and unstable air that can enhance the smoke column or produce thunderstorms. Foehn winds occur on the lee side of mountain ranges and are typically very strong, often occurring suddenly with drastic warming and drying. The area between the upper ridge and upper trough has the most critical upper air pattern because of unstable air and strong winds aloft that descend to ground level.

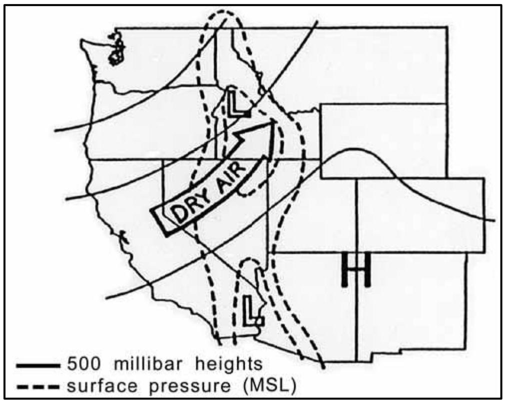
East of the Rocky Mountains, most critical fire weather patterns are associated with the periphery of high-pressure areas, particularly in the prefrontal and postfrontal areas.

- *In the northern plains, Great Lakes, and the Northeastern US*, prefrontal high pressure from the Pacific, Northwestern Canada, and Hudson Bay all can produce very dry conditions. Cold fronts produce relatively short lived periods of high winds and instability that can produce extreme fire behavior.
- *In the Southeastern US,* drought is frequently associated with the La Niña state of the southern oscillation pattern or a blocking ridge aloft near the Atlantic coast. Often critical weather patterns follow the frontal passage that brings extremely dry air due to a strong westerly or northwesterly flow. Look for strong winds that accompany the flow. Beware of advancing tropical storms as well.

In the ***Southwestern US***, the breakdown of the upper ridge manifest at the surface as surface, dry cold fronts before the onset of the monsoon. Early stage monsoon can produce gusty wind, low RH, and lightning without much precipitation. The lee surface trough/dryline

In the ***Rocky Mountain and Intermountain Regions***, the most significant pattern is the Upper ridge-Surface thermal trough that produces a dry and windy surface cold front.

- Along the eastern slopes of the Rocky Mountains, weather patterns producing Chinook winds bring strong downslope winds that are unusually dry and warm.
- In the intermountain West, critical fire weather is associated with upper troughs and overhead jet streams, or surface dry cold front passages.



Along the Pacific Coast, from Washington to California, weather patterns producing offshore flow or foehn wind are the most important.

- In the Pacific Northwest, the east wind produces strong winds and dry air west of the cascades. The upper ridge breakdown is similar to that described for the Rocky Mountain & interior west.
- In California, the most important are the north and mono winds of north & central regions and the Santa Ana and sundowner winds of southern California. The subtropical high aloft bring heat waves.

In ***Alaska***, the primary pattern is the breakdown of the upper ridge with a southwest flow. It can bring gusty winds and dry lightning to the interior of Alaska after a period of hot, dry weather.

1.7 Reference

Haines, D.A. 1988. A lower atmospheric severity index for wildland fire. National Weather Digest. Vol 13. No. 2:23-27.

Latham, Don J. and Rothermel, Richard C,; **Probability of Fire-Stopping Precipitation Events**; 1993; USDA Forest Service, Research Note INT-410; 8p.

Schroeder, Mark J. and Buck, Charles C., 1970. **Fire Weather: A Guide For Application of Meteorological Information to Forest Fire Control Operations**, USDA Forest Service Agricultural Handbook 360, pp. 85-126.

Werth, Paul and Ochoa, Richard; The Haines Index and Idaho Wildfire Growth; 1990; Fire Management Notes; 51-4.

Werth, John and Werth, Paul; Haines Index Climatology for the Western United States; 1997; NOAA National Weather Service Western Region Technical Attachment No. 97-17.

Werth, Paul A.; Potter, Brian E.; Clements, Craig B.; Finney, Mark A.; Goodrick, Scott L.; Alexander, Martin E.; Cruz, Miguel G.; Forthofer, Jason A.; McAllister, Sara S. 2011**.** Synthesis of knowledge of extreme fire behavior: volume I for fire managers. Gen. Tech. Rep. PNW-GTR-854. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 144 p.

Whiteman, C. David, 2000. **Mountain Meteorology: Fundamentals and Applications**, Oxford University Press, pp. 141-199, 306-307.

2 FUELS

Contents

2.1 SURFACE FUEL MODELS

2.1.1 Carrier Fuel Types

Non-burnable (NB) fuels

- **NB1 (091) – URBAN/SUBURBAN**; Fuel model NB1 consists of land covered by urban and suburban development. To be called NB1, the area under consideration must not support wildland fire spread. In some cases, areas mapped as NB1 may experience structural fire losses during a wildland fire incident; however, structure ignition in those cases is either house-to-house or by firebrands, neither of which is directly modeled using fire behavior fuel models. If sufficient inflammable vegetation surrounds structures such that wildland fire spread is possible, then choose a fuel model appropriate for the wildland vegetation rather than NB1.
- **NB2 (092) – SNOW/ICE;** Land covered by permanent snow or ice is included in NB2. Areas covered by seasonal snow can be mapped to two different fuel models: NB2 for use when snow-covered and another for use in the fire season.
- **NB3 (093) – AGRICULTURAL FIELD;** Fuel model NB3 is agricultural land maintained in a non-burnable condition; examples include irrigated annual crops, mowed or tilled orchards, and so forth. However, there are many agricultural areas that are not kept in a non-burnable condition. For example, grass is often allowed to grow beneath vines or orchard trees, and wheat or similar crops are allowed to cure before harvest; in those cases use a fuel model other than NB3.
- **NB8 (098) – OPEN WATER;** Land covered by open bodies of water such as lakes, rivers and oceans.
- **NB9 (099) – BEAR GROUND;** Land devoid of enough fuel to support wildland fire spread is covered by fuel model NB9. Such areas may include gravel pits, arid deserts with little vegetation, sand dunes, rock outcroppings, beaches, and so forth.

Grass **(GR)** Fuels - The primary carrier of fire in the GR fuel models is grass. Grass fuels can vary from heavily grazed grass stubble or sparse natural grass to dense grass more than 6 feet tall. Fire behavior varies from moderate spread rate and low flame length in the sparse grass to extreme spread rate and flame length in the tall grass models. While the FB fuel models are static, all of the GR fuel models are dynamic, meaning that their live herbaceous fuel load shifts from live to dead as a function of live herbaceous moisture content. The effect of live herbaceous moisture content on spread rate and intensity is very strong.

Grass/Shrub **(GS)** Fuels - The primary carrier of fire in the GS fuel models is grass and shrubs combined; both components are important in determining fire behavior. All GS fuel models are dynamic, meaning that their live herbaceous fuel load shifts from live to dead as a function of live herbaceous moisture content. The effect of live herbaceous moisture content on spread rate and intensity is strong, and depends on the relative amount of grass and shrub load in the fuel model.

Shrub **(SH)** Fuels - The primary carrier of fire in the shrub fuel models is live and dead shrub twigs and foliage in combination with dead and down shrub litter. Fuel models SH1 and SH9 are dynamic, due to a small amount of herbaceous fuel loading in them. The effect of live herbaceous load transfer to dead fine fuel on spread rate and flame length can be significant in those two dynamic SH models.

Timber Understory **(TU)** Fuels - The primary carrier of fire in the TU fuel models is forest litter in combination with herbaceous or shrub fuels. TU1 and TU3 contain live herbaceous load and are dynamic, meaning that their live herbaceous fuel load is allocated between live and dead as a function of live herbaceous moisture content. The effect of live herbaceous moisture content on spread rate and intensity is strong, and depends on the relative amount of grass and shrub load in the fuel model.

Timber Litter **(TL)** Fuels - The primary carrier of fire in the TL fuel models is dead and down woody fuel. Live fuel, if present, has little effect on fire behavior.

Slash/Blow down **(SB)** Fuels - The primary carrier of fire in the SB fuel models is activity fuel or blow down. Forested areas with heavy mortality may be modeled with SB fuel models.

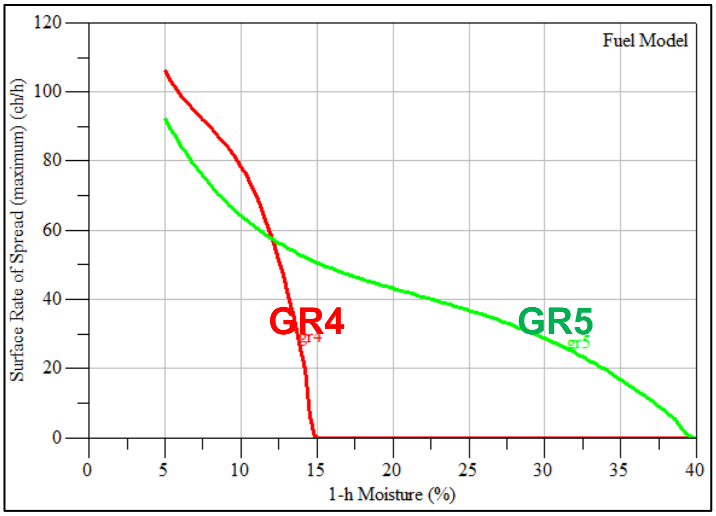
2.1.2 Do 13 and 40 Equal 53?

This guide integrates the original 13 models with the 40 standard models added in June of 2005. Though the developers of the 40 standard models intended that they stand alone, all 53 models are available to the user in current versions of all the fire modeling systems that are designed to use them. And though the original 13 models were grouped into only 4 carrier types, they can be effectively distributed into the 6 types defined with the newer set.

Consider the objectives that guided the development of these two sets. The original 13 were designed to support analysis of wildfires under peak fire conditions with cured herbaceous fuels. Sensitivity to live fuels is represented in only 5 of them, with large responses predominately in fuel models 4 and 5. They were designed before crown fire modeling was implemented, requiring that at least some of the 13 represent crown fire behavior. On the other hand, the 40 standard fuel models were developed to facilitate analysis for fire use and fuel modification treatments. They are designed so that they can represent green, growing season conditions as well as cured, peak season conditions.

The most important benefit of integrating fuel model sets in this guide may be the context the original 13 provide for users familiar with them. Consider it something of a dual language guide, facilitating translation for those users.

2.1.3 Moisture of Extinction



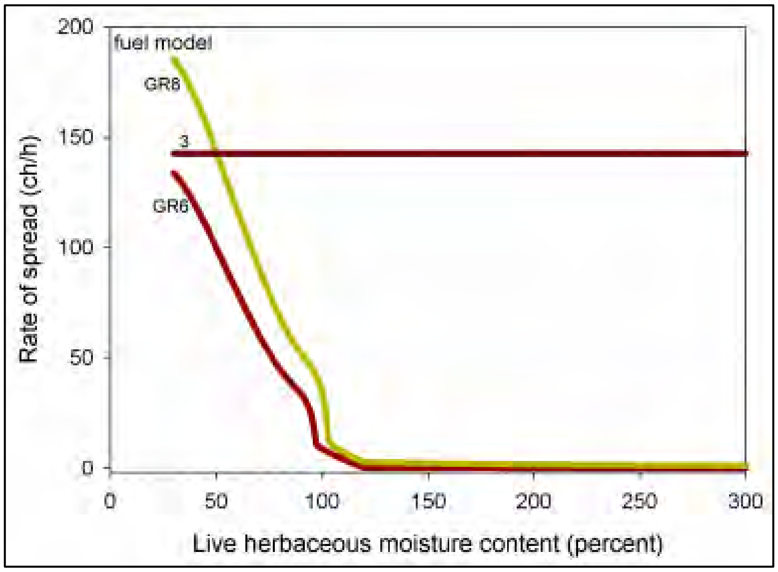
When selecting a fuel model, one of the first considerations should be whether fuels are expected to burn under high fuel moisture conditions. Though many modeling tools allow the user to define a burn period which can truncate fire behavior even when moisture of extinction has not been reached, humid climate fuel models (with high moisture of extinction) will express significant fire behavior even when corresponding dry climate fuels estimate no fire spread. The example here demonstrates that GR4 exhibits no fire spread at 15% fuel moisture and at that same point, GR5 can project spread rates of as much as 50 chi/hr. Ensure that the fuel model selected accurately represents potential fire spread and intensity under the range of fuel moistures conditions that will be encountered.

2.1.4 Fuel Model Parameters and Descriptions

To insure accuracy and precision in modeling efforts, fuel model selection needs to employ a disciplined process. With the addition of 40 fuel models representing 6 carrier fuel types, users will be more likely to find an appropriate fuel model based on fuel model parameters, resulting in reasonable ranges of fire behavior over the range of anticipated environmental conditions. Identifying fuel models that best answer these questions should result in one to several choices that can be carried forward into a calibration process.

1. Looking at the fuel bed, what fuel type (GR, GS, SH, TU, TL, or SB) is observed (or expected) to carry fire spread? Keep in mind that there are analogous characteristics that can cross these fuel types. However, if your fuelbed has a significant canopy layer, it may be more descriptive to select a TU or TL fuel.
2. Which fuel categories (1hr, 10hr, 100hr, Herb, Woody) are observed (or expected) to be available for burning in the flaming front under anticipated range of environmental conditions? Does one (or several) represent the distribution of fuel loads better than another?
3. Is it a shallow or deep fuelbed? Will any shrub layer burn as part of the surface or canopy layer?
4. Is the fuel model description a reasonable description of conditions encountered?

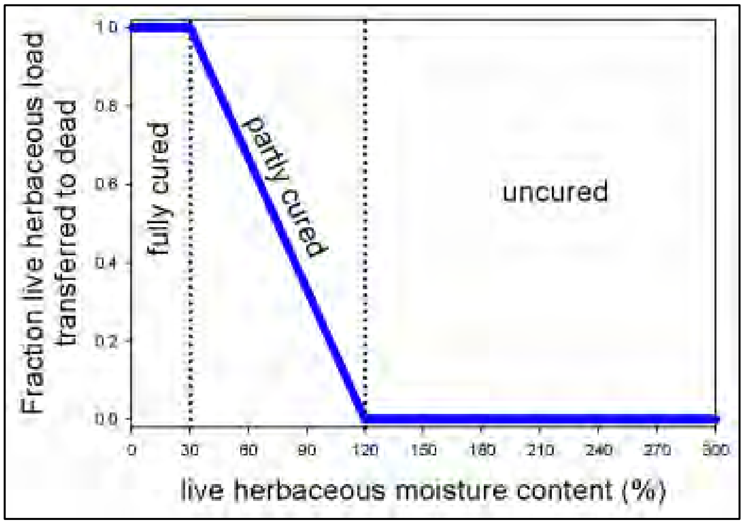
2.1.5 Dynamic (proportional) Fuel Load Transfer



A feature that was implemented with the development of the National Fire Danger Rating System (NFDRS) recognizes that most herbaceous fuels transition between green and cured conditions over the course of a fire season. Effectively, this transfer of herbaceous fuel loads between live and dead categories redefines the fuel complex with each proportion transferred, making it a critical fuel model characteristic. The changes in output fire behavior can be dramatic, when compared to the static fuel models among the original 13. The example here shows spread rate for dynamic fuels GR6 & GR8 with static FB3.

In the development of the new set of fuel models, this "dynamic" (or proportional) fuel load transfer has been implemented for all fuel models that include herbaceous loads. It includes all grass, grass/shrub, two shrub (SH1 & SH9), and two timber understory (TU1 & TU3) models.

As depicted in the graph and table below, the fuel load transfer (implemented in FARSITE, FLAMMAP, and WFDSS Fire Behavior tools) is dependent on the input herbaceous moisture content.



Herbaceous Moisture Content	Level of Curing (fuel load transferred)	
120% or more	0/1 cured	Uncured
98%	¼ cured	Partially cured
90%	1/3 cured	
75%	½ cured	
60%	2/3 cured	
53%	¾ cured	
30% or less	1/1 cured	Fully cured

- If input Live Herbaceous Moisture Content (LHMC) is 120% or higher, none of the load is transferred.
- If input LHMC is 30% or lower, the entire load is transferred to dead herbaceous fuel and the 1hr moisture content is assigned to it.
- If input LHMC is between 30% and 120%, part of the herbaceous load is transferred to dead load and is assigned the 1hr moisture content. The input LHMC that represents a particular portion of the load transferred from live to dead can be calculated using this equation and an assumed curing percentage:

$$input\ LHMC\ = 120 - (90 * fraction\ cured).$$

<u>Important cautions</u>: Between 95% and 100% input LHMC, very rapid changes in fire behavior outputs can occur. Be sure to test the sensitivity to this input. Though it is agreed that live fuels can provide a critical influence on fire behavior, serving as both the heat sink and heat source in varying combinations, the specifics are not well modeled or understood. There are findings that indicate that curing is not directly related to herbaceous moisture content. As a result, BehavePlus allows the user to input curing % separate from LHMC.

2.1.6 Fuel Model Fire Behavior Calibration

Fire Behavior Class	Rate of Spread (ch/hr)	Flame Length (ft)
Very Low	0-2	0-1
Low	2-5	1-4
Moderate	5-20	4-8
High	20-50	8-12
Very High	50-150	12-25
Extreme	150+	25+

The final step in selecting a fuel model is evaluation of the fire behavior outputs, rate of spread and flame length. Ultimately, the primary value of these fuel models is their use in making fire behavior and fire growth projections. However, making a good fuel model selection is only the first step in the calibration process.

As suggested here, when comparing modeled and observed fire behavior, it may be helpful to think of spread rates and flame lengths in ranges or Fire Behavior Classes. If fireline personnel can effectively report observed fire behavior in these terms, differentiating what they see through the burn period and as environmental inputs change, the analysis will be improved dramatically.

Testing the range of a fuel model's characteristic fire behavior requires analysis of several environmental inputs. Consider these. Most analysis tools only allow consideration of two variables at a time. However, there are generally at least 3 significant environmental factors in addition to fuel selection; wind, slope, and fuel moisture. Fortunately the Rothermel fire spread model depicts the effect of slope as an equivalent windspeed. If the calibration analysis represents the windspeed as a range of effective windspeed, slope should be at least generally incorporated. In some cases, it may still be necessary to consider its effect separately.

1. 1hr Moisture & Effective Windspeed: The dominant factors in any analysis are wind, slope, and fuel moisture. None of the tools mentioned earlier allow display of all three factors at once. But once a range of expected midflame windspeeds is established, it is possible to add the effect of slope by identifying the slope equivalent windspeed, producing a range of effective windspeeds for the calibration analysis.
2. Live Herbaceous Moisture: With other environmental inputs set at representative levels, evaluate the range of fire behavior produced between 30% and 120% live herbaceous fuel moisture for dynamic fuel models.
3. Live Woody Moisture: This consideration is critical for grass/shrub, shrub, and timber understory fuel models. Because there is no fuel load transfer in the live woody category, there is no default range to consider. Set other environmental inputs at representative levels. Keep in mind that live woody moisture levels change rather slowly in most cases. Depending on the time of year and the drought situation, it may not be necessary to consider a wide range of moistures. However, it is critical that appropriate levels are identified for the analysis.
4. Slope and Spread Direction: Though this combination of factors is probably secondary in most cases, backing and flanking fire behavior related to slope reversals and prescribed fire ignitions may be important.

2.1.7 Nomenclature

Fuel Type	Fuel Model Bloc	Pre-Defined	Reserved for future pre-defined models	Available for Custom fuel Models
FB	01-13	01-13	--	--
Custom	14-89	---	--	14-89
NB	90-99	91-93, 98-99	94, 95	90, 96, 97
GR	100-119	101-109	110-112	100, 113-119
GS	120-139	121-124	125-130	120, 131-139
SH	140-159	141-149	150-152	140, 153-159
TU	160-179	161-165	166-170	160, 171-179
TL	180-199	181-189	190-192	180, 193-199
SB	200-219	201-204	205-210	200, 211-219
Custom	220-256	--	--	220-256

2.1.8 Surface Fuel Model Selection Guide (*Dynamic Fuel Model)

Low Moist. Of Extinction	Grass (GR) Grass/Shrub (GS)	**Low** FB1, GR1*, GR2* GS1*	**Moderate** GR4* FB2, GS2*	**High** GR7* GS2*
	Shrub (SH) Timber Understory (TU)	**Low** SH1*, SH4, SH6 TU1*	**Moderate** FB5, FB6, SH2 TU2, TU3*, TU4	**High** FB4, SH5, SH7 FB10, TU5
DEAD FUELS ONLY	Timber Litter (TL)	**Low** FB8, TL1, TL3 TL2 (Broadleaf)	**Moderate** TL4, TL5, TL7 TL6 (Broadleaf)	**High** TL8 FB9, TL9 (Brdlf)
	Slash/Blowdown (SB)	**Low** FB11, SB1	**Moderate** FB12, SB2, SB3	**High** FB13, SB4
High Moist. Of Extinction	Grass (GR) Grass/Shrub (GS)	**Low** GR3*, GR5* GS1*	**Moderate** GR6* GS3*	**High** GR8*, GR9* GS4*
	Shrub (SH) Timber Understory (TU)	**Low** FB7, SH4, SH6 TU1*	**Moderate** SH3 TU2, TU3*	**High** SH8, SH9* TU5

2.1.9 Grass & Grass-Shrub Fuel Model Table (fuels in shaded rows: dynamic transfer of herb fuel load from live to dead)

Carrier	FM #	FM Code	Fuel Model Name	***Wind Adj***	1hr Load	10hr Load	100hr Load	Herb Load	Woody Load	***Total Load***	1hr SAV	Herb SAV	Woody SAV	***Bed Depth***	***Moist Extinct***	Dead Heat	Live Heat
Dry Climate Fuel Models																	
GR	1	FB1	Short grass	0.36	0.7	--	--	--	--	0.7	3500	--	--	1.0	12	8000	--
GR	2	FB2	Timber grass and understory	0.36	2.0	1.0	0.5	0.5	--	4.0	3000	1500	--	1.0	15	8000	8000
GR	101	GR1	Short, sparse dry climate grass	0.31	0.1	--	--	0.3	--	0.4	2200	2000	--	0.4	15	8000	8000
GR	102	GR2	Low load dry climate grass	0.36	0.1	--	--	1.0	--	1.1	2000	1800	--	1.0	15	8000	8000
GR	104	GR4	Moderate load dry climate grass	0.42	0.3	--	--	1.9	--	2.2	2000	1800	--	2.0	15	8000	8000
GR	107	GR7	High load dry climate grass	0.46	1.0	--	--	5.4	--	6.4	2000	1800	--	3.0	15	8000	8000
GS	121	GS1	low load dry climate grass-shrub	0.35	0.2	--	--	0.5	0.7	1.4	2000	1800	1800	0.9	15	8000	8000
GS	122	GS2	moderate load dry climate grass-shrub	0.39	0.5	0.5	--	0.6	1.0	2.6	2000	1800	1800	1.5	15	8000	8000
Humid Climate Fuel Models																	
GR	3	FB3	tall grass	0.44	3.0	--	--	--	--	3.0	1500	--	--	2.5	25	8000	--
GR	103	GR3	Low load very coarse humid climate grass	0.42	0.1	0.4	--	1.5	--	2.0	1500	1300	--	2.0	30	8000	8000
GR	105	GR5	low load humid climate grass	0.39	0.4	--	--	2.5	--	2.9	1800	1600	--	1.5	40	8000	8000
GR	106	GR6	moderate load humid climate grass	0.39	0.1	--	--	3.4	--	3.5	2200	2000	--	1.5	40	9000	9000
GR	108	GR8	High load very coarse humid climate grass	0.49	0.5	1.0	--	7.3	--	8.8	1500	1300	--	4.0	30	8000	8000
GR	109	GR9	very high load humid climate grass	0.52	1.0	1.0	--	9.0	--	11.0	1800	1600	--	5.0	40	8000	8000
GS	123	GS3	moderate load humid climate grass-shrub	0.41	0.3	0.3	--	1.5	1.3	3.3	1800	1600	1600	1.8	40	8000	8000
GS	124	GS4	high load humid climate grass-shrub	0.42	1.9	0.3	0.1	3.4	7.1	12.8	1800	1600	1600	2.1	40	8000	8000

2.1.10 Grass & Grass-Shrub Fuel Model Descriptions (fuels in shaded rows: dynamic transfer of herb fuel load from live to dead)

Dry Climate Grass & Grass –Shrub Fuel Descriptions

FB1 (01): Fire spread is governed by the fine herbaceous fuels that are cured or nearly cured. Fires move rapidly through cured grass & associated material. Very little shrub or timber is present, generally less than one-third of the area. Grasslands & savanna are represented along with stubble, grass tundra, & grass-shrub combinations that meet the above area constraint. Annual & perennial grasses are included fuels.

FB2 (02): Fire spread is primarily through the fine herbaceous fuels, either curing or dead. These are surface fires where the herbaceous material, besides litter and dead-down stem wood from the open shrub or timber overstory, contribute to the fire intensity. Open shrub lands 1 and pine stands or scrub oak stands that cover one-third or two thirds of the area may generally fit this model, but may include clumps of fuels that generate higher intensities and may produce firebrands. Some pinyon-juniper may be in this model.

GR1 (101): The primary carrier of fire is sparse grass, though small amounts of fine dead fuel may be present. The grass in GR1 is generally short, either naturally or by heavy grazing, and may be sparse or discontinuous. The moisture of extinction of GR1 is indicative of a dry climate fuelbed, but GR1 may also be applied in high-extinction moisture fuelbeds, because in both cases predicted spread rate and flame length are low compared to other GR models

GR2 (102): The primary carrier of fire is grass, though small amounts of fine dead fuel may be present. Load is greater than GR1, and fuelbed may be more continuous. Shrubs, if present, do not affect fire behavior.

GR4 (104): The primary carrier of fire is continuous, dry-climate grass. Load and depth are greater than GR2; fuelbed depth is about 2 feet.

GR7 (107): The primary carrier of fire is continuous dry-climate grass. Load and depth are greater than GR4. Grass is about 3 feet tall.

GS1 (121): The primary carrier of fire is grass and shrubs combined. Shrubs are about 1 foot high, grass load is low. Spread rate is moderate; flame length low. Moisture of extinction is low.

GS2 (122): The primary carrier of fire is grass and shrubs combined. Shrubs are 1-3 feet high, grass load is moderate. Spread rate is high; flame length moderate. Moisture of extinction is low.

Humid Climate Grass & Grass Shrub Fuel Descriptions

FB3 (03): Fires in this fuel are the most intense of the grass group and display high rates of spread under the influence of wind. The fire may be driven into the upper heights of the grass stand by the wind and cross standing water. Stands are tall, averaging about 3 ft., but may vary considerably. Approximately one-third or more of the stand is considered dead or cured and maintains the fire. Wild or cultivated grains that have not been harvested can be considered similar to tall prairie and marshland grasses.

GR3 (103): The primary carrier of fire is continuous, coarse, humid-climate grass. Grass and herb fuel load is relatively light; fuelbed depth is about 2 feet. Shrubs are not present in significant quantity to affect fire behavior.

GR5 (105): The primary carrier of fire is humid-climate grass. Load is greater than GR3 but depth is lower, about 1-2 feet.

GR6 (106): The primary carrier of fire is continuous humid-climate grass. Load is greater than GR5 but depth is about the same. Grass is less coarse than GR5.

GR8 (108): The primary carrier of fire is continuous, very coarse, humid-climate grass. Load and depth are greater than GR6. Spread rate and flame length can be extreme if grass is fully cured.

GR9 (109): The primary carrier of fire is dense, tall, humid-climate grass. Load and depth are greater than GR8, about 6 feet tall. Spread rate and flame length can be extreme if grass is fully or mostly cured.

GS3 (123): The primary carrier of fire is grass and shrubs combined. Moderate grass/shrub load, average grass/shrub depth less than 2 feet. Spread rate is high; flame length moderate. Moisture of extinction is high.

GS4 (124): The primary carrier of fire is grass and shrubs combined. Heavy grass/shrub load, depth greater than 2 feet. Spread rate high; flame length very high. Moisture of extinction is high.

2.1.11 Shrub &Timber Understory Fuel Model Table (fuels in shaded rows: dynamic transfer of herb fuel load from live to dead)

Carrier	FM #	FM Code	Fuel Model Name	***Wind Adj***	1hr Load	10hr Load	100hr Load	Herb Load	Woody Load	***Total Load***	1hr SAV	Herb SAV	Woody SAV	***Bed Depth***	***Moist Extinct***	Dead Heat	Live Heat
Dry Climate Fuel Models																	
SH	4	FB4	chaparral	***0.55***	5.0	4.0	2.0	--	5.0	***16.0***	2000	--	1500	***6***	***20***	8000	8000
SH	5	FB5	brush	***0.42***	1.0	0.5	--	--	2.0	***3.5***	2000	--	1500	***2***	***20***	8000	8000
SH	6	FB6	dormant brush	***0.44***	1.5	2.5	2.0	--	--	***6.0***	1750	--	--	***2.5***	***25***	8000	--
SH	141	SH1	low load dry climate shrub	***0.36***	0.3	0.3	0.0	0.2	1.3	***2.0***	2000	1800	1600	***1***	***15***	8000	8000
SH	142	SH2	mod. load dry climate shrub	***0.36***	1.4	2.4	0.8	--	3.9	***8.4***	2000	--	1600	***1***	***15***	8000	8000
SH	145	SH5	high load dry climate shrub	***0.55***	3.6	2.1	--	--	2.9	***8.6***	750	--	1600	***6***	***15***	8000	8000
SH	147	SH7	very high load dry climate shrub	***0.55***	3.5	5.3	2.2	--	3.4	***14.4***	750	--	1600	***6***	***15***	8000	8000
TU	161	TU1	light load dry climate timber-grass-shrub	***0.33***	0.2	0.9	1.5	0.2	0.9	***3.7***	2000	1800	1600	***0.6***	***20***	8000	8000
TU	164	TU4	dwarf conifer with understory	***0.32***	4.5	--	--	--	2.0	***6.5***	2300	--	2000	***0.5***	***12***	8000	8000
TU	165	TU5	very high load dry climate timber-shrub	***0.33***	4.0	4.0	3.0	--	3.0	***14.0***	1500	--	750	***1***	***25***	8000	8000
TU	10	FB10	timber litter and understory	***0.36***	3.0	2.0	5.0	--	2.0	***12.0***	2000	--	1500	***1***	***25***	8000	8000
Humid Climate Fuel Models																	
SH	7	FB7	southern rough	***0.44***	1.1	1.9	1.5	--	0.4	***4.9***	1750	--	1500	***2.5***	***40***	8000	8000
SH	143	SH3	mod. load humid climate shrub	***0.44***	0.5	3.0	--	--	6.2	***9.7***	1600	--	1400	***2.4***	***40***	8000	8000
SH	144	SH4	low load humid climate timber-shrub	***0.46***	0.9	1.2	0.2	--	2.6	***4.8***	2000	--	1600	***3***	***30***	8000	8000
SH	146	SH6	low load humid climate shrub	***0.42***	2.9	1.5	--	--	1.4	***5.8***	750	--	1600	***2***	***30***	8000	8000
SH	148	SH8	high load humid climate shrub	***0.46***	2.1	3.4	0.9	--	4.4	***10.7***	750	--	1600	***3***	***40***	8000	8000
SH	149	SH9	very high load humid climate shrub	***0.50***	4.5	2.5	--	1.6	7.0	***15.5***	750	1800	1500	***4.4***	***40***	8000	8000
TU	162	TU2	Moderate load humid climate timber-shrub	***0.36***	1.0	1.8	1.3	--	0.2	***4.2***	2000	--	1600	***1***	***30***	8000	8000
TU	163	TU3	moderate load humid climate timber-grass-shrub	***0.38***	1.1	0.2	0.3	0.7	1.1	***3.3***	1800	1600	1400	***1.3***	***30***	8000	8000

2.1.12 Shrub & Timber Understory Fuel Model Descriptions (fuels in shaded rows: dynamic transfer of herb fuel load from live to dead)

Dry Climate Shrub & Timber Understory Fuel Descriptions	Humid Climate Shrub & Timber Understory Fuel Descriptions
FB4 (04): Fire intensity and fast-spreading fires involve the foliage and live and dead fine woody material in the shrub layer. Besides flammable foliage, there is dead woody material that significantly contributes to fire intensity. Deep litter layer may also confound suppression efforts. **FB5 (05):** Primary carrier is litter cast by the shrubs, and the grasses or forbs in the understory. Shrubs are generally not tall, but have nearly total coverage of the area. Young, green stands with no deadwood. **FB6 (06):** Fire carries through the shrub layer, requiring at least moderate winds. Fire will drop to the ground at low windspeeds or openings in the stand. The shrubs are older. A broad range of shrub conditions is included here. **SH1 (141):** The primary carrier of fire in SH1 is woody shrubs and shrub litter. Low shrub fuel load, fuelbed depth about 1 foot; some grass may be present. Spread rate is very low; flame length very low. **SH2 (142):** The primary carrier of fire in SH2 is woody shrubs and shrub litter. Moderate fuel load (higher than SH1), depth about 1 foot, and no grass fuel present. Spread rate is low; flame length low. **SH5 (145):** The primary carrier of fire in GS4 is grass and shrubs combined. Heavy grass/shrub load, depth greater than 2 feet. Spread rate very high; flame length very high. Moisture of extinction is high. **SH7 (147):** The primary carrier of fire is woody shrubs and shrub litter. Very heavy shrub load, depth 4-6 feet. Spread rate lower than SH5, but flame length similar. Spread rate is high; flame length very high. **FB10 (10):** Dead down fuels include greater quantities of 3-inch or larger limbwood resulting from overmaturity or natural events that create a large load of dead material. Crown fire and spotting is more frequent in this fuel situation. **TU1 (161):** The primary carrier of fire in is low load of grass and/or shrub with litter. Spread rate is low; flame length low. **TU4 (164):** The primary carrier of fire is grass, lichen or moss understory plants. If live woody moisture content is set to 100 percent, this fuel model mimics the behavior of Norum's (1982) empirical calibration for Alaska Black Spruce. Spread rate is moderate; flame length moderate. **TU5 (165):** The primary carrier of fire in TU5 is heavy forest litter with a shrub or small tree understory. Spread rate is moderate; flame length moderate.	**FB7 (07):** Fires burn through the surface and shrub strata with equal ease and can occur at higher dead fuel moisture contents because of the flammable nature of live foliage and other live material. Stands of shrubs are generally between 2 and 6 ft. high. Palmetto-gallberry understory within pine overstory sites are typical and low pocosins may be represented. Black spruce-shrub combinations in Alaska may also be represented. **SH3 (143):** The primary carrier of fire in SH3 is woody shrubs and shrub litter. Moderate shrub load, possibly with pine overstory or herbaceous fuel, fuel bed depth 2-3 feet. Spread rate is low; flame length low. **SH4 (144):** The primary carrier of fire in SH4 is woody shrubs and shrub litter. Low to moderate shrub and litter load, possibly with pine overstory, fuel bed depth about 3 feet. Spread rate is high; flame length moderate. **SH6 (146):** The primary carrier of fire in SH6 is woody shrubs and shrub litter. Dense shrubs, little or no herbaceous fuel, fuelbed depth about 2 feet. Spread rate is high; flame length high. **SH8 (148):** The primary carrier of fire in SH8 is woody shrubs and shrub litter. Dense shrubs, little or no herbaceous fuel, fuelbed depth about 3 feet. Spread rate is high; flame length high. **SH9 (149):** The primary carrier of fire in SH9 is woody shrubs and shrub litter. Dense, finely branched shrubs with significant fine dead fuel, about 4-6 feet tall; some herbaceous fuel may be present. Spread rate is high, flame length very high. **TU2 (162):** The primary carrier of fire in TU2 is moderate litter load with shrub component. High extinction moisture. Spread rate is moderate; flame length low. **TU3 (163):** The primary carrier of fire in TU3 is moderate forest litter with grass and shrub components. Extinction moisture is high. Spread rate is high; flame length moderate.

2.1.13 Timber Litter & Slash/Blowdown Fuel Model Table

Carrier	FM #	FM Code	Fuel Model Name	***Wind Adj***	1hr Load	10hr Load	100hr Load	Herb Load	Woody Load	***Total Load***	1hr SAV	Herb SAV	Woody SAV	***Bed Depth***	***Moist Extinct***	Dead Heat	Live Heat
Timber Litter Fuel Models																	
TL	8	FB8	compact timber litter	***0.28***	1.5	1.0	2.5	--	--	***5.0***	2000	--	--	***0.2***	***30***	8000	--
TL	9	FB9	hardwood litter	***0.28***	2.9	0.4	0.2	--	--	***3.5***	2500	--	--	***0.2***	***25***	8000	--
TL	181	TL1	Low load compact conifer litter	***0.28***	1.0	2.2	3.6	--	--	***6.8***	2000	--	--	***0.2***	***30***	8000	--
TL	182	TL2	low load broadleaf litter	***0.28***	1.4	2.3	2.2	--	--	***5.9***	2000	--	--	***0.2***	***25***	8000	--
TL	183	TL3	moderate load conifer litter	***0.29***	0.5	2.2	2.8	--	--	***5.5***	2000	--	--	***0.3***	***20***	8000	--
TL	184	TL4	Small downed logs	***0.31***	0.5	1.5	4.2	--	--	***6.2***	2000	--	--	***0.4***	***25***	8000	--
TL	185	TL5	high load conifer litter	***0.33***	1.2	2.5	4.4	--	--	***8.1***	2000	--	--	***0.6***	***25***	8000	--
TL	186	TL6	moderate load broadleaf litter	***0.29***	2.4	1.2	1.2	--	--	***4.8***	2000	--	--	***0.3***	***25***	8000	--
TL	187	TL7	Large downed logs	***0.31***	0.3	1.4	8.1	--	--	***9.8***	2000	--	--	***0.4***	***25***	8000	--
TL	188	TL8	long-needle litter	***0.29***	5.8	1.4	1.1	--	--	***8.3***	1800	--	--	***0.3***	***35***	8000	--
TL	189	TL9	very high load broadleaf litter	***0.33***	6.7	3.3	4.2	--	--	***14.1***	1800	--	--	***0.6***	***35***	8000	--
Slash/Blowdown Fuel Models																	
SB	11	FB11	light slash	***0.36***	1.5	4.5	5.5	--	--	***11.5***	1500	--	--	***1.0***	***15***	8000	--
SB	12	FB12	medium slash	***0.43***	4.0	14.0	16.5	--	--	***34.6***	1500	--	--	***2.3***	***20***	8000	--
SB	13	FB13	heavy slash	***0.46***	7.0	23.0	28.1	--	--	***58.1***	1500	--	--	***3.0***	***25***	8000	--
SB	201	SB1	low load activity fuel	***0.36***	1.5	3.0	11.0	--	--	***15.5***	2000	--	--	***1.0***	***25***	8000	--
SB	202	SB2	moderate load activity or low load blowdown	***0.36***	4.5	4.3	4.0	--	--	***12.8***	2000	--	--	***1.0***	***25***	8000	--
SB	203	SB3	high load activity fuel or moderate load blowdown	***0.38***	5.5	2.8	3.0	--	--	***11.3***	2000	--	--	***1.2***	***25***	8000	--
SB	204	SB4	high load blowdown	***0.45***	5.3	3.5	5.3	--	--	***14.0***	2000	--	--	***2.7***	***25***	8000	--

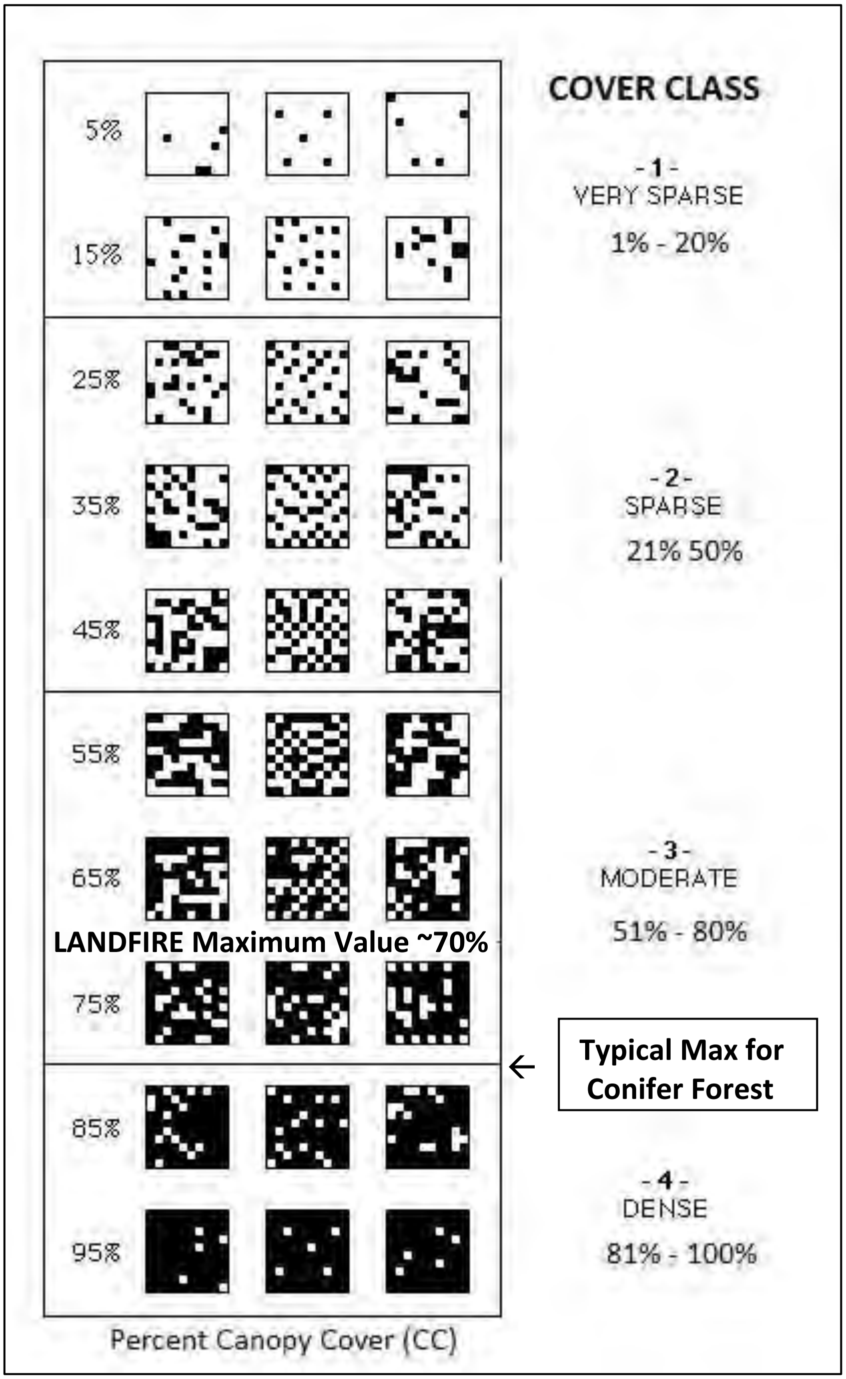
2.1.14 Timber Litter & Slash/Blowdown Fuel Model Descriptions

Timber Litter Fuel Descriptions	Slash Blowdown Fuel Descriptions
FB8 (08): Slow-burning ground fires with low flame heights are the rule, although the fire may encounter an occasional "jackpot" or heavy fuel concentration that can flare up. Only under severe weather conditions involving high temperatures, low humidities, and high winds do the fuels pose fire hazards. This layer is mainly needles, leaves, and some twigs since little undergrowth is present in the stand. **FB9 (09):** Fire runs through the surface litter faster than FB8 and have higher flame height. Both long-needle conifer & hardwood stands, especially the oak-hickory types, are typical. Fall fires in hardwoods are representative, but spotting by rolling and blowing leaves in high winds will actually cause higher rates of spread than predicted. Concentrations of dead-down woody material will contribute to torching & spotting. **TL1 (181):** The primary carrier of fire is compact forest litter. Light to moderate load, fuels 1-2 inches deep. May be used to represent a recently burned forest. Spread rate is very low; flame length very low. **TL2 (182):** The primary carrier of fire is broadleaf (hardwood) litter. Low load, compact litter. Spread rate is very low; flame length very low. **TL3 (183):** The primary carrier of fire is moderate load conifer litter, light load of coarse fuels. Spread rate is very low; flame length low. **TL4 (184):** The primary carrier of fire is moderate load of fine litter and coarse fuels. Includes small diameter downed logs. Spread rate is low; flame length low. **TL5 (185):** The primary carrier of fire is High load conifer litter; light slash or mortality fuel. Spread rate is low; flame length low. **TL6 (186):** The primary carrier of fire is moderate load broadleaf litter, less compact than TL2. Spread rate is moderate; flame length low. **TL7 (187):** The primary carrier of fire is heavy load forest litter, includes larger diameter downed logs. Spread rate low; flame length low. **TL8 (188):** The primary carrier of fire in is moderate load long-needle pine litter, may include small amount of herbaceous load. Spread rate is moderate; flame length low. **TL9 (189):** The primary carrier of fire is very high load, fluffy broadleaf litter. Can also be used to represent heavy needle-drape. Spread rate is moderate; flame length moderate.	**FB11 (11):** Fires are fairly active in the slash and intermixed herbaceous material. The spacing of the rather light fuel load, shading from overstory, or the aging of the fine fuels can contribute to limiting the fire potential. The less-than-3-inch material load is less than 12 tons per acre. The greater-than-3-inch material is represented by not more than 10 pieces, 4 inches in diameter, along a 50-ft transect. **FB12 (12):** Rapidly spreading fires with high intensities capable of generating firebrands can occur. When fire starts, it is generally sustained until a fuel break or change in fuels is encountered. The visual impression is dominated by slash, most of it less than 3 inches in diameter. Fuels total less than 35 tons per acre & seem well distributed. **FB13 (13):** Fire is generally carried across the area by a continuous layer of slash. Large quantities of greater-than-3-inch material are present. Active flaming is sustained for long periods and firebrands of various sizes may be generated. These contribute to spotting problems. Situations where the slash still has "red" needles attached but the total load is lighter, more like model 12, can be represented because of the earlier high intensity and quicker area involvement. **SB1 (201):** Primary carrier of fire is light dead & down activity fuel. Fine fuel load is 10 to 20 t/ac, weighted toward fuels 1-3 in diameter class, depth is less than 1 foot. Spread rate is moderate; flame length low. **SB2 (202):** The primary carrier of fire is moderate dead and down activity fuel or light blowdown. Fine fuel load is 7 to 12 t/ac, evenly distributed across 0-0.25, 0.25-1, and 1-3 inch diameter classes, depth is about 1 foot. Blowdown is scattered, with many trees still standing. Spread rate is moderate; flame length moderate. **SB3 (203):** The primary carrier of fire is heavy dead and down activity fuel or moderate blowdown. Fine fuel load is 7 to 12 t/ac, weighted toward 0-0.25 inch diameter class, depth is more than 1 foot. Blowdown is moderate; trees compacted to near the ground. Spread rate is high; flame length high. **SB4 (204):** The primary carrier of fire is heavy blowdown fuel. Blowdown is total, fuelbed not compacted, most foliage and fine fuel still attached to blowdown. Spread rate very high; flame length very high.

2.2 Canopy Fuel Characteristics

2.2.1 Canopy Cover, % or class

The Forest Canopy Cover (CC) describes the percent cover or cover class of the tree canopy in a stand. Specifically, canopy cover describes the vertical projection of the tree canopy onto an imaginary horizontal surface representing the ground's surface. **Estimate of Canopy Cover is used in adjustment of 20ft winds to mid-flame, in fuel moisture conditioning, and in spotting distance models**. The scale to the right illustrates the look of representative canopy cover percentages and ranges within each cover class.



LANDFIRE Maximum Value ~70%

Typical Max for Conifer Forest

For Surface Fuels sheltered by a forest canopy on flat terrain (Scott 2007)	
Canopy Cover	**Wind Sheltering**
CC ≤ 5%	Unsheltered
5% < CC ≤ 10%	Partially Sheltered
10% < CC ≤ 15%	
15% < CC ≤ 30%	Fully Sheltered, Open
30% < CC ≤ 50%	
CC > 50%	Fully Sheltered, closed

2.2.2 Canopy (Stand) Height, ft or m

The Canopy Height (CH) describes the average height of the top of the vegetated canopy. **Canopy Height estimates are used in adjustment of 20ft winds to mid-flame and in spotting distance models**.

2.2.3 Canopy Base Height, ft or m

The Forest Canopy Base Height (CBH) describes the average height from the ground to a forest stand's canopy bottom. Specifically, it is the lowest height in a stand at which there is a sufficient amount of forest canopy fuel to propagate fire vertically into the canopy. Using this definition, ladder fuels such as lichen, dead branches, and small trees are incorporated. **Estimate of Canopy Base Height is used in the Crown Fire Initiation model.**

2.2.4 Canopy Bulk Density, kg/m^3 or lb/ft^3

The Forest Canopy Bulk Density (CBD) describes the density of available canopy fuel in a stand. It is defined as the mass of available canopy fuel per canopy volume unit. Typical units are either kg/m^3 (LANDFIRE default) or lb/ft^3 (BehavePlus default). **Canopy Bulk Density estimates are used to determine the threshold spread rate (or surface windspeed) used to determine the likelihood of active crown fire.**

2.3 Landscape (lcp) Acquisition, Critique, & Editing (ACE)

This guide provides much more detail about the data and the processes involved in geospatial fire analysis.

> Stratton, Richard D. 2009. Guidebook on LANDFIRE fuels data acquisition, critique, modification, maintenance, and model calibration. Gen. Tech. Rep. RMRS-GTR-220. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 54 p. (http://www.fs.fed.us/rm/pubs/rmrs_gtr220.pdf)

2.3.1 LCP Data Sources

LANDFIRE Version Comparison: http://www.landfire.gov/version_comparison.php)
Wildland Fire Decision Support System (WFDSS); http://wfdss.usgs.gov
USGS Rapid Data Delivery System (RDDS); http://firedata.cr.usgs.gov

2.3.2 LCP Fuel Themes

Layer/Theme	LANDFIRE Units	Primary References
Surface Fuel Model	**1-13** **91-99 (barriers)**	Anderson, H. E. 1982. Aids to determining fuel models for estimating fire behavior. Gen. Tech. Rep. INT-122. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 22 p. http://www.fs.fed.us/rm/pubs_int/int_gtr122.pdf
	101-204 **91-99 (barriers)**	Scott, Joe H.; Burgan, Robert E. 2005. Standard fire behavior fuel models: a comprehensive set for use with Rothermel's surface fire spread model. Gen. Tech. Rep. RMRS-GTR-153. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 72 p. http://www.treesearch.fs.fed.us/pubs/9521
Canopy Cover (CC)	**Percent, 0-100%** 70% practical max	Scott, Joe H.; Reinhardt, Elizabeth D. 2005. Stereo photo guide for estimating canopy fuel characteristics in conifer stands. Gen. Tech. Rep. RMRS-GTR-145. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 49 p. http://www.treesearch.fs.fed.us/pubs/8473 http://www.landfire.gov/notifications16.php
Canopy Height (CH or SH)	**Meters, *10**	
Canopy Base Height (CBH)	**Meters, *10**	
Canopy Bulk Density (CBD)	**Kilograms/meter^3, *100**	

Following is a list of GIS layers for fuels critique, modifications, and model calibration

Wildland Fire/Treatment History
Burn severity layers
Fire progression layers
Fuel treatments
Prescribed fire perimeters
Wildfire perimeters

Ecological Considerations
Areas of critical environmental concern
Sensitive or critical wildlife habitat
Threatened, endangered, and sensitive (TES) flora and fauna habitat
Rivers and streams
Water bodies
Vegetation or cover-type classification

Socio-economic Considerations
Ownership & jurisdiction layer
Historical and recreational sites
Primary and secondary residences
Remote automated weather stations (RAWS)
Roads & Trails
Urban development

Other Base Layers
Aerial photos
Digital orthophoto quad (DOQ) or quarter quad (DOQQ)
Digital raster graph (DRG)

2.3.3 Acquiring the Landscape (lcp) File

- From Incident Analysis in Wildland Fire Decision Support System (http://wfdss.usgs.gov)
- From LANDFIRE Data Acquisition Tool (LFDAT) in ArcGIS. (Be very careful when identifying the data units for each theme) (http://www.frames.gov/portal/server.pt/community/niftt/382/tools_and_user_documents/1675)

2.3.4 Obtain & Evaluate a LCP Critique report (S495 Unit 5 Lesson 1 – Data Sources)

The LCP Critique report is an essential element in the calibration process. It can be obtained from the same WFDSS analysis landscape tab that the LCP was obtained from. Or, if the lcp is downloaded, there is a stand-alone version (LCPCritique) available at http://frames.nacse.org/11000/11606.html.

On the first page:

- View the filename, latitude, cell resolution, and coordinate system in the header information to insure the file used is correct
- View the Theme units, ranges, and value distributions to make sure that the lcp is valid and that there is no corrupted data.
- Determine the important surface fuel models in the lcp. As an example, the histogram to the right shows that fuel models 183, 165, 102, and 122 are the primary surface fuels. Is that what you expect? What are the critical inputs for each of these fuel models? Are any of them dynamic?

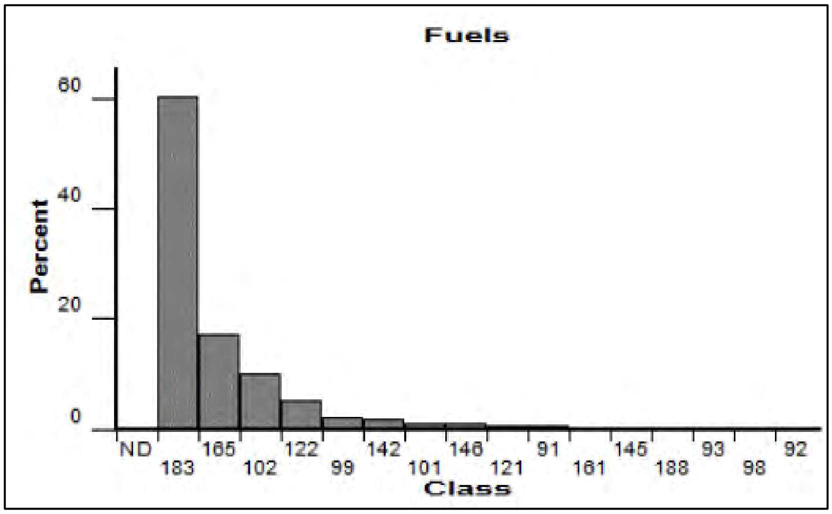


Image & legend pages for each Theme

Some data problems can be identified visually here, such as vertical and horizontal lines in slope themes. The fuel model image can be reviewed by comparing mapped fuel models with areas that have had ground verification or high confidence classifications.

Theme Value Distributions for each Surface Fuel Model (in order by importance)

- Evaluate the terrain theme ranges and distributions for elevation, slope, & aspect. Are these appropriate for the fuel model? How would you revise or adjust them? Consider whether the fuel model needs to be changed for certain terrain value combinations.
- Canopy characteristics should be evaluated carefully to insure that canopy cover (wind adjustment, fuel shading), tree heights (wind adjustment, spotting distance), and canopy base height (crown fire initiation), distributions make sense for the specific fuel model.
- Canopy bulk density (active crown fire propagation) values are not only related to the fuel model and canopy tree species, they also must be appropriately scaled for the crown fire propagation model used (surface fire control - Finney vs. crown fire control - Scott & Reinhardt; see crown fire topic in Section 5 (Fire Behavior).

Any errors or adjustments identified here should be provided for in the landscape edits performed before the first analyses are conducted. These edits can be performed in the FARSITE "Landscape Calculator", the WFDSS Analysis "Landscape Editor", the raster calculator in ArcGIS, or NIFTT's Area & Raster Change Tools.

Once the Landscape has been evaluated and initial edits have been identified, the next step is to evaluate the fire behavior outputs that result from combining the landscape and environmental (wind and fuel moisture) inputs. Stratton (2009) recommends identifying 3 reference fires from analogous landscapes that represent a range of environmental conditions and manifest fire behavior to begin the calibration. Look for fires with strong fire behavior narratives and several progressive perimeters so that observed fire behavior and fire growth can be compared to modeled outputs. If this is not possible, calibration may be progressive and depend on earlier periods for the fire of interest.

2.3.5 Configuring Environmental Inputs for Calibration Exercise

While the LCP file critiqued earlier contains all the fuel and terrain inputs, representative fuel moistures and windspeed/direction inputs need to be determined. Field observations and representative RAWS records are the most likely sources. Firefamily Plus can be utilized to evaluate reasonable ranges during periods of interest.

- Fuel Moisture Estimates & Scenarios are discussed in section 3. Look at historic ranges of dead fuel moistures during the part of the fire season you are interested in. Consider what woody fuel moistures currently make sense and how they may trend in the future. Visit the National Fuel Moisture Database (http://72.32.186.224/nfmd/public/index.php) to find local sampling efforts. Look at the full range of herbaceous fuel moistures for dynamic fuels identified in the LCP Critique.
- Similarly, it is important to evaluate the ranges of windspeed and wind direction possible for the analysis area. Historic RAWS records, discussions with local experts and contacts with GACC predictive services should all be considered sources for this information.

2.3.6 Compare Fire Behavior outputs for primary surface fuel models

The next step in evaluating the fuels information found in landscapes (LCP) acquired for the analysis area is in evaluating the primary fuel models in terms of the environmental inputs identified above. Both BehavePlus and CompareModels495.xls are useful tools in the initial review. Look at ranges of spread rates and flame lengths produced.

2.3.7 Conduct a WFDSS Basic Analysis or FlamMap Fire Behavior Run

These analyses provide perspective on the flammability of the landscape.

- Use the fuel moisture and wind scenarios identified above.
- Consider using fuel moisture conditioning using the last several days' weather.
- Consider the value of gridded winds for a recent day with known fire behavior.
- Look at the spread rate, flame length, and crown fire outputs to determine whether the landscape inputs are capturing fire potential as you anticipate it.
- Evaluate fuel moistures across the landscape using the output themes.

This analysis may suggest the need for changes to fuel model to increase surface spread or intensity and canopy base height or canopy bulk density to adjust crown fire behavior outputs over portions of the landscape.

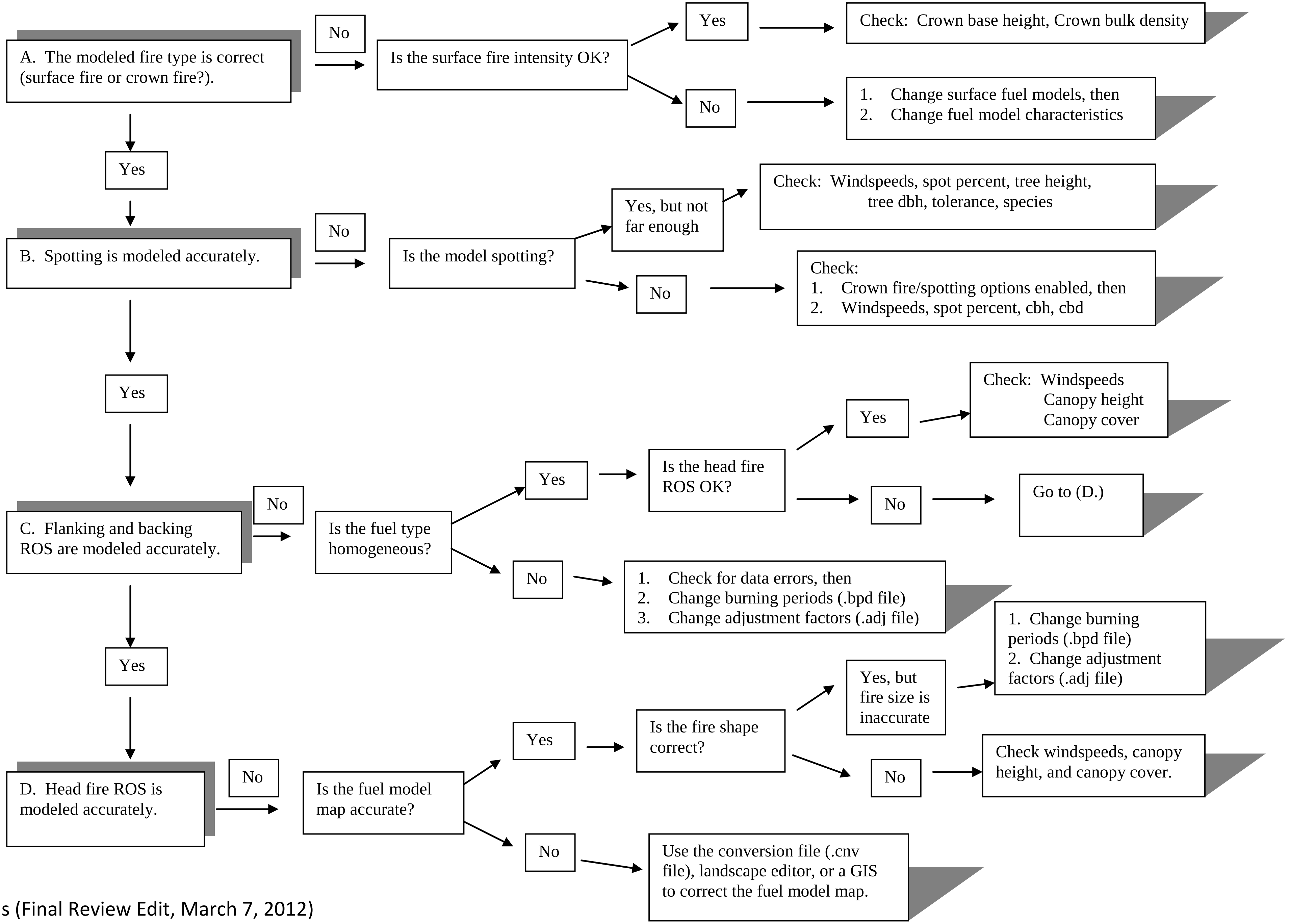
2.3.8 Edit & Update the Landscape (LCP) file

Again, these edits can be performed in the FARSITE "Landscape Calculator", the WFDSS Analysis "Landscape Editor", the raster calculator in ArcGIS, or NIFTT's Area & Raster Change Tools.

2.3.9 Conduct WFDSS Near Term Fire Behavior (NTFB) or FARSITE calibration run with iterative LCP edits

Finally, conducting iterative fire growth runs using WFDSS NTFB or FARSITE with actual wind and weather streams allows for comparing modeled projections to actual growth events. Make LCP edits as necessary.

S495 FARSITE Calibration Diagnostics



References

Anderson, H. E. 1982. Aids to determining fuel models for estimating fire behavior. Gen. Tech. Rep. INT-122. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 22 p.

Andrews, Patricia L. 2009. BehavePlus fire modeling system, version 5.0:Variables.Gen. Tech. Rep. RMRS-GTR-213 Revised. Fort Collins, CO; Department of Agriculture, Forest Service, Rocky Mountain Research Station. 111 p.

Bradshaw, Larry S.; Deeming, John E.; Burgan, Robert E.; Cohen, Jack D., compilers. The 1978 National Fire-Danger Rating System: technical documentation. General Technical Report INT-169. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 44 p.

Burgan, Robert E. 1987. Concepts and interpreted examples in advanced fuel modeling. Gen. Tech. Rep. INT-238. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 40 p.

Finney, M. A. 1998. FARSITE: Fire Area Simulator—model development and evaluation. Res. Pap. RMRS-RP-4. Ft. Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 47 p.

Keane, Robert E.; Garner, Janice L.; Schmidt, Kirsten M.; Long, Donald G.; Menakis, James P.; Finney, Mark A. 1998. Development of input data layers for the FARSITE fire growth model for the Selway-Bitterroot Wilderness Complex, USA. Gen. Tech. Rep. RMRSGTR- 3. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 66 p.

Keane, Robert E.; Mincemoyer, Scott A.; Schmidt, Kirsten M.; Long, Donald G.; Garner, Janice L. 2000. Mapping vegetation and fuels for fire management on the Gila National Forest Complex, New Mexico, [CD-ROM]. Gen. Tech. Rep. RMRS-GTR-46-CD. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, 126 p.

Rothermel, R. C. 1972. A mathematical model for predicting fire spread in wildland fuels. Res. Pap. INT-115. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 40 p.

Rothermel, R. C. 1983. How to predict the spread and intensity of forest and range fires. Gen. Tech. Rep. INT-143. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 161 p

Schlobohm, Paul, and Brain, Jim, compilers. 2002. Gaining an understanding of the National Fire Danger Rating System. PMS 932. Boise, ID. National wildfire Coordinating Group. 72p.

Scott, Joe H.; Burgan, Robert E. 2005. Standard fire behavior fuel models: a comprehensive set for use with Rothermel's surface fire spread model. Gen. Tech. Rep. RMRS-GTR-153. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 72 p.

Scott, Joe H. 2007. Nomographs for estimating surface fire behavior characteristics. Gen. Tech. Rep. RMRS-GTR-192. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 119 p.

Stratton, Richard D. 2006. Guidance on spatial wildland fire analysis: models, tools, and techniques. Gen. Tech. Rep. RMRS-GTR-183. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 15 p.

Stratton, Richard D. 2009. Guidebook on LANDFIRE fuels data acquisition, critique, modification, maintenance, and model calibration. Gen. Tech. Rep. RMRS-GTR-220. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 54 p.

3. Fuel Moisture

Contents

3.1 Fuel Moisture Sampling

General Guidelines

- Record site name, date, time, observer name, observed weather, general site description
- DO NOT collect samples if water drops or dew are present on samples
- Keep samples in a cool and dry location
- Seal containers with tape that will not leave residue

Live Fuels

- Only collect foliage (needles) and very small twigs remove flowers, seeds, nuts, or berries
- Pack containers loosely to avoid spillage but ensure container is full
- Include stems of herbaceous plants
- Replace lid on container immediately after collecting sample

Dead Fuels

- Samples should not be attached to live trees or shrubs
- Avoid decayed samples that crumble or splinter when rubbed
- Collect samples from several different plants
- Ensure container is full or about 20 grams
- Do not collect buried samples
- Pick samples of different size within the time lag class
- Recently fallen material should be avoided
- Remove all lichen, moss, and very loose bark from sample

Duff and Soil

- Remove all soil and live tree or plant roots from sample
- Avoid any soil particles in duff samples and vice versa

Litter

- Collect only un-compacted dry litter from both sunny and shady areas

Drying Samples:

- Preheat drying oven between 60°C (140°F) – 100°C (212°F). Be sure to note temp used.
- Place sample cans with closed lids on scale and record “wet” weights
- Remove lid just prior to placing in oven. If material is lost, re-weigh sample
- Dry sample for 24 hours (very wet samples 48 hours)
- Replace Lids immediately after sample is removed from oven and weigh
- Calculate fuel moisture using the following formula:

$$\%\ Moisture\ Content = \frac{wet\ weight\ of\ sample - dry\ weight\ of\ sample}{dry\ weight\ of\ sample - container\ tare\ weight}\ X\ 100$$

Gross Weight		C. Container Weight	D. Water Weight **(D = A – B)**	E. Dry Weight **(E = B – C)**	F. % Moisture **F=(D/E) X 100**
A. Wet Wt	B. Dry Wt.				

3.2 1-hr Moisture Content

1. Using Table A, determine Reference Fuel Moisture (RFM) % from intersection of temperature & relative humidity. Record this RFM percentage.
2. Select Table B, C, or D to adjust RFM for local conditions by finding current month in table title.
    - Are the fine fuel more than 50% shaded by canopies and clouds? If yes, use bottom (**shaded**) portion of table. If no, use top (**Exposed**) portion of table.
    - Determine the appropriate row based on aspect and slope. Determine the appropriate column based on time of day and elevation of area of concern when compared to the wx site elevation.
    - Obtain the 1-hr Moisture Content Correction (%) from the intersection of row & column.
3. Add the resulting 1-hr Moisture Content Correction (%) to the Reference Fuel Moisture (%)

3.2.1 Table A. Reference Fuel Moisture

Dry Bulb Temp (°F)	Relative Humidity (%)																				
	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39	40 to 44	45 to 49	50 to 54	55 to 59	60 to 64	65 to 69	70 to 74	75 to 79	80 to 84	85 to 89	90 to 94	95 to 99	100
10-29	1	2	2	3	4	5	5	6	7	8	8	8	9	9	10	11	12	12	13	13	14
30-49	1	2	2	3	4	5	5	6	7	7	7	8	9	9	10	10	11	12	13	13	13
50-69	1	2	2	3	4	5	5	6	6	7	7	8	8	9	9	10	11	12	12	12	13
70-89	1	1	2	2	3	4	5	5	6	7	7	8	8	8	9	10	10	11	12	12	13
90-109	1	1	2	2	3	4	4	5	6	7	7	8	8	8	9	10	10	11	12	12	13
109+	1	1	2	2	3	4	4	5	6	7	7	8	8	8	9	10	10	11	12	12	12

3.2.2 Table B. 1-hr Moisture Content Corrections; May-Jun-Jul

Unshaded – Less than 50% shading of surface fuels

Aspect	Slope	0800-0959			1000-1159			1200-1359			1400-1559			1600-1759			1800-1959		
		B	L	A	B	L	A	B	L	A	B	L	A	B	L	A	B	L	A
N	0-30	2	3	4	1	1	1	0	0	1	0	0	1	1	1	1	2	3	4
	31%	3	4	4	1	2	2	1	1	2	1	1	2	1	2	2	3	4	4
E	0-30	2	2	3	1	1	1	0	0	1	0	0	1	1	1	2	3	4	4
	31%	1	2	2	0	0	1	0	0	1	1	1	2	2	3	4	4	5	6
S	0-30	2	3	3	1	1	1	0	0	1	0	0	1	1	1	1	2	3	3
	31%	2	3	3	1	1	2	0	1	1	0	1	1	1	1	2	2	3	3
W	0-30	2	3	4	1	1	2	0	0	1	0	0	1	0	1	1	2	3	3
	31%	4	5	6	2	3	4	1	1	2	0	0	1	0	0	1	1	2	2

Shaded – 50 % or more shading of surface fuels due to canopy and/or cloud cover

N	All	4	5*	5	3	4	5	3	3	4	3	3	4	3	4	5	4	5	5
E	All	4	4*	5	3	4	5	3	3	4	3	4	4	3	4	5	4	5	6
S	All	4	4*	5	3	4	5	3	3	4	3	3	4	3	4	5	4	5	5
W	All	4	5*	6	3	4	5	3	3	4	3	3	4	3	4	5	4	4	5

3.2.3 Table C. 1-hr Moisture Content Corrections; Feb-Mar-Apr & Aug-Sep-Oct

Unshaded – Less than 50% shading of surface fuels

Aspect	Slope	0800-0959			1000-1159			1200-1359			1400-1559			1600-1759			1800-1959		
		B	L	A	B	L	A	B	L	A	B	L	A	B	L	A	B	L	A
N	0-30	3	4	5	1	2	3	1	1	2	1	1	2	1	2	3	3	4	5
	31%	3	4	5	3	3	4	2	3	4	2	3	4	3	3	4	3	4	5
E	0-30	3	4	5	1	2	3	1	1	1	1	1	2	1	2	4	3	4	5
	31%	3	3	4	1	1	1	1	1	1	1	2	3	3	4	5	4	5	6
S	0-30	3	4	5	1	2	2	1	1	1	1	1	1	1	2	3	3	4	5
	31%	3	4	5	1	2	2	0	1	1	0	1	1	1	2	2	3	4	5
W	0-30	3	4	5	1	2	3	1	1	1	1	1	1	1	2	3	3	4	5
	31%	4	5	6	3	4	5	1	2	3	1	1	1	1	1	1	3	3	4
Shaded – 50 % or more shading of surface fuels due to canopy and/or cloud cover																			
N	All	4	5*	6	4	5	5	3	4	5	3	4	5	4	5	5	4	5	6
E	All	4	5*	6	3	4	5	3	4	5	3	4	5	4	5	6	4	5	6
S	All	4	5*	6	3	4	5	3	4	5	3	4	5	3	4	5	4	5	6
W	All	4	5*	6	4	5	6	3	4	5	3	4	5	3	4	5	4	5	6

3.2.4 Table D. 1-hr Moisture Content Corrections; Nov-Dec-Jan

Unshaded – Less than 50% shading of surface fuels

Aspect	Slope	0800-0959 (+ night)			1000-1159			1200-1359			1400-1559			1600-1759			1800-1959		
		B	L	A	B	L	A	B	L	A	B	L	A	B	L	A	B	L	A
N	0-30	4	5	6	3	4	5	2	3	4	2	3	4	3	4	5	4	5	6
	31%	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6
E	0-30	4	5	6	3	4	4	2	3	3	2	3	3	3	4	5	4	5	6
	31%	4	5	6	2	3	4	2	2	3	3	4	4	4	5	6	4	5	6
S	0-30	4	5	6	3	4	5	2	3	3	2	2	3	3	4	4	4	5	6
	31%	4	5	6	2	3	3	1	1	2	1	1	2	2	3	3	4	5	6
W	0-30	4	5	6	3	4	5	2	3	3	2	3	3	3	4	4	4	5	6
	31%	4	5	6	4	5	6	3	4	4	2	2	3	2	3	4	4	5	6
Shaded – 50 % or more shading of surface fuels due to canopy and/or cloud cover																			
N	All	4	5*	6	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6
E	All	4	5*	6	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6
S	All	4	5*	6	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6
W	All	4	5*	6	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6

3.2.5 Night Time Estimates of 1-hr Moisture Content

Published Reference Fuel Moisture and Correction Tables for Night time Conditions are not included here based on recommendation from Pat Andrews at the Missoula Fire Lab. She recommends:

- Dry Bulb Temperature and RH should be estimated for the location of interest first
- Use Table A (above) to estimate the Reference Fuel Moisture
- Use the appropriate 1-hr Moisture Content Correction Table based on the time of the year
- Obtain the correction for 0800, shaded conditions, and appropriate aspect from that table and add it to the Reference Fuel Moisture to estimate 1-hr moisture content for night time conditions.

3.3 Probability of Ignition

	DB Temp (°F)	1-hr Moisture Content (%)															
		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0-10% shading	110+	100	100	90	80	70	60	50	40	40	30	30	30	20	20	20	10
	100-109	100	90	80	70	60	60	50	40	40	30	30	20	20	20	10	10
	90-99	100	90	80	70	60	50	50	40	30	30	30	20	20	20	10	10
	80-89	100	90	80	70	60	50	40	40	30	30	20	20	20	20	10	10
	70-79	100	80	70	60	60	50	40	40	30	30	20	20	20	10	10	10
	60-69	90	80	70	60	50	50	40	30	30	30	20	20	20	10	10	10
	50-59	90	80	70	60	50	40	40	30	30	20	20	20	10	10	10	10
	40-49	90	80	70	60	50	40	40	30	30	20	20	20	10	10	10	10
	30-39	90	70	60	60	50	40	40	30	30	20	20	20	10	10	10	10
10-50% shading	110+	100	100	80	70	60	60	50	40	40	30	30	20	20	20	20	10
	100-109	100	90	80	70	60	50	50	40	40	30	30	20	20	20	10	10
	90-99	100	90	80	70	60	50	40	40	30	30	30	20	20	20	10	10
	80-89	100	90	80	70	60	50	40	40	30	30	20	20	20	10	10	10
	70-79	100	80	70	60	50	50	40	40	30	30	20	20	20	10	10	10
	60-69	90	80	70	60	50	50	40	30	30	20	20	20	20	10	10	10
	50-59	90	80	70	60	50	40	40	30	30	20	20	20	10	10	10	10
	40-49	90	80	70	60	50	40	40	30	30	20	20	20	10	10	10	10
	30-39	80	70	60	50	50	40	30	30	20	20	20	10	10	10	10	10
60-90% shading	110+	100	90	80	70	60	50	50	40	40	30	30	20	20	20	10	10
	100-109	100	90	80	70	60	50	50	40	30	30	30	20	20	20	10	10
	90-99	100	80	80	70	60	50	40	40	30	30	20	20	20	10	10	10
	80-89	100	80	70	60	60	50	40	40	30	30	20	20	20	10	10	10
	70-79	90	80	70	60	50	50	40	30	30	30	20	20	20	10	10	10
	60-69	90	80	70	60	50	40	40	30	30	20	20	20	10	10	10	10
	50-59	90	80	70	60	50	40	40	30	30	20	20	20	10	10	10	10
	40-49	90	70	60	50	50	40	30	30	30	20	20	20	10	10	10	10
	30-39	80	70	60	50	50	40	30	30	20	20	20	10	10	10	10	10
100% shading	110+	100	90	80	70	60	50	50	40	30	30	30	20	20	20	10	10
	100-109	100	90	80	70	60	50	40	40	30	30	20	20	20	20	10	10
	90-99	100	80	70	60	60	50	40	40	30	30	20	20	20	10	10	10
	80-89	90	80	70	60	60	50	40	30	30	30	20	20	20	10	10	10
	70-79	90	80	70	60	50	40	40	30	30	20	20	20	10	10	10	10
	60-69	90	80	70	60	50	40	40	30	30	20	20	20	10	10	10	10
	50-59	90	70	60	60	50	40	40	30	30	20	20	20	10	10	10	10
	40-49	80	70	60	50	50	40	30	30	20	20	20	10	10	10	10	10
	30-39	80	70	60	50	40	40	30	30	20	20	20	10	10	10	10	10

3.4 10-hr, 100-hr, and 1000-hr Moisture Content

As inputs to the surface fire spread and/or fire danger models, these estimates do not usually have a large influence on spread rates. Values may be determined in a variety of ways:

1. After estimating 1-hr moisture content, 10-hr and 100-hr moisture content can be estimated by adding incremental amounts to each (e.g. adding 1% for 10-hr and 2% for 100-hr or 2% and 4% respectively).
2. Using a local RAWS station or the Geographic Area's Predictive Service summaries, NFDRS moisture content estimates or forecast values may be available for each of these fuel categories.
3. The National Fuel Moisture Database (http://72.32.186.224/nfmd/public/index.php) may have sampling locations near your setting that have estimates for these fuel moistures.

3.5 Live Moisture Content

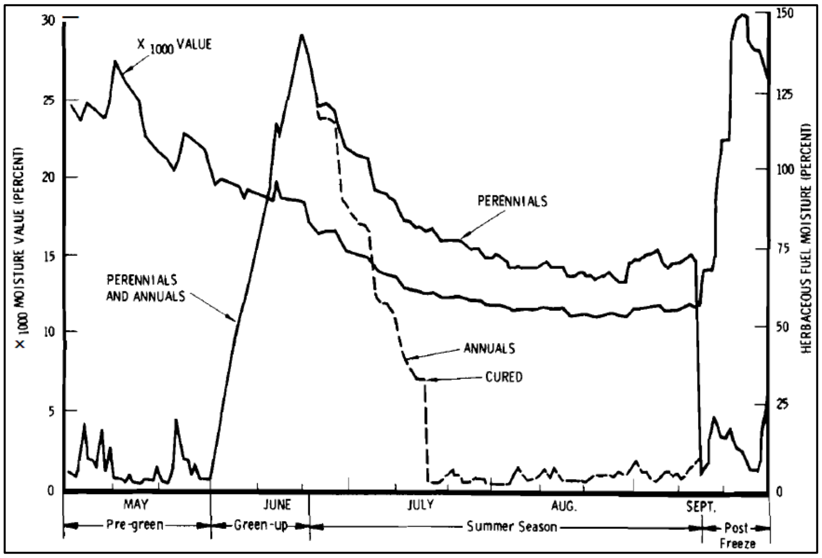
The Rothermel Surface fire model employed in fire danger and fire behavior calculations include live fuel moisture estimates as inputs in many cases. Both NFDRS and NFBPS systems include dynamic fuel models.

As discussed in fuel model descriptions, live (foliage) moisture content estimates can be critical to effective fire behavior modeling. Live moisture inputs are required for 5 of the original 13 fuel models (FB2, FB4, FB5, FB7, and FB10) and all of the GR, GS, SH, and TU fuels among the 40 standard fuel models.

This general guide is intended to reflect overall trends in the moisture content found in live foliage among surface fuels. It does not reflect the differences between conifer and broadleaf species. It does not reflect the role of flammable chemical content in some species. In any situation, estimates of moisture content for important species in a given fire environment may require field measurements.

Moisture Content (%)	Stage of Vegetative Development
300%	Fresh foliage, annuals developing early in the growing cycle.
200%	Maturing foliage, still developing, with full turgor.
100%	Mature foliage, new growth complete and comparable to older perennial foliage.
50%	Entering dormancy, coloration starting, some leaves may have dropped from stem.
30%	Completely cured, treat as dead fuel.

3.5.1 Live Herbaceous Moisture Content



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 dramatically 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.

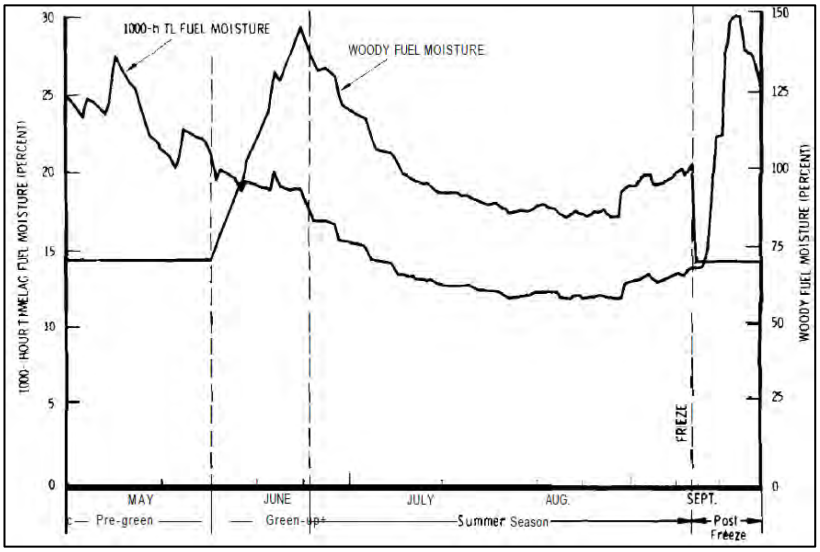
Typical herbaceous fuel moisture values start out low (equal to 1- hour fuel moisture), then increase rapidly as the growing season progresses. They may range from a high of 250, typical of the peak of the growing season, to as low as 3 or 4 when the foliage is dead or has reached maximum dormancy and 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.

Though herbaceous fuels do exhibit a peak in moisture content as they reach full development early in the growing cycle, these generalizations may not reflect the actual moisture content at any point in time.

Live Herbaceous moisture estimates can be very important when used as inputs to fire behavior models, especially when dynamic fuel models are used (see section 2.2.5). In these cases, models can produce large changes with moisture estimates that range between 30% and 120%, especially between 95% and 100%.

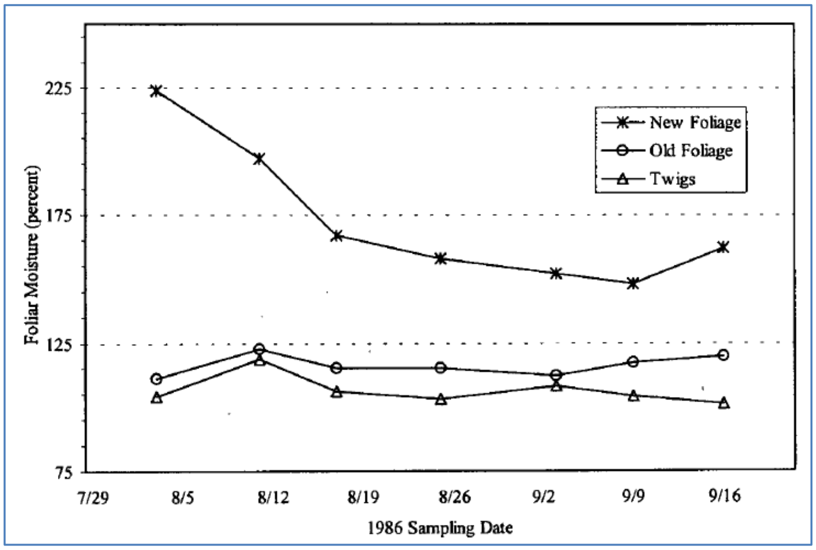
3.5.2 Live Woody Moisture Content

This fuel moisture category 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.



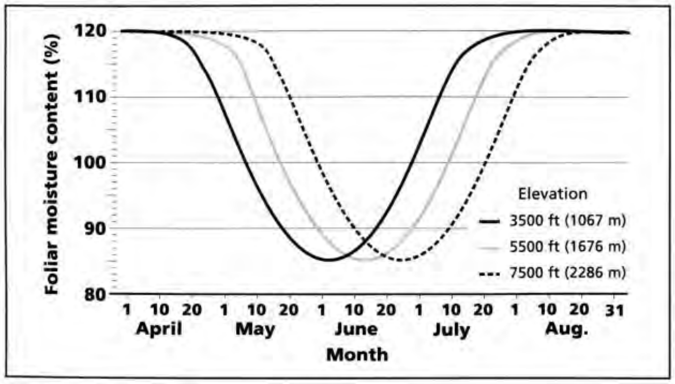
3.5.3 Foliar Moisture Content

Foliar Moisture Content is defined in the BehavePlus Variable help as the moisture content of the conifer overstory foliage (needles only). It is used along with surface fire intensity and crown base height as input to the crown fire initiation model (***see section 5.5.3.1***). Further, the CFFBP defines it as the moisture content using only conifer needles that are at least one-year old. BehavePlus allows a range of 30%-300% as with other live fuels, but WFDSS allows only a range of 70% to 130%, corresponding to the CFFBP definition. Default value is typically 100%. The example plot to the right is for Abies lasiocarpa, or Subalpine Fir. (Agee, et al 2001)



3.5.3.1 Spring Dip in Northern Conifers

As shown in the graph below, there is a measurable drop in foliar moisture content associated with the emergence of new growth each year, at least among northern conifers. CFFBP models have identified both longitude and elevation as factors in its prediction.

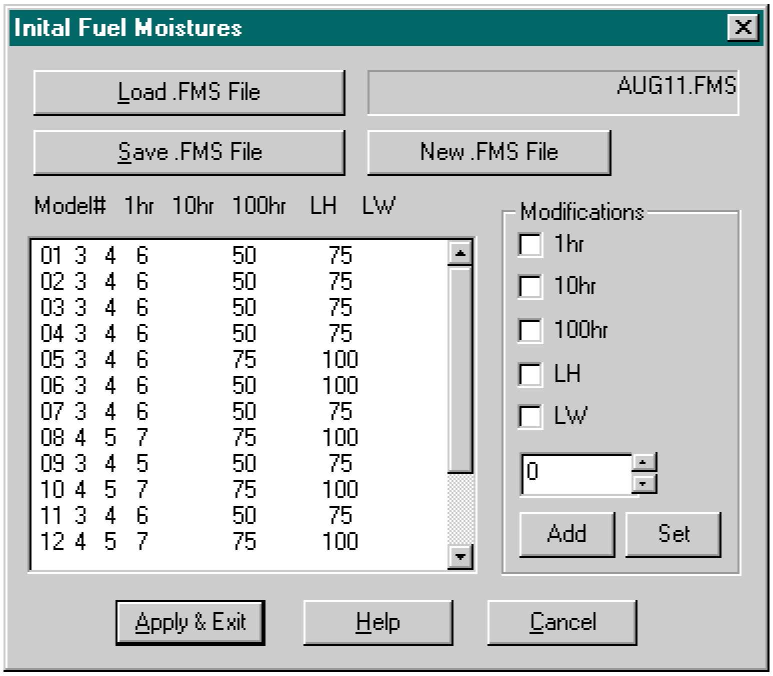


3.5.3.2 Foliar Moisture in Broadleaf Species

For deciduous species, foliar moisture follows trends similar to Live Woody Moisture. Though in many situations, it is not a crown fire risk, some examples like oak should be considered carefully.

3.6 NTFB/FARSITE & STFB/FLAMMAP Fuel Moisture (.FMS) File and Conditioning Period

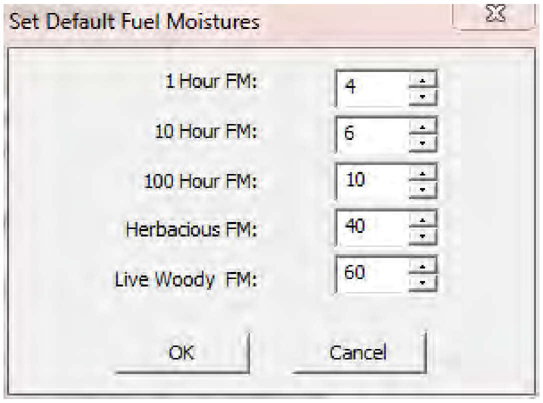
FMS files are simple space delimited text files that identify fuel moisture values for each fuel model to be used at the beginning of the analysis period. Included are 1hr, 10hr, 100hr, Live Herbaceous, and Live Woody moisture contents for each fuel model that is found on the accompanying landscape (lcp) file.



AUG11.FMS

Model#	1hr	10hr	100hr	LH	LW
01	3	4	6	50	75
02	3	4	6	50	75
03	3	4	6	50	75
04	3	4	6	50	75
05	3	4	6	75	100
06	3	4	6	50	100
07	3	4	6	50	75
08	4	5	7	75	100
09	3	4	5	50	75
10	4	5	7	75	100
11	3	4	6	50	75
12	4	5	7	75	100

☐ 1hr
☐ 10hr
☐ 100hr
☐ LH
☐ LW
0



1 Hour FM: 4
10 Hour FM: 6
100 Hour FM: 10
Herbacious FM: 40
Live Woody FM: 60

Though these files can be created and edited in simple text editors, it is best to create new FMS files using the tool in either the FARSITE Project Inputs dialog box or the FLAMMAP Run/Inputs dialog box shown he

In WFDSS, default data for fuel moistures and conditioning weather are provided for analyst review and edit.

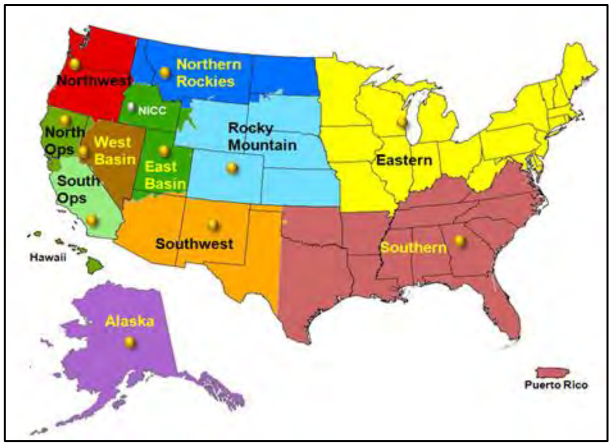
These fuel moisture values are either used to initiate fuel moistures at the beginning of a conditioning period in STFB/FLAMMAP and NTFB/FARSITE or applied across the landscape at the beginning of the analysis. Though it is possible to adjust fuel moistures for each fuel model independently in the FMS file, these adjustments are unlikely to reflect differences based on changing weather patterns and differences in solar radiation based on fuel and terrain characteristics in the landscape over the conditioning period.

Firefamily Plus may be used to estimate current fuel moistures for a given date, using stored weather observations from selected RAWS stations or defined Special Interest Groups (SIG) of stations. Simply define the dates of interest in the Active Working Set Definition and produce a ***"Weather/Season Reports/Daily Listing"*** report that includes them.

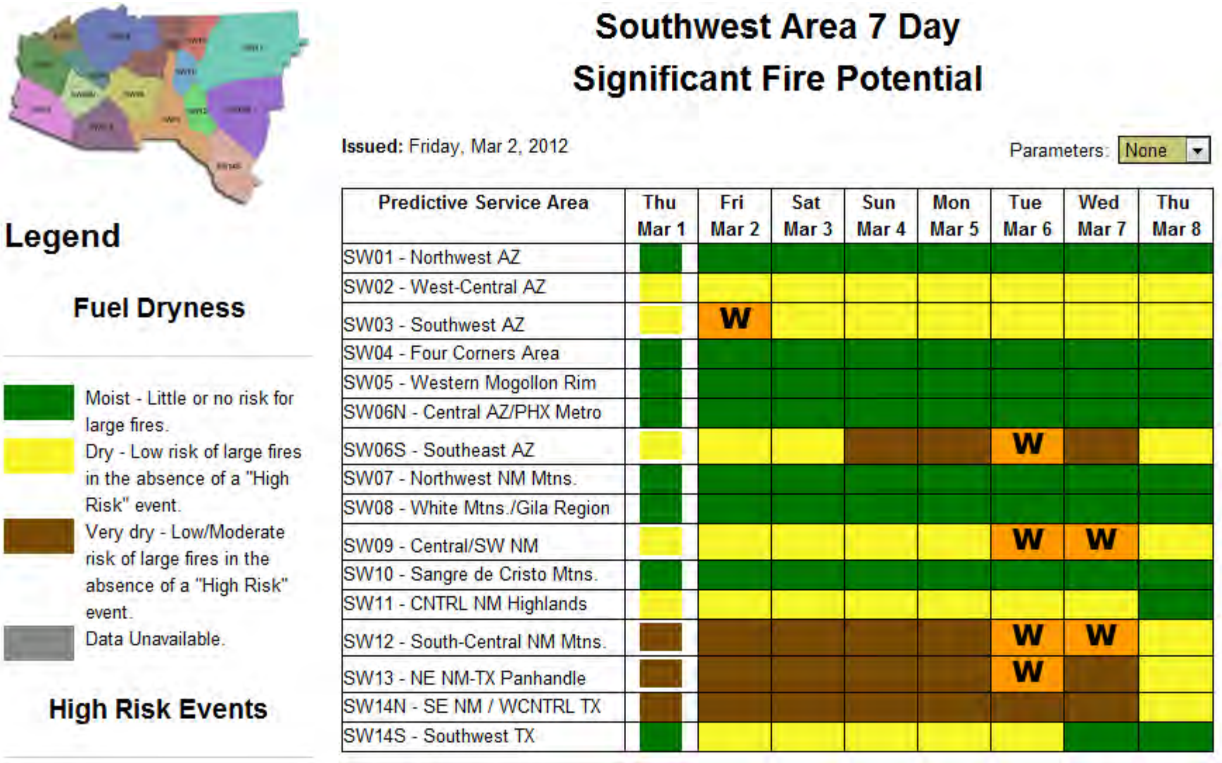
The ***Conditioning Period*** generally should include weather for 3-7 days. Additional days produce little benefit.

3.7 Predictive Services Resources

Each Geographic Area Coordination Center (GACC) collects weather observations and forecasts, from which fuel moisture, fire danger, and fire potential assessments are made. All of the geographic area predictive service products can be referenced from the National Interagency Coordination Center (NICC) page (http://www.predictiveservices.nifc.gov/outlooks/outlooks.htm)



Generally, ***a 7-Day Significant Fire Potential Outlook*** is produced each day during the fire season and can be found among the outlook products on the GACC predictive services page. This example is from the southwest.



Southwest Area 7 Day Significant Fire Potential

Issued: Friday, Mar 2, 2012

Parameters: None

Predictive Service Area	Thu Mar 1	Fri Mar 2	Sat Mar 3	Sun Mar 4	Mon Mar 5	Tue Mar 6	Wed Mar 7	Thu Mar 8
SW01 - Northwest AZ	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
SW02 - West-Central AZ	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
SW03 - Southwest AZ	🟨	🟧 W	🟨	🟨	🟨	🟨	🟨	🟨
SW04 - Four Corners Area	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
SW05 - Western Mogollon Rim	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
SW06N - Central AZ/PHX Metro	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
SW06S - Southeast AZ	🟨	🟨	🟨	🟫	🟫	🟧 W	🟫	🟨
SW07 - Northwest NM Mtns.	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
SW08 - White Mtns./Gila Region	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
SW09 - Central/SW NM	🟨	🟨	🟨	🟨	🟨	🟧 W	🟧 W	🟨
SW10 - Sangre de Cristo Mtns.	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
SW11 - CNTRL NM Highlands	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟩
SW12 - South-Central NM Mtns.	🟫	🟫	🟫	🟫	🟫	🟧 W	🟧 W	🟨
SW13 - NE NM-TX Panhandle	🟫	🟫	🟫	🟫	🟫	🟧 W	🟫	🟨
SW14N - SE NM / WCNTRL TX	🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟨
SW14S - Southwest TX	🟩	🟨	🟨	🟨	🟨	🟨	🟩	🟩

Legend

Fuel Dryness

🟩 Moist - Little or no risk for large fires.
🟨 Dry - Low risk of large fires in the absence of a "High Risk" event.
🟫 Very dry - Low/Moderate risk of large fires in the absence of a "High Risk" event.
▨ Data Unavailable.

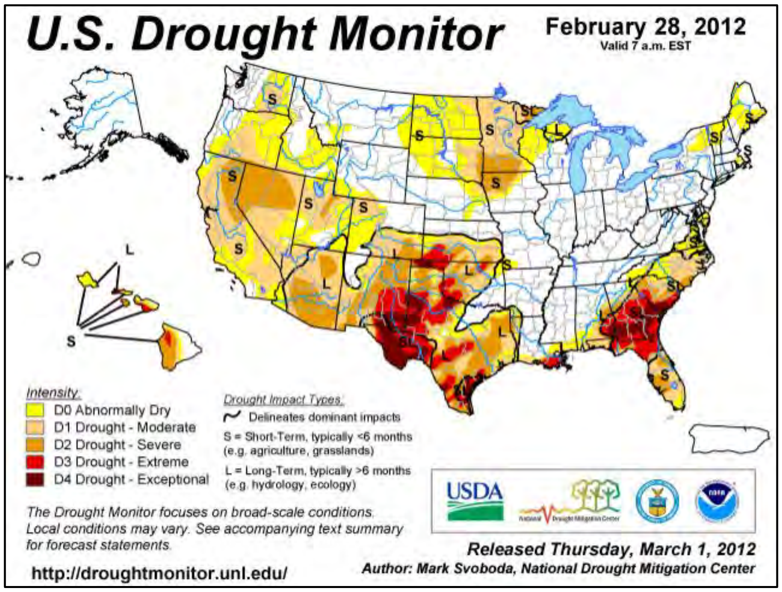
High Risk Events

This 7 day outlook also includes forecasts for the weather elements, fuel moistures, and fire danger indices that are used to produce these potential classifications. These 7-day forecasts represent averages for areas defined by the geographic area to be climatologically distinct. These products can be valuable for making strategic decisions for short and near term. Keep in mind that, like weather forecasts, values for the first day or two of the outlook are generally the most accurate and provide the greatest value.

Other standard products include daily, monthly, and seasonal assessments. Several produce multi-media briefings that can be linked from the outlooks page.

During the active fire season, each geographic area predictive service office is staffed 7 days a week to support the assessment needs of fire program managers, incident personnel, and coordination of regional fire management resources.

3.8 US Drought Monitor



The US Drought Monitor, (http://droughtmonitor.unl.edu/monitor.html), provides a clickable map of national, regional, and state summaries of drought assessment produced weekly. This product is a synthesis of multiple indices and impacts and represents a consensus of federal and academic scientists.

In addition to the overall drought monitor summaries, the site provides important links to current condition and forecasts for a range of drought measures, such as Palmer Drought Severity Index (PDSI), Standardized Precipitation Index (SPI), snowpack, soil moisture, and climate outlook products.

3.9 Wildland Fire Assessment System (WFAS)

Maintained by the Fire Behavior Unit at the Fire Sciences Laboratory in Missoula, WFAS (http://www.wfas.net/) provides a range of fire potential/danger, Weather, Moisture/Drought, and experimental products from a national perspective.

3.9.1 Google Earth Map Data

Current and historic RAWS data is available in a Google Earth compatible format. The files are updated daily and include current weather, fire danger and fuel moisture observations as well as forecast conditions when available. Because products like these are updated periodically, it is a good idea to update to latest versions of these files to insure best utility.

3.9.2 Energy Release Component (ERC-G) and Seasonal Fuel Moisture Assessment

Though National Fire Danger Rating System (NFDRS) components and indices are usually based on locally selected fuel models, national assessments of seasonal severity utilize NFDRS Fuel Model G in their calculations of ERC. Fuel Model G includes significant loadings in all live and dead fuel classes and, as a result, is more sensitive to cumulative temperature, humidity, and precipitation anomalies than others. While the Geographic Area Predictive Services units produce summary estimates of current and forecast ERC-g, WFAS produces 7 days of gridded forecasts for ERC-G that are based on the National Digital Forecast Database (NDFD). Both maps and lat/long queries are available for users to consult for their area and specific location.

3.9.3 Experimental Growing Season Index and NDVI Live Fuel Moisture

Among several experimental products produced by WFAS, two may provide insight to overall live fuel conditions.

The Growing Season Index, or Live Fuel Index, (GSI/LFI) are the same index with GSI scaled from 0-1 and LFI scaled from 0-100. LFI estimates can be produced in Firefamily Plus. It uses basic data of Minimum Temperature, Vapor Pressure Deficit, and Day length to produce a simple metric of plant physiological limits to photosynthesis.

Utilizing AVHRR NDVI technology, the Live Fuel (or shrub) Moisture estimates are characterizations of composite live fuel moisture content based on satellite imagery. See section 3.10 below. As the name would suggest, the values give best estimates in plant communities that are dominated by shrubs.

3.10 Normalized Difference Vegetation Index (NDVI) Greenness Imagery

These images, derived from a satellite sensor, have been produced weekly since 1989, producing a historical record of vegetation phenology that can be used to characterize current vegetation "greenness". They can be used to cross-reference with drought assessments and other characterizations of plant development, moisture stress and curing. Cloud cover can have a significant impact on image quality in portions of the image.

3.10.1 Depictions

3.10.1.1 Departure from Average Greenness (DA)

Departure from Average Greenness maps portrays the absolute difference between current value and the historic average greenness for the corresponding week of the year based on all years 1989-last year.

3.10.1.2 Relative Greenness (RG)

Relative Greenness maps portray how green the vegetation is compared to how green it has been over the historical reference period (1989-last year). Because each pixel is normalized to its own historical range, all areas (dry to wet) can appear fully green at some time during the growing season.

3.10.1.3 Visual Greenness (VG)

Visual Greenness maps portray vegetation greenness compared to a very green reference such as an alfalfa field or a golf course. The resulting image is similar to what you would expect to see from the air. Normally dry areas will never show as green as normally wetter areas.

3.10.1.4 Normalized Diff. Vegetation Index (ND)

Normalized Difference Vegetation Index is the base data from which all the other depictions are derived.

3.10.2 Data Sources

Wildland Fire Assessment System (WFAS) AVARR NDVI Greenness Reference is the comprehensive source of images and data archives. NDVI Archive (ftp://ftp2.fs.fed.us/pub/ndvi) is an ftp site that provides ascii grids for the recent years. RMRS-GTR-179-DVD can be ordered and has archives from 1989-2005.

3.10.3 GIS Display Considerations in ArcGIS

3.10.3.1 Projection for Full US Image

1. Create New Blank Map Document
2. Set Data Frame Coordinate System Properties from the *View* menu
   - Use Predefined Coordinate System
   - Polar – North Pole Lambert Azimuthal Equal Area
   - Central Meridian - -100° (West Longitude)
   - Latitude of Origin - 45° (North Latitude)
   - Linear Unit: - Meter, 1
3. Save Map Document as "US_NDVI" and use this map document to when adding future images.
4. Individual grids can be geo-referenced by using this information to define the projection.

3.10.3.2 Add the grid file (.bil) data (✚)*

1. Obtain the dated zip file from the NDVI Archive and extract contents
2. Add "*.bil" file to map display. Colors should display because colormap (clr) file is included.

3.10.3.3 Define Projection for added bil file

1. Use ArcToolbox→Data Management Tools→Projections and Transformations→Define Projection
2. Use coordinate system used for data frame.

3.10.3.4 Convert Ascii Grid to Arc Grid

1. Requires spatial analyst extension
2. Use ArcToolbox→Conversion Tools→To Raster→Raster to Other Format
3. Identify the *.bil file as the input raster.
4. Identify a folder of your choice as the location where ESRI Grid will be created

3.10.3.5 Add the ESRI Grid (✚) you created

3.10.3.6 Attach Legend (lyr file) to ESRI Grid

1. Display layer properties for ESRI Grid
2. Highlight Symbology Tab and "Show" Classified symbology.
3. "Import" provided lyr file (DA_9.lyr or NDVI DA grouped legend.lyr)

References

Agee, James K, Wright, Clinton S. Williamson, Nathan, and Huff, Mark H.; Foliar Moisture Content of Pacific Northwest Vegetation and its Relation to Wildland Fire Behavior; 2002; Forest Ecology and Management; 167: 57-66.

Bradshaw, Larry S.; Deeming, John E.; Burgan, Robert E.; Cohen, Jack D., compilers. 1984. The 1978 National Fire-Danger Rating System: technical documentation. Gen. Tech. Rep. INT-169. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 44 pp.

Burgan, R.E.; Hartford, R.A. 1993. Monitoring vegetation greenness with satellite data. United States Department of Agriculture, Forest Service, General Technical Report INT-297, Intermountain Forest and Range Experiment Station, Ogden, Utah. 13 pages.

Burgan, Robert E.; Hartford, Roberta A.; Eidenshink, Jeffery C. 1996. Using NDVI to assess departure from average greenness and its relation to fire business. Gen. Tech. Rep. INT-GTR-333. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 8 p..

Hirsch, Kelvin G.; Canadian Forest Fire Behavior Prediction (FBP) System: User’s Guide; 1996; Canadian Forest Service Special Report 7; 122p.

Norum, Rodney A.; Miller, Melanie. 1984. Measuring fuel moisture content in Alaska: standard methods and procedures..   Gen. Tech. Rep. PNW-GTR-171. 1984. U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 34 p.

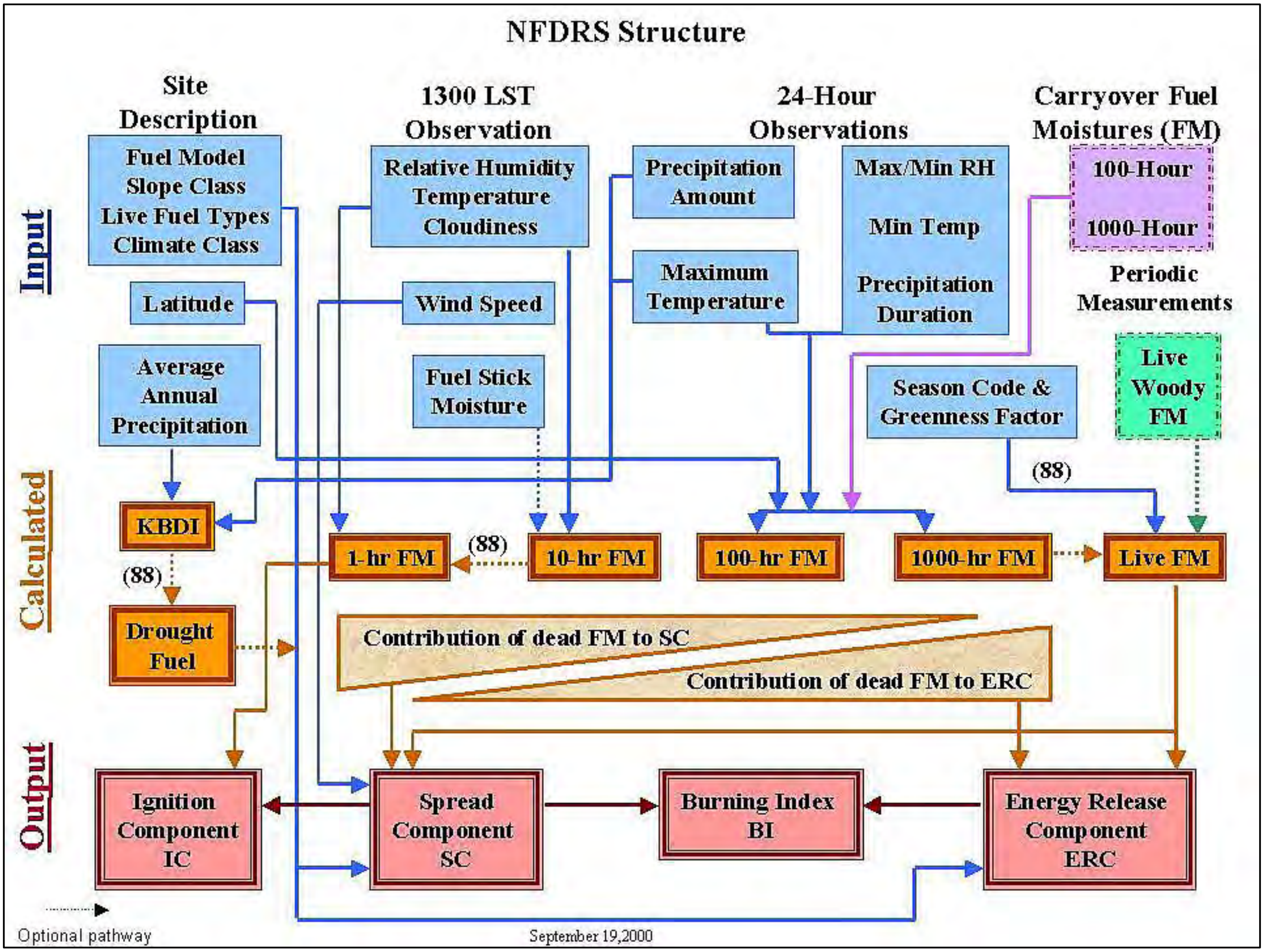
Rothermel, Richard C. 1983. How to predict the spread and intensity of forest and range fires.   Gen. Tech. Rep. INT-143. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 161 p..

4. FIRE DANGER

Contents

4.1 National Fire Danger Rating System (NFDRS)

4.1.1 System Overview



4.1.2 Station Catalog Settings

4.1.2.1 Climate Class and Greenup

Clim Class	Humidity Profile	Characteristic Vegetation	Greenup Days
1	**Arid Semi-Arid**	**Desert & Steppe**	**7**
2	**Sub-Humid** (rainfall deficient in summer)	**Savanna & Open Conifer Forest**	**14**
3	**Sub-Humid** to **Humid** (rainfall adequate in all seasons)	**Savanna &Forests**	**21**
4	**Wet**	**Rain Forests**	**28**

4.1.2.2 Annual vs Perennial

The loading of fine fuels associated with **annual grasses** shift from live to dead and stays there for the duration of the season. For **perennial grasses**, the shift from live to dead is much and may even stop or reverse if the right combinations of temperature and precipitation occur during the season.

4.1.2.3 Deciduous vs Evergreenp

In the 1988 revision to the NFDRS, separate equations were developed for deciduous and evergreen shrub vegetation, requiring users to enter a code indicating whether their local shrub vegetation is deciduous (D) or evergreen (E)

4.1.3 National Fire Danger Rating System (NFDRS) Fuel Models (**_*1988 Fuel Model changes_**)

Carrier	Fuel Model	Fuel Model Name	1hr Load t/ac	10hr Load t/ac	100hr Load t/ac	1000hr Load t/ac	Herb Load t/ac	Woody Load t/ac	Total Load t/ac	1hr SAV	Herb SAV	Woody SAV	Bed Depth ft	Moist Extinct %	Heat Cntnt btu/lb
GR	**A**	Western Annual Grasses	0.2	--	--	--	.03	--	0.5	3000	3000	--	0.8	15	8000
GR	**L**	Western Perennial Grasses	0.25	--	--	--	0.5	--	0.75	2000	2000	--	1.0	15	8000
GS	**C***	Pine Grass Savanna	0.4	1.0	--	--	0.8	**0.5 (*0.8)**	2.1	2000	2500	1500	0.75	20	8000
GS	**N***	Sawgrass	1.5	1.5	--	--	--	2.0	5.0	1600	--	1500	3.0	**25 (*40)**	8700
GS	**S**	Tundra	0.5	0.5	0.5	0.5	0.5	0.5	3.0	2500	1500	1200	0.4	25	8000
GS	**T**	Sagebrush Grass	1.0	0.5	--	--	0.5	2.5	4.5	2500	2000	1500	1.25	15	8000
SH	**B**	California Mixed Chaparral	3.5	4.0	0.5	--	--	11.5	19.5	700	--	1250	4.5	15	9500
SH	**O**	High Pocosin	2.0	3.0	3.0	2.0	--	7.0	17.0	1500	--	1500	4.0	30	9000
SH	**F**	Intermediate Brush	2.5	2.0	1.5	--	--	9.0	15.0	700		1250	4.5	15	9500
SH	**Q**	Alaskan Black Spruce	2.0	2.5	2.0	1.0	0.5	4.0	12.0	1500	1500	1200	3.0	25	8000
SH	**D**	Southern Rough	2.0	0.5	--	--	0.75	3.0	6.25	1250	1500	1500	2.0	30	9000
TU/L	**H**	Short Needle Pine (Normal Dead)	1.5	1.0	2.0	2.0	0.5	0.5	7.5	2000	2000	1500	0.3	20	8000
TU/L	**G**	Short Needle Pine (Heavy Dead)	2.5	2.0	5.0	12.0	0.5	0.5	22.5	2000	2000	1500	1.0	25	8000
TU/L	**E***	Winter Hardwoods	**1.5 (*1.0)**	2.0	0.25	--	**0.5 (*1.0)**	0.5	4.75	2000	2000	1500	**4.0***	25	8000
TU/L	**R**	Summer Hardwoods	0.5	0.5	0.5	--	0.5	0.5	2.5	1500	2000	1500	0.25	25	8000
TU/L	**U**	Western Long Needle Conifer	1.5	1.5	1.0	--	0.5	0.5	5.0	1750	2000	1500	0.5	20	8000
TU/L	**P**	Southern Pine Plantation	1.0	1.0	0.5	--	0.5	0.5	3.5	1750	2000	1500	0.4	30	8000
SB	**K**	Light Logging Slash	2.5	2.5	2.0	2.5	--	--	9.5	1500	--	--	0.6	25	8000
SB	**J**	Intermediate Logging Slash	7.0	7.0	6.0	5.5	--	--	25.5	1500	--	--	1.3	25	8000
SB	**I**	Heavy Logging Slash	12.0	12.0	10.0	12.0	--	--	46.0	1500	--	--	2.0	25	8000

National Fire Danger Rating System (NFDRS) Fuel Models – Narrative Descriptions

Grass and Grass/Shrub Fuels

Fuel Model A – This fuel model represents western grasslands vegetated by annual grasses and forbs. Brush or trees may be present but are very sparse, occupying less than one-third of the area. Examples of types where Fuel Model A should be used are cheatgrass and medusahead. Open pinyon-juniper, sagebrush-grass, and desert shrub associations may appropriately be assigned this fuel model if the woody plants meet the density criteria. The quantity and continuity of the ground fuels vary greatly with rainfall from year to year.

Fuel Model L – This fuel model is meant to represent western grasslands vegetated by perennial grasses. The principal species are coarser and the loadings heavier than those in Model A fuels. Otherwise the situations are very similar; shrubs and trees occupy less than one-third of the area. The quantity of fuels in these areas is more stable from year to year. In sagebrush areas Fuel Model T may be more appropriate.

Fuel Model C – Open pine stands typify Model C fuels. Perennial grasses & forbs are the primary ground fuel but there is enough needle litter & branchwood present to contribute significantly to the fuel loading. Some brush & shrubs may be present but are of little consequence. Types covered by Fuel Model C are open, longleaf, slash, ponderosa, Jeffery, & sugar pine stands. Some pinyon-juniper stands may qualify.

Fuel Model N – This fuel model was constructed specifically for the sawgrass prairies of south Florida. It may be useful in other marsh situations where the fuel is coarse and reed like. This model assumes that one-third of the aerial portion of the plants is dead. Fast-spreading, intense fires can occur over standing water.

Fuel Model S – Alaskan and alpine tundra on relatively well-drained sites fit this fuel model. Grass and low shrubs are often present, but the principal fuel is a deep layer of lichens and moss. Fires in these fuels are not fast spreading or intense, but are difficult to extinguish.

Fuel Model T – The sagebrush-grass types of the Great Basin and the Intermountain West are characteristic of T fuels. The shrubs burn easily and are not dense enough to shade out grass and other herbaceous plants. The shrubs must occupy at least one-third of the site or the A or L fuel models should be used. Fuel Model T might be used for immature scrub oak and desert shrub associations in the West and the scrub oak-wire grass type of the Southeast.

Timber Understory and Timber Litter Fuels

Fuel Model H – Used for short-needled conifers (white pines, spruces, larches, & firs). In contrast to FM G fuels, FM H describes a healthy stand with sparse undergrowth and a thin layer of ground fuels. Fires in FM H are typically slow spreading and are dangerous only in scattered areas where the downed woody material is concentrated.

Fuel Model G – Used for dense conifer stands where there is a heavy accumulation of litter & down woody material. They are typically over mature & may be suffering insect, disease, & wind or ice damage—natural events that create a very heavy buildup of dead material on the forest floor. The duff & litter are deep and much of the woody material is >3” in diameter. The undergrowth is variable, but shrubs are usually restricted to openings. Types represented here are hemlock-Sitka spruce, coastal Douglas fir, and wind thrown or bug-killed stands of lodgepole pine & spruce.

Fuel Model E – Used after fall leaf fall for hardwood and mixed hardwood-conifer types where the hardwoods dominate. Fuel is primarily hardwood leaf litter. It best represents the oak- hickory types & is a good choice for northern hardwoods and mixed forests of the Southeast. In high winds, the fire danger may be underrated because rolling and blowing leaves are not accounted for.

Fuel Model R – This fuel model represents hardwood areas after the canopies leaf out in the spring. It is the growing season version of FM E. It should be used during the summer in all hardwood and mixed conifer-hardwood stands where more than half of the overstory is deciduous.

Fuel Model U – This fuel model represents the closed stands of western long-needled pines. The ground fuels are primarily litter and small branchwood. Grass and shrubs are precluded by the dense canopy but may occur in the occasional natural opening. Fuel Model U should be used for ponderosa, Jeffery, sugar pine stands of the West and red pine stands of the Lake States. Use FM P for southern pine plantations.

Fuel Model P – Closed, thrifty stands of long- needled southern pines are characteristic. A 2-4 inch layer of lightly compacted needle litter is the primary fuel. Some small diameter branchwood is present but the density of the canopy precludes more than a scattering of shrubs/grass. FM P has the high moisture of extinction characteristic of the Southeast. The corresponding model for other long-needled pines is FM **U**.

National Fire Danger Rating System (NFDRS) Fuel Models – Narrative Descriptions

Shrub Fuels

Fuel Model B – Mature, dense fields of brush six feet or more in height is represented by this fuel model. One-fourth or more of the aerial fuel in such stands is dead. Foliage burns readily. Model B fuels are potentially very dangerous, fostering intense, fast-spreading fires. This model is for California mixed chaparral, generally 30 years or older. The F model is more appropriate for pure chamise stands. The B model may also be used for the New Jersey pine barrens.

Fuel Model O – The O fuel model applies to dense, brush like fuels of the Southeast. In contrast to B fuels, O fuels are almost entirely living except for a deep litter layer. The foliage burns readily except during the active growing season. The plants are typically over six feet tall and are often found under open stands of pine. The high pocosins of the Virginia, North and South Carolina coasts are the ideal of Fuel Model O. If the plants do not meet the 6-foot criteria in those areas, Fuel Model D should be used.

Fuel Model F – Fuel Model F represents mature closed chamise stands and oak brush fields of Arizona, Utah, and Colorado. It also applies to young, closed stands and mature, open stands of California mixed chaparral. Open stands of pinyon-juniper are represented; however, fire activity will be overrated at low wind speeds and where ground fuels are sparse.

Fuel Model Q – Upland Alaska black spruce is represented by Fuel Model Q. The stands are dense but have frequent openings filled with usually flammable shrub species. The forest floor is a deep layer of moss and lichens, but there is some needle litter and small diameter branchwood. The branches are persistent on the trees, and ground fires easily reach into the crowns. This fuel model may be useful for jack pine stands in the Lake States. Ground fires are typically slow spreading, but a dangerous crowning potential exists. Users should be alert to such events and note those levels of SC and BI when crowning occurs.

Fuel Model D – This fuel model is specifically for the palmetto-gallberry understory-pine association of the southeast coastal plains. It can also be used for the so-called “low pocosins” where Fuel Model O might be too severe. This model should only be used in the Southeast because of the high moisture of extinction associated with it.

Slash & Blowdown Fuels

Fuel Model I – Fuel Model I was designed for clear-cut conifer slash where the total loading of materials less than six inches in diameter exceeds 25 tons/acre. After settling and the fines (needles and twigs) fall from the branches, Fuel Model I will overrate the fire potential. For lighter loadings of clear-cut conifer slash use Fuel Model J, and for light thinnings and partial cuts where the slash is scattered under a residual overstory, use Fuel Model K.

Fuel Model J – This model complements Fuel Model I. It is for clear-cuts and heavily thinned conifer stands where the total loading of material less than six inches in diameter is less than 25 tons per acre. Again as the slash ages, the fire potential will be overrated.

Model K – Slash fuels from light thinnings and partial cuts in conifer stands are represented by Fuel Model K. Typically the slash is scattered about under an open overstory. This model applies to hardwood slash and to southern pine clear-cuts where loading of all fuels is less than 15 tons/acre.

4.1.4 Indices and Components

- ***Ignition Component (IC*****)** The Ignition Component is a rating of the probability that a firebrand will cause a fire requiring suppression action. Expressed as a probability; it ranges on a scale of 0 to 100. An IC of 100 means that every firebrand will cause an "actionable" fire if it contacts a receptive fuel. Likewise an IC of 0 would mean that no firebrand would cause an actionable fire under those conditions. Note the emphasis is on action
- ***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. Highly variable 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. It should also be pointed out that 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 does not enter into the ERC calculation, the daily variation will be relatively small. The 1000 hr time lag fuel moisture (TLFM) is a primary entry into the ERC calculation through its affect 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 lives fuel moistures.
- ***Lightning Occurrence Index (LOI)*** – The Lightning Occurrence Index is a numerical rating of the potential occurrence of lightning-caused fires. It is intended to reflect the number of lightning caused fires one could expect on any given day. The Lightning Occurrence is scaled such that a LOI value of 100 represents a potential of 10 fires per million acres. It is derived from a combination of Lightning Activity Level (LAL) and Ignition Component. To effectively develop this index the user must perform an extensive analysis to develop a local relationship between thunderstorm activity level and number of actual fire starts that result. Since our ability to accurately quantify thunderstorm intensity is limited it is difficult to develop a relationship between activity and fire starts. Thus the Lightning Occurrence Index is seldom used in fire management decisions. Local fire managers should however monitor the lightning activity level provided by the National Weather Service and with a little experience can develop their own rating of lightning fire potential.
- ***Human Caused Fire Occurrence Index (MCOI)*** – This is a numeric rating of the potential occurrence of human-caused fires. Similar to the Lightning Occurrence Index, this value is intended to reflect the number of human-caused fires one could expect on any given day. It is derived from a measure of daily human activity and its associated fire start potential, the human caused fire risk input, and the ignition component. The MCOI is scaled such that the number is equal to 10 times the number of fires expected

that day per million acres. An index value of 20 represents a potential of 2 human caused fires per million acres that day if the fuel bed was receptive for ignition.

The original developers of the National Fire Danger Rating System recognized that "where the total fires per million acres average twenty or fewer, the evaluations are questionable". This has been validated through application. As with the Lightning Occurrence Index, the Human-caused Fire Occurrence Index requires considerable analysis to establish a local relationship between the level of human activity and fire starts. Since human activity is fairly constant throughout the season and human-caused fire occurrence in, for example, the Pacific Northwest, is relatively low in terms of fires per million acres per day, most analyses result in very low risk inputs that don't change much from day to day. Few fire managers, if any, are using this index in making day to day decisions.

- ***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 is derived from a combination of Spread and Energy Release Components. It is expressed as a numeric value closely related to the flame length in feet multiplied by 10. The scale is open ended which allows the range of numbers to adequately define fire problems, even in time of low to moderate fire danger. Table 1, adapted from Deeming et al (1977) gives several cross references that relate BI to fireline intensity and flame length with narrative comments relative to the affects on prescribed burning and fire suppression activities. It's important to remember that computed BI values represent 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 of the rating area, these numbers indicate its expected fireline intensities and flame length.

  Studies have indicated that difficulty of containment is not directly proportional to flame length alone but rather to fireline intensity, the rate of heat release per unit length of fireline, (Byram 1959). The use of fireline intensity as a measure of difficulty shows that the containment job actually increases more than twice as fast as BI values increase. It is still safe to say that flame length is related to fireline intensity because BI is based on flame length

- ***Fire Load Index (FLI)*** – Fire Load Index is a rating of the maximum effort required to contain all probable fires occurring within a rating area during the rating period. The FLI was designed to be the end product of the NFDRS – the basic preparedness or strength of-force pre-suppression index for an administrative unit. It was to be used to set the readiness level for the unit. It focuses attention upon the total fire containment problem. Because the FLI is a composite of the various components and indexes of the NFDRS, including the local lighting and human caused fire risk inputs, the comparability of values varied significantly from one unit to another. To be useful managers must establish the relationship between the FLI calculated for their unit and the true fire containment effort needed. The FLI is represented as a number on a scale of 1-100. It provides no specific information as to the nature of the potential fire problem as individual indexes and components do. Because the Fire Load Index is a composite of several pieces of the NFDRS, its utility is impacted by of the inherent weaknesses of the individual components and indexes. Very few fire management decisions are made based on the Fire Load Index alone.
- ***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 affects 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 fuel models, KBDI values can be used in conjunction with the National Fire Danger Rating System outputs to aid decision making. If you are using the modified NFDRS fuel models that were developed in 1988, KBDI values are a required input to calculate daily NFDRS outputs. Since most fire danger stations are not being operated when the soil is in a saturated condition, it is necessary to estimate what the KBDI value is when daily observations are began. The technical documentation describing the KVBDI includes methodology to estimate the initiating value is included in the attached reference list. Most processors include a default initiation value of 100.

-

4.1.5 Lightning Activity Level (LAL)

A scale developed with the National Fire Danger Rating System (NFDRS) to describe lightning activity.

Scale	Description
LAL 1	No Thunderstorms
LAL 2	Isolated thunderstorms. Light rain will occasionally reach the ground. Lightning is very infrequent, 1-5 cloud to ground strikes in a 5 minute period.
LAL 3	Widely scattered thunderstorms. Light to moderate rain will reach the ground. Lightning is infrequent, 6-10 cloud to ground strikes in a 5 minute period.
LAL 4	Scattered thunderstorms. Moderate rain is commonly produced. Lightning is frequent, 11-15 cloud to ground strikes in a 5 minute period
LAL 5	Numerous thunderstorms. Rainfall is moderate to heavy. Lightning is frequent and intense, greater than 15 cloud to ground strikes in a 5 minute period.
LAL 6	Same as LAL 3 except thunderstorms are dry (no rain reaches the ground). This type of lightning has the potential for extreme fire activity and is normally highlighted in fire weather forecasts with a Red Flag Warning.

4.1.6 Pocket Cards

http://fam.nwcg.gov/fam-web/pocketcards/default.htm

The Fire Danger Pocket Card provides a format for interpreting and communicating key index values provided by the National Fire Danger Rating System. The objective is to lead to greater awareness of fire danger and subsequently increased firefighter safety. The Pocket Card provides a description of seasonal changes in fire danger in a local area. It is useful to both local and out-of-area firefighters.

The Pocket Card has very important day-to-day "pre-suppression" uses. When the morning and afternoon weather is read each day, the actual and predicted indices are announced. Firefighters can reference their card and assess where today falls in the range of historical values for danger-rating. This important information should be discussed at morning crew meetings, tailgate safety meetings, incident briefings, etc.

Local fire management personnel can produce the cards using Fire Family Plus. Cards should be developed locally with local fire management involvement to meet local fire management needs.

References

NFDRS Reference Material (http://fam.nwcg.gov/fam-web/pocketcards/reference_cd_2009/nfdr_contents.html)

Bradshaw, Larry S.; Deeming, John E.; Burgan, Robert E.; Cohen, Jack D compilers. The 1978 National Fire-Danger Rating System: technical documentation.General Technical Report INT-169. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range ExperimentStation; 1984. 44 p.

Burgan, Robert E. 1988. 1988 Revisions to the 1978 National Fire-Danger Rating System . Res. Pap. SE-273. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 144 p..

Schlobohm, Paul, and Brain, Jim; 2002; Gaining an Understanding of the National Fire Danger Rating System, NWCG-PMS932, 58p

5 FIRE BEHAVIOR

Contents

5.1 Assessing Current and Expected Fire Behavior

5.1.1.1 Examine the current fire situation (location, factors, spread direction & fire behavior)

- Fuel: Is it burning in grass, litter, or into shrubs and crowns?
- Fuel Moisture: are fuels dry? Are they still green?
- Terrain: Is it burning upslope, downslope?
- Weather: Is the wind pushing it, is it sheltered from the wind?
- Fire Behavior: is it smoldering, creeping, or actively spreading? Are the flames low, or is it burning hot?

5.1.1.2 Evaluate the unburned areas where you are and will be working

- Which spread directions do you expect to be active?
- Which seems like the spread directions that will produce the most problems?
- Which of the spread directions are of most concern to you?

5.1.1.3 Anticipate the expected fire situation in those areas

- Fuel: What fuel is it going to move into in that direction? Will it burn hotter and faster? Slower & cooler?
- Fuel Moisture – will the change in fuel moisture encourage extreme fire behavior?
- Terrain – slope reversal? Flat to upslope? Will the changes increase or reduce fire behavior?
- Weather - As the fire moves, will it be more exposed to the wind? Will the wind increase in the future?
- Fire Behavior - do you anticipate the fire behavior, based on your anticipated changes being manageable?

5.1.1.4 Assess Fire Risk: Interpret Ignition & Crown Fire Potential

- Is it the typical dry period for the area?
- Is the overall drought situation enough to make it worse?
- Has there been recent crown fire on this or other fires in the area?
- Is the humidity, and fine fuel moisture, low enough to encourage intense surface fire?
- Is backing fire causing torching? If so, expect crown fire with head fire.
- Is fire moving up ladder fuels? Expect at least short crown fire runs.

5.1.1.5 Project Fire Spread, Flame Length and Spotting Distance

- Select the proper tool for the assessment. FLAME, Surface Fire Behavior Lookup Tables and Nomographs, Spotting Nomograms, and crown fire assessment tools are included here
- Can you calibrate projections with current fire behavior?
- How precise do the projections need to be?

5.1.1.6 Determine decision thresholds to insure LCES

- Determine time frames for escape to safety and escape routes that make sense in each situation. What windspeeds or changes in fire behavior will render those time frames insufficient?
- Identify best locations and methods for lookout to monitor and validate your assessment
- Insure that weather and fire behavior observations are communicated regularly to the entire crew.
- Will Fatigue and Logistics factors impact these decisions?

5.1.1.7 Document your Assessment

- Record your observations and assumptions
- Use worksheets and include notes for each assessment
- Include assessments and decisions in personal logs
- Remember: “If you’re not keeping score, it’s just practice”

5.1.2 Observing Current Fire Behavior

Rate of Spread Estimator

Spread Distance (ft)				
1	3	5	10	ROS ch/hr (ft/min)
Time in Minutes (‘) and seconds (“)				
3'38"	10'55"	18'10"	36'22"	¼ (¼)
1'49"	5'27"	9'05"	18'10"	½ (½)
55"	2'44"	4'33"	9'05"	1 (1)
36"	1'49"	3'02"	6'04"	1.5 (1-2)
27"	1'22"	2'16"	4'33"	2 (2)
18"	55"	1'31"	3'02"	3 (3)
14"	41"	1'08"	2'16"	4 (4-5 ft)
11"	33"	55"	1'49"	5 (5-6)
9"	27"	45"	1'31"	6 (6-7)
8"	23"	39"	1'18"	7 (7-8)
7"	20"	34"	1'08"	8 (9)
6"	18"	30"	1'01"	9 (10)
5"	16"	27"	55"	10 (11)
4"	11"	18"	36"	15 (16-17)
3"	8"	14"	27"	20 (22)
2"	7"	11"	22"	25 (27-28)
2"	5"	9"	18"	30 (33)
2"	5"	8"	16"	35 (38-39)
1"	4"	7"	14"	40 (44)
1"	3"	5"	11"	50 (55)
1	3	5	10	
Spread Distance (ft)				

Use this chart as an aid to estimate rate of spread

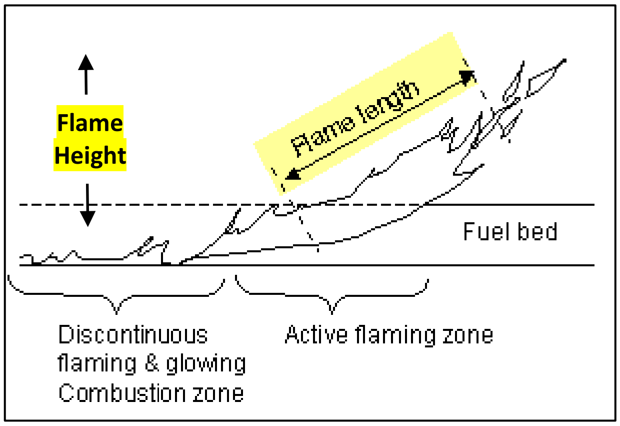
Here’s how:

1. Measure out 1, 3, 5 or 10 feet. Mark distance with two points.
2. Time fire as it spreads between your two points and record this time.
3. Using the appropriate spread distance column (1, 3, 5 or 10), place your time on the sheet between two times listed, your “bracketed” times.
4. Move to the right with the bracket times. This is your ROS range.

Time Key
1’ 49” = 1 minute and 49 seconds
36” = 36 seconds

Example: Say you’re monitoring a backing fire burning in light ponderosa needle cast. You measure out 3 feet, and place two stones at each of the points. You time the fire as it moves between the stones. In this case, say the fire takes 1 minute 6 seconds (1’6”) to move 3 feet. Looking at the 3 column, you move down until you see two times which bracket our time: 1’22” and 55”. You then scroll right and see that the rate of spread is between 2 and 3 chains per hour.

Flame Length vs. Flame Height



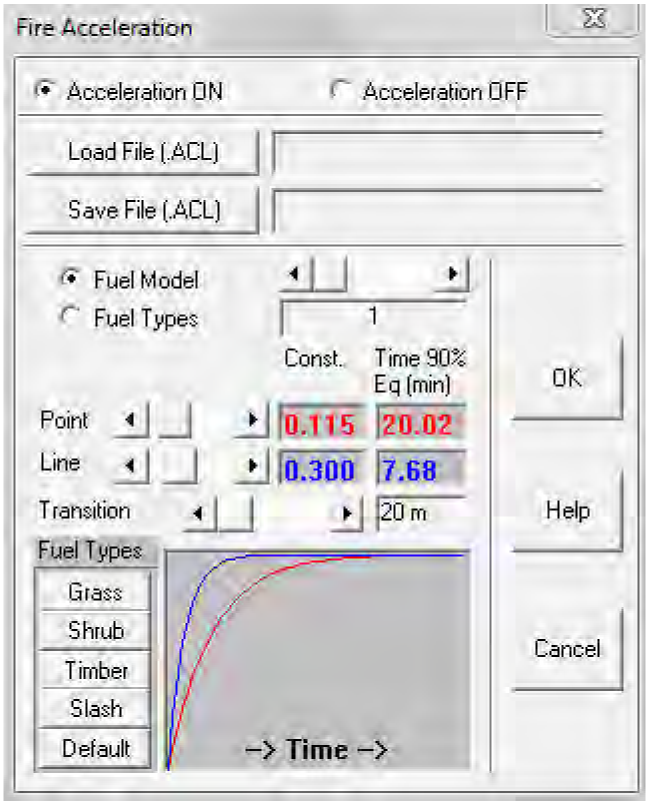
Flame Length: The distance measured from the average flame tip to the middle of the active flaming zone at the base of the fire. It is measured on a slant when the flames are tilted due to effects of wind and slope.

Flame Height: The average height of flames as measured vertically, up and down. It is estimated by comparing the flame to a nearby object of known height. Flame height is needed to estimate spot distance from a burning pile.

5.1.3 Acceleration Effect on Rate of Spread

Fire acceleration is defined as the rate of increase in fire spread rate. It affects the amount of time required for a fire spread rate to achieve the theoretical steady state spread rate given 1) its existing spread rate, and 2) constant environmental conditions. Because initiating fires can take 20 minutes to over an hour to reach a steady spread rate, fire behavior and fire growth can be significantly over predicted in the first burn period. Conversely, calibration efforts, based on this early growth period, that do not consider acceleration can lead to significant under prediction in subsequent burn periods.

At this time, fire acceleration is implemented only in FARSITE, using the model developed for the Canadian Forest Fire Behavior Prediction System (Alexander et. al. 1992). It is active by default, but can be turned off as a model input. As implemented, inputs are segregated by type of Ignition (**point** vs. **line** source) and potentially by **fuel type** (grass, shrub, timber, slash, a default, or by fuel model). Grass fuels are expected to have more rapid acceleration rates (shorter time to reach equilibrium) than fuel types with larger woody material (slash etc.).


Fire Acceleration

● Acceleration ON ○ Acceleration OFF

● Fuel Model ○ Fuel Types

1

	Const.	Time 90% Eq (min)
Point	0.115	20.02
Line	0.300	7.68
Transition		20 m

5.1.4 Surface Fire Behavior

This section highlights surface fire behavior assessments and references tools used in the process:

- A ***Worksheet*** **(5.4.1)** designed to conduct a complete assessment for surface fire behavior and growth using either the lookup tables or the nomographs.
- ***EWS Tables*** **(5.4.2)** for estimating Effective Windspeed from Slope and Midflame Windspeed. The Effective Windspeeds that result from these tables assumes that wind is blowing ± 30° from upslope. For other situations, manual vectoring without using the ***EWS Table*** would be necessary.
- ***Surface Fire Behavior Lookup Tables (5.4.3)*** for making estimates of surface fire spread and flame length. 10-hr and 100-hr moisture values of 6% and 8% are used in the lookup tables. ***Two cautions*** **to consider with these tables**. *(1) The *20ft/FCST wind line is provided as a convenience, but only works with stated WAF & no slope adjustments. (2) Backing & flanking columns are only rough estimates based on ½ & 1 mph windspeeds. Use BehavePlus for more precise estimates.*
- ***Surface Fire Behavior Nomographs (5.****4.4)*
- ***Flanking and Backing Fire Behavior Nomograms (5.****4.5)*

5.1.4.1 Inputs

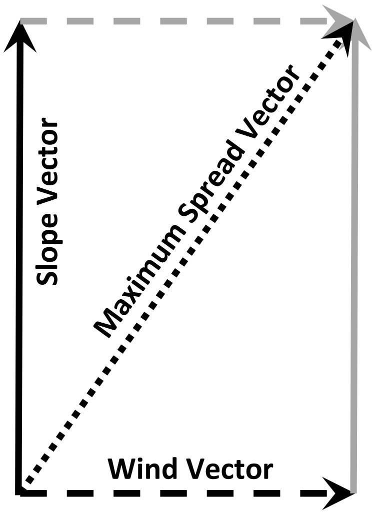
- Time and Place from Section 6 (Burn Period, Duration)
- Fuel/Terrain from Section 2 (Surface Fuel Model, Canopy Cover, Aspect, Slope)
- Dead Fuel Moisture from Section 3 (Temp, R,H, Month, Time, Elev Diff, Shading, Slope)
- Live Fuel Moisture from Section 3 (Herbaceous Moisture Content, Woody Moisture Content)
- Effective Windspeed and Direction from Sections 1 (20 ft & Midflame) and 5 (Effective Windspeeds)

5.1.4.2 Output

- Fire Behavior from Section 3(Probability of Ignition) & 5 (Spread, Flame Length)
- Fire Size and Shape from Section 6 (Spread Distance, Fire Size, Fire Perimeter, Fire Shape)

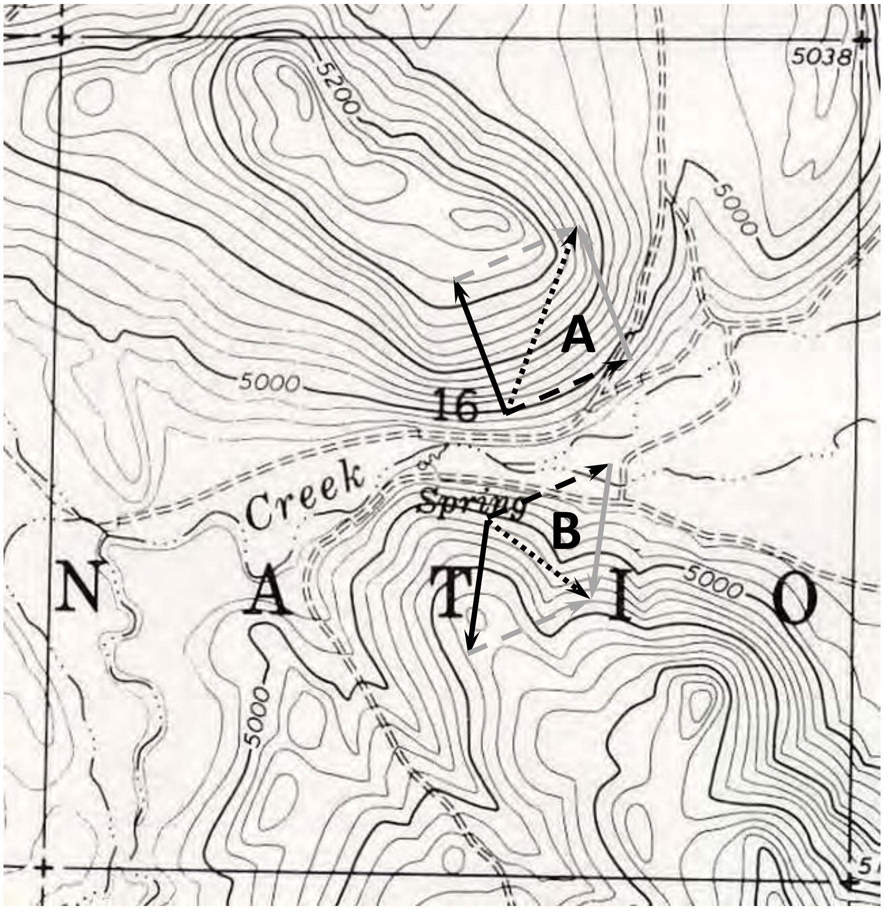
5.1.5 Vectoring Fire Behavior (Cross Slope Winds & Backing/Flanking Spread)

5.1.5.1 Projections With Cross Slope Winds



Projecting fire spread with cross slope winds utilizes a vectoring process, where the effect of wind and the effect of slope on Rate of Spread (ROS) may be represented by separate vectors that represent both a magnitude and a direction. The resultant vector represents both a direction and magnitude of maximum spread in that direction.

- **Slope Vector** is drawn directly upslope and estimated by calculating ROS with the estimated slope steepness and Zero (0) windspeed for inputs.
- **Wind Vector** is drawn in the direction of the wind and estimated by calculating ROS with the estimated windspeed and Zero (0) slope.
- **Maximum Spread Vector** can be drawn as shown and measured to determine the resultant ROS and spread direction



In example **A** here, wind is crossing more upslope, resulting in an enhanced maximum ROS.

In example **B**, wind is crossing more downslope, resulting in a reduced maximum ROS.

With winds blowing downslope (±30°), the difference between the spread rates is the resulting ROS using the direction from the larger vector.

If the vectoring process is completed manually, fireline intensity (FLI) and flame length (FL) can be calculated from ROS and Heat Per Unit Area (HPA) using these calculations

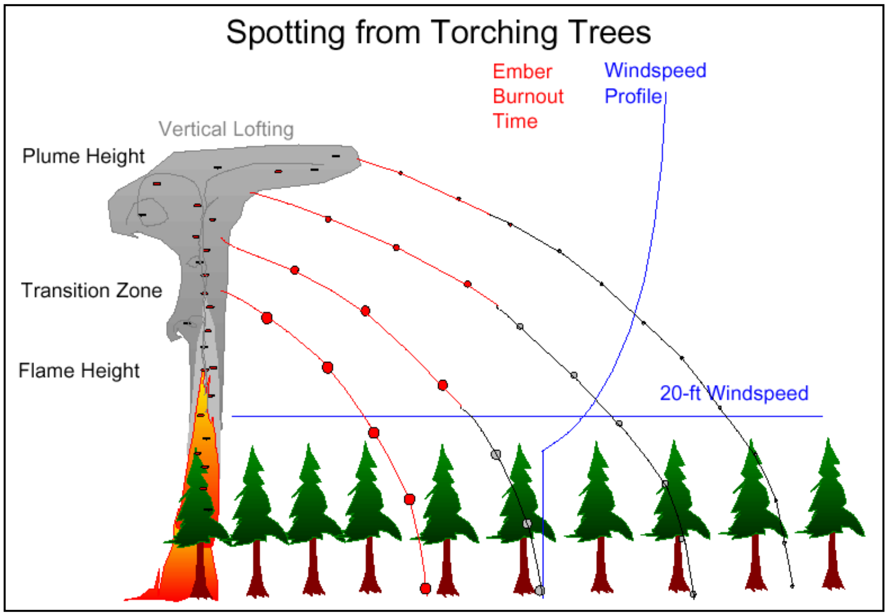
$$FLI = (ROS * HPA)/55$$

$$FL = .45 * FLI^{.46}$$

5.1.5.2 Backing and Flanking Spread Projections

Estimating flanking and backing fire behavior provide important insights for safety and control activities on the fireline, as well as accurate estimates fire growth around an active fire perimeter. These can be estimated utilizing the geometry of the elliptical fire shape. The nomgram in section 5.4.5 provides a quick method for estimating Rate Of Spread and Flame Length (FL) for these spread directions.

5.1.6 Assessing Spotting Fire Behavior Potential



Evaluating the importance of spotting fire behavior requires the integration of three factors:

- the firebrand source
- the distance the firebrand is carried into the wind
- the probability of igniting a new fire at the downwind location.

Short-Range Spotting is not generally considered as significant in the growth if wildfires, because the advancing fire usually overruns the developing spot fire.

Long-Range Spotting is differentiated from short-range spotting, primarily because firebrands are being lofted by a convection column and carried beyond the immediate fire area.

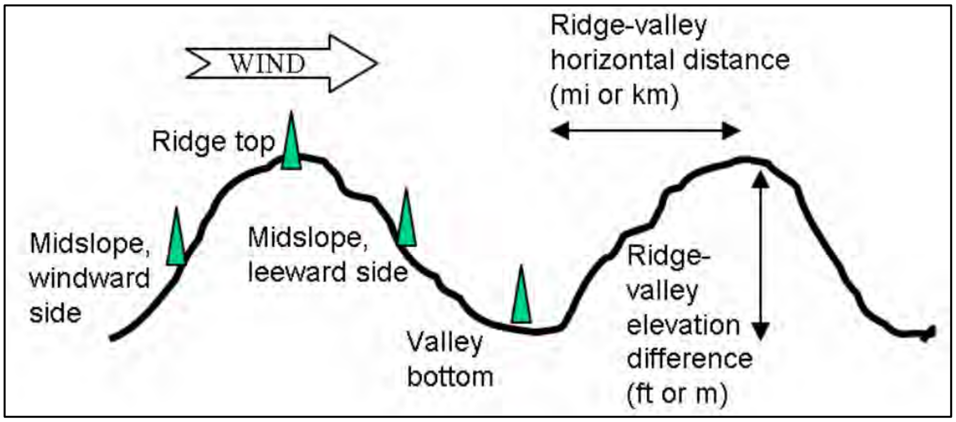
The table in section 5.1.5.1 compares the spotting assessment in the different fire behavior systems.

Estimating Maximum Spotting Distance

Both the included Spotting Distance Nomograms (with the associated worksheet in Section 5.5) and BehavePlus provide methods for estimating the Maximum Spotting Distance from a Torching Tree, or trees.

As suggested by the graphic above, the model requires identification of ***tree species, height, and DBH*** to estimate the flame height and duration from the torching tree that will initiate the lofting of the ember into the windfield.

Further, the ***open windspeed*** is used to suggest how far the fire brand will be transported as it falls back to the ground. The nomogram, because it assumes level ground uses the surface (20ft) windspeed and direction.



The graphic here depicts additional inputs to the BehavePlus spotting module. In mountainous terrain, ***ridge top winds*** are used if wind is blowing across valleys as shown. The shape of the valley is considered with inputs for ***Ridge-to-Valley*** distance and elevation difference.

The downwind ***Canopy, or Tree Cover, Height*** (reduced for open canopies) is used to factor out embers intercepted by the canopy before reaching surface fuels.

Integrating Spotting Spread into Fire Growth Projections

FARSITE, FLAMMAP, and FSPro attempt to integrate the estimate of the number of embers and the distribution of distances they travel into the fire growth projection. Estimating maximum spotting distance from nomograms or BehavePlus only suggests an outer perimeter for spotting potential.

5.1.6.1 Comparing Systems for Modeling Long Range Spotting Potential

	Nomogram System	BehavePlus System	Spatial Grid System Short Term (STFB/FLAMMAP)	Spatial Vector System Near Term (NTFB/FARSITE)
Model Outputs and Limitations	Estimates only maximum spotting distance		• Estimates a distribution of spotfire distance and direction • Uses only Passive (torching) and Active Crown fire for source of embers. • Spotting not modeled in FLAMMAP 3 • The same Species and DBH (Grand Fir, 20cm DBH) are used for the entire landscape.	
	• Assumes single torching tree • Assumes level terrain between source location and downwind destination • Subjective evaluation of crown fire initiation	• Crown Fire initiation model available, but not linked to the spotting module • Ember size not evaluated		
Spotting Source	• Torching Tree Species • Torching Tree DBH • Torching Tree Height	**<u>Torching Trees</u>** • Torching Tree Species • Torching Tree DBH • Torching Tree Height • Number of Torching Trees (1-30 trees) **<u>Wind-Driven Surface Fire</u>** • Flame Length **<u>Burning Piles</u>** • Flame Height	• Torching Tree default is Grand Fir, 20cm DBH. • Canopy Cover (CC) and Crown Fraction Burned (CFB) determines # of torching trees • Faster spread rates increase the # of opportunities for lofting, though STFB/FLAMMAP is more limited • User set Spot Probability used to determine whether node (STFB/FLAMMAP) or vertex (NTFB/FARSITE) lofts ember	
			• More embers will be lofted with finer landscape or distance resolution • Fewer nodes than vertices	• More embers will be lofted with shorter timesteps and/or distance/perimeter resolution
Firebrand Transport Inputs	• 20-ft windspeed • Downwind Canopy Height • Downwind Canopy Cover	• 20-ft windspeed • Torching Tree Location • Ridge-to-Valley Distance • Ridge-to Valley Elev. Diff. • Downwind Canopy Height • Downwind Canopy Cover	• Firebrand size and lofting height from spotting source • 20 ft windspeed • Uses Landscape downwind canopy and terrain characteristics	
			Less likely embers will travel max dist than NTFB/FARSITE	
Ignition Probability Inputs	• Dry Bulb Temperature • Shading • 1-hr Moisture Content	• Dry Bulb Temperature • Shading • 1-hr Moisture Content	Embers tracked until they burnout or land. Embers landing on burnable pixel always ignite	
			With fewer embers, user should use higher Spot Probability than NTFB/FARSITE	With more embers, user should use lower Spot Probability than STFB/FLAMMAP

5.1.7 Crown Fire Behavior

5.1.7.1 Approaches to Modeling Crown Fire

	SURFACE-FIRE CONTROL (Finney, 1998)	**CROWN-FIRE CONTROL (Scott/Reinhardt, 2001)**
Surface Fire Behavior	• Uses Rothermel Surface Fire Model to estimate Rate of Spread (ROS), Flame Length (FL), and Fireline Intensity (FLI)	• Uses Rothermel Surface Fire Model to estimate Rate of Spread (ROS), Flame Length (FL), and Fireline Intensity (FLI)
Passive Crown Fire	• Uses Van Wagner Crown Fire Initiation Model to distinguish surface fire behavior from crown fire (passive and active). • Calculates Crown Fraction Burned (CFB) between 0 & 1. Concept created by Van Wagner for use as a transition scale between surface and active crown fire. CFB calculations produce lower values than Crown Fire Control Method. • Spread rate and flame length for Passive Crown fire assumed to be the same as the surface fire spread rate.	• Uses Van Wagner Crown Fire Initiation Model to distinguish surface fire behavior from crown fire (passive and active). • Calculates Crown Fraction Burned (CFB) between 0 & 1. Concept created by Van Wagner for use as a transition scale between surface and active crown fire. CFB calculations produce higher values than Surface Fire Control method • Spread rate for Passive Crown fire is determined to be intermediate between the estimated Crown Fire and Surface Rates Of Spread based on the CFB • Combines estimates of surface and crown fuels consumed and actual spread rate to determine final fire intensity.
Active Crown Fire	• Uses Van Wagner criteria for Active Crown Fire to distinguish Passive from Active Crown Fire. • Because calculated CFB is lower is lower than what is produced by the Crown Fire Control method, active crown fire spread rates remain less than that estimated by Rothermel model even after active crown fire is predicted. • Combines estimates of surface and crown fuels consumed and actual spread rate to determine final fire intensity. • Estimates Flame Length from fireline intensity using Thomas' (1963) equation	• Uses Van Wagner criteria for Active Crown Fire to distinguish Passive from Active Crown Fire. • Uses Rothermel's Crown Fire Model to estimate Crown Fire ROS. Default result is based on the average rate, but Max ROS can be estimated by setting multiplier to 1.7. • Combines estimates of surface and crown fuels consumed and actual spread rate to determine final fire intensity • Estimates Flame Length from fireline intensity using Thomas' (1963) equation.

- Both approaches identify the threshold for predicting crown fire initation and active crown fire spread using the same criteria, based on the Van Wagner Crown Fire Initiation model.

- BehavePlus identifies the fire type for a given scenario but does not provide estimate separate passive crown fire behavior characteristics (ROS, FL). The user must select surface or crown fire characteristics from separate tables based on the fire type (surface or active) expected.

- The Surface Fire Control model (implemented only in FLAMMAP, FARSITE, and FSPro) produces specific fire behavior characteristics for surface and active crown fire. Passive crown fire is accounted for by modeling new spot fires at frequencies and distances estimated separately...

5.1.7.2 Comparisons and critiques

Cruz, M.G. and M.E. Alexander. 2010. Assessing crown fire potential in coniferous forests of western North America: a critique of current approaches and recent simulation studies. International Journal of Wildland Fire 19(4):377-398.

Scott, Joe H. 2006. Comparison of crown fire modeling systems used in three fire management applications. Res. Pap. RMRS-RP-58. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 25 p.

5.2 Selecting The Assessment Tool

Assuming that most users will be using geospatial tools such as WFDSS STFB & NTFB or FARSITE & FLAMMAP to project fire growth and behavior from larger fire perimeters, this fire behavior section has been developed as both a desk and field guide for basic projections from one or several locations on the fireline. Resources and tools provided in other sections, such as Fine Fuel Moisture and Probability of Ignition estimation, are available and should be considered a part of these systems as needed.

To support those analyses for fireline decisions, three systems are represented here:

- The Fireline Assessment Method (FLAME) in Section 5.3.

  Purpose: Provided as the first fire behavior processor taught in the NWCG Fire Behavior series, it is intended primarily for assessments conducted on the fireline and helping prospective fireline supervisors learn how important various fire environment factors are. It expects the user to identify both a current situation (including an assessment of current fire spread) and a future one. Using the changes discovered evaluating the two situations, it produces a Rate of Spread (ROS) Ratio and includes a process for converting that into either a spread distance or a spread time that can be used for evaluating tactical time frames and escape routes.

  Process: Observe current fire spread rate, distance, or time. Identify next big change (wind, fuel, slope reversal). Determine Effective Windspeed (EWS) Ratio from current and expected wind scenarios using observations and/or forecasts. Basic fuel type (grass, litter, shrub/crown) and slope changes using current and expected scenarios. Estimate ROS Ratio and expected spread distance or time for expected situation.

  Limitations: Does not calculate a flame length, no spotting distance assessment incorporated. Fuel moisture incorporated only subjectively.

- Lookup Tables, Nomograms and Nomographs in Section 5.4 and 5.5

  Purpose: Objectively determine surface fire behavior (Rate of Spread and Flame Length) from a set of current or expected fire environment (fuel, fuel moisture, slope, wind) inputs. Estimate maximum spotting distance and crown fire potential.

  Process: Using the Surface Fire Behavior Worksheet in Section 5.4.1, identify Fuel/Terrain, estimate Live and Dead Fuel Moistures, determine an Effective Windspeed, and project a spread rate and flame length using either a lookup table or nomograph for the selected fuel model. Maximum Spotting Distance Is estimated using the spotting distance nomograms in Section 5.5.2. Crown Fire Potential may be estimated using the charts in section 5.5.3

  Limitations: Spotting Distance nomograms are for single tree only and do not account for position in mountainous terrain.

- BehavePlus system in Section 5.6

  Purpose: Comprehensive set of single scenario fire behavior models and tools.

  Process: Identify processes to employ (Surface Fire, Crown Fire, Elliptical Fire Size And Shape, Spotting Distance, Crown Scorch, Tree Mortality, Probability Of Ignition, Safety Zone Size). Provide fire environment inputs for selected processes, outputs in tabular and graphic format.

  Limitations:

5.3 Fireline Assessment Method (FLAME)

5.3.1 FLAME Worksheet

Date:	Time:	Incident:	Observer:

Initial Application

CURRENT Fuel Type, Slope-Aspect-Position, Wind, RH, Spread Direction (backing, flanking, headfire)	EXPECTED Fuel Type, Slope-Aspect-Position, Wind, RH, Spread Direction (backing, flanking, headfire).

Next Big Change(s):

Standard Application

Current - RELATIVE HUMIDITY - Expected

Current - FUEL TYPE - Expected

Litter (surface) ☐	☐ Litter (surface)
Crown (aerial) ☐	☐ Crown (aerial)
Grass (surface) ☐	☐ Grass (surface)

EFFECTIVE WINDSPEED (EWS) RATIO (Table 1)

CURRENT WINDS			EXPECTED WINDS
Eye level winds (observed)			Forecast Windspeed (20 ft)
Eye level winds at fire (Fig A)			Predicted Winds at fire (Fig A)
MidFlame Wind (Fig B)			Midflame Winds (Fig B)
Slope contribution (Fig C +/-)			Slope contribution (Fig C +/-)
Current Effect Wndspd (EWS)			Expected Effect Wnspd (EWS)
EWS-Ratio (compare current & expected EWS) bigger EWS/smaller EWS (use Table 1)			

Complete Application

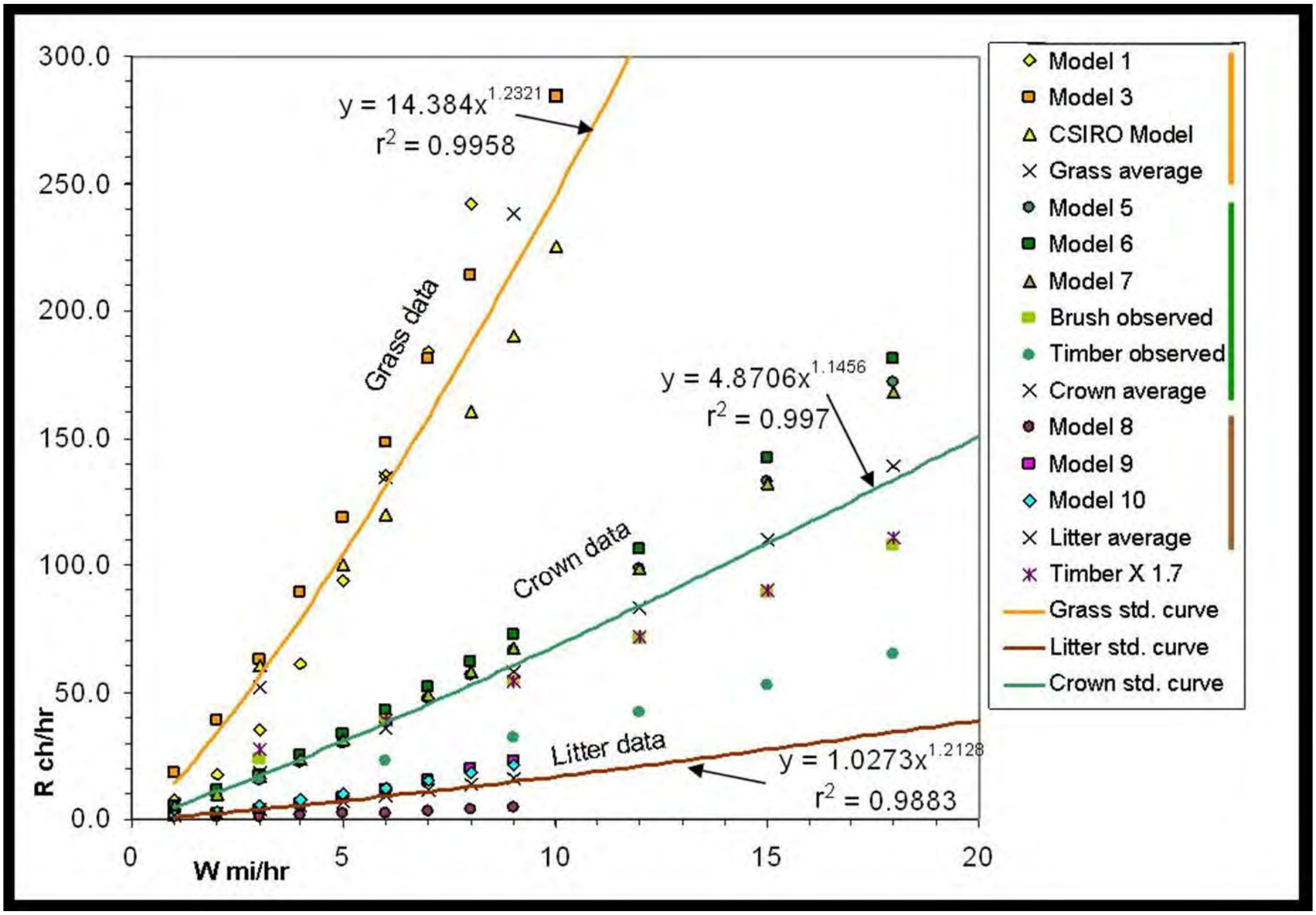
ROS-RATIO (Table 2) _________☐Expected Faster ⇓ ☐Expected Slower ⇓

Observed Spread	(Obs spread÷ROS-Ratio)	Obs Spread X ROS-Ratio

Time	Fire Behavior & Weather Observation – ENSURE LCES

5.3.2 Background

The graph here identifies how the FLAME processor uses established fire behavior models to produce estimates of fire spread for groups of similar fuels. Using Effective Windspeed (EWS) as the primary factor, spread rates can be compared based on changes in windspeed and/or changes in fuel type to arrive at an estimate of change, or ROS-Ratio. The ROS-Ratio can demonstrably assist in identifying critical fireline threats. This graph can also be used to produce approximate estimates of spread rates for each of the fuel types based on the observed or forecasted effective windspeed.



5.3.3 FLAME Process

- INITIAL APPLICATION: requires description of ***current*** fire environment (wind, slope, & fuel) & fire behavior, ***expected*** fire environment & fire behavior, and identification of "***Next Big Change***". Suitable for all firefighters and draws upon concepts learned in S190 (Introduction to Wildland Fire Behavior).
- STANADARD APPLICATION: requires assessment of fuels & fuel moisture for crown fire potential, adjustment of wind forecasts to Effective Windspeed (EWS), & estimation of the change in Rate of Spread, or ***ROS-Ratio.*** All single resource bosses should be able to take a forecast, evaluate the effects of terrain and time on their expected winds, combine that with fuels, slope, & spread direction, and estimate the expected change in fire behavior. Concepts and Skills taught in S290 (Intermediate Wildland Fire Behavior)
- COMPLETE APPLICATION: requires good observation/estimate of fire spread rates, and application of expected changes to estimate new spread rates, times, and/or distances. Strike Team Leaders need to insure that escape routes are planned effectively and can use this tool to evaluate plans put in place.

5.3.4 Effective Windspeed (EWS) Ratio & Rate of Spread (ROS) Ratio Tables

Table 1. Effective Windspeed (EWS)-Ratio Compare the EWS for current and expected conditions. The resulting EWS-Ratio is the bigger EWS divided by the smaller EWS.

SMALLER EFFECTIVE WINDSPEED →

BIGGER EFFECTIVE WINDSPEED ↑

	back	flank	2	3	4	5	6	7	8	10	12	14	16	20	24	30
40	80	40	20	13	10	8	7	6	5	4	3	3	3	2	2	1
36	72	36	18	12	9	7	6	5	5	4	3	3	2	2	1.5	1
32	64	32	16	11	8	6	5	5	4	3	3	2	2	1.5	1.5	
28	56	28	14	9	7	6	5	4	4	3	2	2	2	1.5		
24	48	24	12	8	6	5	4	3	3	2	2	2	1.5			
20	40	20	10	7	5	4	3	3	3	2	2	1.5				
16	32	16	8	5	4	3	3	2	2	2	1					
14	28	14	7	5	4	3	2	2	2	1.5						
12	24	12	6	4	3	2.5	2	2	1.5							
10	20	10	5	3	2.5	2	1.5	1.5								
8	16	8	4	3	2	1.5	1									
6	12	6	3	2	1.5	1										
5	10	5	2.5	2	1											
4	8	4	2	1												
3	6	3	1.5													
2	4	2														
flank	2															

Special Cases for ROS-Ratio (below)

- ROS in slash is about 1.5x ROS in litter.
- If your fuel is compact short needle litter, double the ROS-Ratio
- For mixed conditions (fuel types and/or wind adjustments), estimate both combinations. Consider both average and maximum results.

EWS-Ratio

Because wind is the biggest single factor in assessing potential fire behavior, evaluating the change in wind speed over time and across the landscape is a critical skill.

Table 1 is not a required lookup. The EWS-Ratio can be estimated by simply comparing the current and future windspeeds.

ROS-Ratio

More experienced users with only this ROS-Ratio table, based on expected changes in effective windspeed, can quickly identify whether the expected change in fire spread will threaten fireline safety.

In most cases, where wind and fuel changes work together, the left portion of the table applies. Only if the factors oppose each other, such as with slope reversals from downslope in grass to litter upslope, would the right columns apply.

Table 2. Rate Of Spread (ROS)-Ratio Table (Compare current & expected EWS & Fuel)

EWS-ratio	no fuel change	Bigger EWS in Faster Fuel litter to crown	 litter to grass	 Crown to grass
1	1	4	14	4
2	2	10	30	8
3	4	15	**60**	13
4	5	20	**80**	20
5	7	30	**100**	27
6	9	35	**130**	35
8	12	**50**	**180**	**Unrealistic Conditions**
10	16	**60**	**240**	
12	20	**80**	**300**	
16	30	**100**	**440**	
20	40	**140**	**600**	
24	**50**	**180**	**700**	
30	**60**	**220**	**1000**	
40	**80**	**300**	**1300**	
50	**110**	**400**	**1800**	
60	**140**	**500**	**2200**	
80	**200**	**700**	**3100**	

Use right side ⇒ of table only if the grass situation calls for lower winds, such as fire backing in grass becoming headfire in litter or crown. ***Bold Italics here mean faster ROS in grass***

Crown Fire?
Pocket card Briefing?
Recent Crown fire?
Critically low RH?
Torching w/backing or flanking fire?
Fire climbing up ladder fuels?

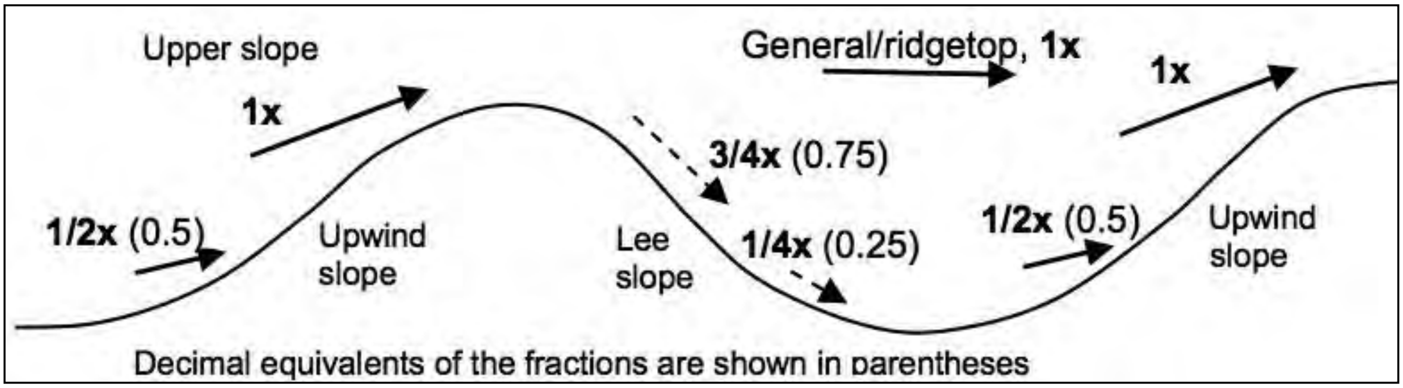
ROS-ratios of 60x & greater (shaded combinations here) have been associated with fire fatalities.

Lower EWS in Grass Crown to grass	 Litter to grass	EWS-ratio
4	***14***	1
2	***5***	2
1	***3***	3
1.5	***3***	4
2	***2***	5
3	***2***	6
4	1	8
5	1	10
6	1.5	12
8	2	16
10	3	20
13	3	24
17	4	30
25	6	40
30	8	50
40	10	60
60	16	80

5.3.5 Wind Adjustment (Table 3 can be used to aid adjustments from Fig A & Fig B below)

Table 3.	**Reference Windspeed from current location or forecast**														
Adjustment ⇓	**2**	**4**	**6**	**8**	**10**	**12**	**16**	**20**	**24**	**28**	**32**	**36**	**40**	**50**	**60**
1⇒½ or ½⇒¼	1	2	3	4	5	6	8	10	12	14	16	18	20	25	30
½ ⇒1 or ¼⇒½	4	8	12	16	20	24	32	40	48	56	64				
1 ⇒ ¾	2	3	4	6	8	9	12	15	18	21	24	27	30	38	45
¾ ⇒ 1	3	5	8	11	13	16	21	27	32	37	43	48	53	67	80
¾ ⇒ ¼	1	2	2	3	3	4	5	7	8	9	11	12	13	17	20
¼ ⇒ ¾	6	12	18	24	30	36	48	60							
1 ⇒ ¼	<1	1	2	2	3	3	4	5	6	7	8	9	10	12	15
¼ ⇒ 1	8	16	24	32	40	48									
½ ⇒ ¾	3	6	9	12	15	18	24	30							
¾ ⇒ ½	1	3	4	5	7	8	12	14	16						

Fig A Terrain Influence (Wind adjustment as it blows across hills (100s of feet of relief or less)
-Use this adjustment only if your measurement or forecast location is different than the fire location.
-Not for dense air/terrain flows (Night downslope, thunderstorm outflows, sea breeze & foehn winds)
-On windward side, wind speed is typically greater on upper slopes than on lower ones.
-On lee side, expect turbulence & variability. Use dashed adjustments only on hills w/ slopes <30%



Decimal equivalents of the fractions are shown in parentheses

Fig B: Tree Sheltering and Flame Height Adjustment.

Use only if your measurement or forecast location is different than the fire location.

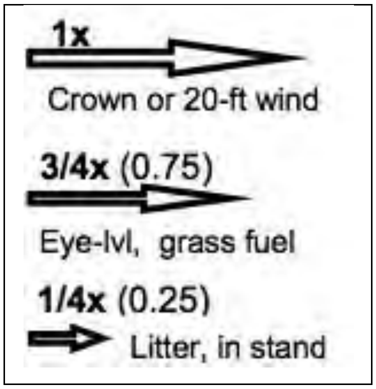
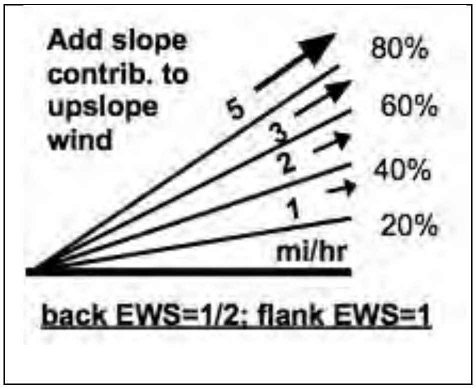


Fig C: Slope equivalent Effective Windspeed.

Use only if your measurement or forecast location is different than the fire location.



5.4 Surface Fire Behavior Lookup Tables, Nomographs, & Nomograms

5.4.1 Surface Fire Behavior Worksheet (with Size & Shape)

Incident/Project: **Observer/Analyst:** **Date:**

Time and Place					**Notes**
1	Projection Point Identifier				
2	Projection Month/Day				
3	Projection Hour of the Day				
4	Burn Period/Duration, hr or min				
Section 2. Fuel/Terrain					
5	**Surface Fuel Model**				
6	Canopy Cover, %				
7	Aspect (N, E ,S ,W)				
8	**Slope, %**				
Section 3. Dead Fuel Moisture – add 1-2 % each for 10-hr and 100-hr					
9	Cloud Cover, %				
10	Dry Bulb Temperature, °F				
11	Wet Bulb Temperature, °F				
12	Relative Humidity, %				
13	Reference Fuel Moisture, %				
14	(S)haded or (U)nshaded				
15	Elevation Difference (B, L, A)				
16	Fuel Moisture Correction, %				
17	**1-hr Moisture Content (L13 + L15)**				
Section 3. Live Fuel Moisture					
18	**Herbaceous Moisture Content, %**				
19	**Woody Moisture Content, %**				
Section 1. Windspeed and Wind Direction					
20	Wind Direction				
21	Surface (20ft) Windspeed, mph				
22	(S)heltered or (U)nsheltered				
23	Wind Adjustment Factor				
24	Midflame Windspeed, mph				
25	**Effective Windspeed, mph**				
Section 5. Fire Behavior					
26	**Probability of Ignition**				
27	Spread Direction				(H)ead, (B)ack, (F)lank
28	Direction of Max Spread				
29	Head Fire Rate of Spread (HFROS)				Chains (66ft)/hour
30	Head Fire Flame Length (HFFL)				Feet
31	Fraction of HFROS				
32	Fraction of HFFL				
33	**ROS in Spread Direction**				Chains (66ft)/hour
34	**FL in Spread Direction**				Feet
Section 6. Fire Size and Shape					**Notes**
35	Spread Distance, chains (66ft)				
36	**Fire Size, acres**				
37	**Fire Perimeter, chains (66ft)**				

5.4.2 Effective Windspeed (EWS)

Fuel Models 1, 2, 9; Effective Windspeed (EWS), in mph

MFWS	Slope Steepness									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
0	1	1	2	3	3	4	5	5	6	7
2	2	2	3	3	4	4	5	6	6	7
4	4	4	5	5	5	6	6	7	7	8
6	6	6	6	7	7	7	8	8	9	9
8	8	8	8	8	9	9	9	9	10	11
10	10	10	10	10	11	11	11	12	12	13
12	12	12	12	12	13	13	13	14	14	14
14	14	14	14	14	15	15	15	15	16	16
16	16	16	16	16	16	17	17	17	18	18
18	18	18	18	18	18	19	19	19	19	20
20	20	20	20	20	20	21	21	21	21	22

Fuel models 3, 4, 5, 6, 7, 8, 10; Effective Windspeed (EWS), in mph

MFWS	Slope Steepness									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
0	0	1	1	2	3	3	4	5	6	7
2	2	2	3	3	4	5	5	6	7	8
4	4	4	5	5	5	6	7	8	8	9
6	6	6	7	7	7	8	9	9	10	11
8	8	8	8	9	9	10	10	11	12	12
10	10	10	10	11	11	11	12	13	13	14
12	12	12	12	13	13	13	14	15	15	16
14	14	14	14	15	15	15	16	16	17	18
16	16	16	16	17	17	17	18	18	19	20
18	18	18	18	19	19	19	20	20	21	21
20	20	20	20	21	21	21	21	22	23	23

Fuel models 11, 12, 13; Effective Windspeed (EWS), in mph

MFWS	Slope Steepness									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
0	0	1	1	2	3	4	5	6	7	9
2	2	2	3	3	4	5	6	7	9	10
4	4	4	5	5	6	7	8	9	10	12
6	6	6	7	7	8	9	10	11	12	14
8	8	8	9	9	10	11	12	13	14	15
10	10	10	11	11	12	13	14	15	16	17
12	12	12	13	13	14	15	16	17	18	19
14	14	14	15	15	16	17	18	19	20	21
16	16	16	17	17	18	19	19	21	22	23
18	18	18	19	19	20	20	21	22	24	25
20	20	20	21	21	22	22	23	24	25	26

5.4.3 Surface Fire Behavior Lookup Tables for Original 13 Fuel Models

5.4.3.1 FUEL MODEL 1

SPREAD Ch/hr		**Effective Windspeed(EWS), mph** *Use 20ft/FCST wind only if EWS = MFWS and assumes unsheltered wind adjustment (0.4)												
*20ft/FCST		NWNS-0	Back - ½	Flank - 1	5	10	15	20	25	30	35	40	45	50
EWS					**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**
1-hr Moisture, %	**1**	**8**	**9**	**14**	**32**	**111**	**247**	**442**	**697**	**1014**	**1145**	**1145**	**1145**	**1145**
	2	**6**	**7**	**11**	**26**	**90**	**201**	**360**	**568**	**666**	**666**	**666**	**666**	**666**
	3	**5**	**6**	**9**	**22**	**77**	**172**	**307**	**446**	**446**	**446**	**446**	**446**	**446**
	4	**5**	**6**	**8**	**20**	**69**	**154**	**275**	**345**	**345**	**345**	**345**	**345**	**345**
	5	**4**	**5**	**8**	**19**	**64**	**143**	**255**	**297**	**297**	**297**	**297**	**297**	**297**
	6	**4**	**5**	**7**	**18**	**61**	**135**	**242**	**270**	**270**	**270**	**270**	**270**	**270**
	7	**4**	**5**	**7**	**17**	**57**	**127**	**228**	**242**	**242**	**242**	**242**	**242**	**242**
	8	**4**	**4**	**6**	**15**	**52**	**117**	**199**	**199**	**199**	**199**	**199**	**199**	**199**
	9	**3**	**4**	**6**	**13**	**45**	**101**	**136**	**136**	**136**	**136**	**136**	**136**	**136**
	10	**2**	**3**	**4**	**10**	**35**	**65**	**65**	**65**	**65**	**65**	**65**	**65**	**65**
	11	**1**	**2**	**2**	**6**	**13**	**13**	**13**	**13**	**13**	**13**	**13**	**13**	**13**
	12	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

FLAME Feet		**Effective Windspeed(EWS), mph** *Use 20ft/FCST wind only if EWS = MFWS and assumes unsheltered wind adjustment (0.4)												
*20ft/FCST		NWNS-0	Back - ½	Flank - 1	5	10	15	20	25	30	35	40	45	50
EWS					**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**
1-hr Moisture, %	**1**	**2**	**2**	**2**	**3**	**6**	**9**	**11**	**14**	**17**	**18**	**18**	**18**	**18**
	2	**1**	**2**	**2**	**3**	**5**	**7**	**10**	**12**	**13**	**13**	**13**	**13**	**13**
	3	**1**	**1**	**2**	**3**	**4**	**6**	**8**	**10**	**10**	**10**	**10**	**10**	**10**
	4	**1**	**1**	**2**	**2**	**4**	**6**	**8**	**9**	**9**	**9**	**9**	**9**	**9**
	5	**1**	**1**	**2**	**2**	**4**	**6**	**7**	**8**	**8**	**8**	**8**	**8**	**8**
	6	**1**	**1**	**1**	**2**	**4**	**5**	**7**	**7**	**7**	**7**	**7**	**7**	**7**
	7	**1**	**1**	**1**	**2**	**4**	**5**	**7**	**7**	**7**	**7**	**7**	**7**	**7**
	8	**1**	**1**	**1**	**2**	**3**	**5**	**6**	**6**	**6**	**6**	**6**	**6**	**6**
	9	**1**	**1**	**1**	**2**	**3**	**4**	**5**	**5**	**5**	**5**	**5**	**5**	**5**
	10	**1**	**1**	**1**	**1**	**2**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**
	11	**0**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
	12	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

5.4.3.2 FUEL MODEL 2

SPREAD
Ch/hr

Effective Windspeed(EWS), mph
*Use 20ft/FCST wind only if EWS = MFWS and assumes unsheltered wind adjustment (0.4)

*FCST/20ft		NWNS-0	Back - ½	Flank - 1	7	13	20	27	33	40	47	53	60	67
EWS					**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**
1-hr Moisture, %; (Herbaceous moisture 120% - 80%)	**1**	3-4	4-5	6-7	12-14	36-41	71-82	118-136	176-202	245-281	324-371	412-473	511-586	619-710
	3	3	3-4	5	10-11	28-32	56-64	93-106	138-158	192-220	253-290	323-370	400-458	484-555
	5	2-3	3	4-5	8-10	24-27	48-55	79-91	118-135	164-188	217-248	277-316	343-392	415-475
	7	2	3	4	8-9	22-25	44-50	73-83	108-123	150-171	198-226	253-288	313-357	379-432
	9	2	2-3	3-4	7-8	20-23	40-46	66-76	99-113	138-157	182-207	232-264	287-327	348-396
	11	2	2	3	6-7	17-20	34-39	57-65	85-97	118-134	155-177	198-226	245-280	297-339
	13	1	1-2	2	4-5	12-14	24-27	40-45	60-68	83-94	110-124	140-159	173-196	210-238
	15	0	0-1	0-1	0-2	0-4	0-9	0-13	0-13	0-13	0-13	0-13	0-13	0-13
	17	0	0	0	0	0	0	0	0	0	0	0	0	0

FLAME
Ch/hr

Effective Windspeed(EWS), mph
*Use 20ft/FCST wind only if EWS = MFWS and assumes unsheltered wind adjustment (0.4)

*20ft/FCST		NWNS-0	Back - ½	Flank - 1	7	13	20	27	33	40	47	53	60	67
EWS					**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**
1-hr Moisture, %; (Herbaceous moist. 120% - 80%)	**1**	2-3	3	3-3	5	7-8	10-11	13-14	15-16	18-19	20-22	23-24	25-27	27-29
	3	2	2	3-3	4	6	8-9	10-11	12-13	14-16	16-18	18-20	20-22	22-24
	5	2	2	2-3	3-4	5-6	7-8	9-10	11-12	13-14	15-16	16-18	18-19	20-21
	7	2	2	2	3	5	7	9	10-11	12-13	14-15	15-16	17-18	18-20
	9	2	2	2	3	5	6-7	8-9	10	11-12	13-14	14-16	16-17	17-19
	11	1	2	2	3	4	6	7-8	9	10-11	11-12	13-14	14-15	15-17
	13	1	1	1	2	3	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12
	15	0	<1	<1	0-1	0-1	0-2	0-2	0-2	0-2	0-2	0-2	0-2	0-2
	17	0	0	0	0	0	0	0	0	0	0	0	0	0

5.4.3.3 FUEL MODEL 3

SPREAD Ch/hr		**Effective Windspeed(EWS), mph** *Use 20ft/FCST wind only if EWS = MFWS and assumes unsheltered wind adjustment (0.4)											
*20ft/FCST		**NWNS/0**	**Back - ½**	**Flank - 1**	5	10	15	20	25	30	35	40	45	50
EWS					**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**
1-hr Moisture, %	**1**	8	18	32	68	157	261	377	502	636	776	923	1076	1234
	3	6	14	25	52	121	201	290	387	490	598	712	829	951
	5	5	11	20	42	97	162	234	312	395	482	574	669	767
	7	4	9	17	36	82	137	198	264	335	409	486	566	650
	9	4	8	15	32	73	122	176	234	296	362	430	501	575
	11	3	8	14	29	67	111	161	214	271	331	393	458	526
	13	3	7	13	27	62	103	149	198	251	306	364	425	487
	15	3	6	12	25	57	95	137	182	231	282	335	391	448
	17	3	6	10	22	51	85	122	163	207	252	300	350	401
	19	2	5	9	19	43	71	103	137	174	212	253	294	338
	21	2	4	7	14	32	53	77	103	130	159	189	194	194
	23	1	2	4	8	18	30	43	54	54	54	54	54	54

FLAME feet		**Effective Windspeed(EWS), mph** *Use 20ft/FCST wind only if EWS = MFWS and assumes unsheltered wind adjustment (0.4)											
*20ft/FCST		**NWNS/0**	**Back - ½**	**Flank - 1**	5	10	15	20	25	30	35	40	45	50
EWS					**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**
1-hr Moisture, %	**1**	5	7	9	12	18	23	27	31	35	38	41	44	47
	3	4	5	7	10	15	19	22	25	28	31	34	36	38
	5	3	5	6	9	13	16	19	22	24	26	28	31	33
	7	3	4	5	8	11	14	17	19	21	23	25	27	29
	9	3	4	5	7	10	13	15	18	20	21	23	25	27
	11	2	4	5	7	10	12	15	17	19	20	22	24	25
	13	2	3	5	6	9	12	14	16	18	19	21	23	24
	15	2	3	4	6	9	11	13	15	17	19	20	22	23
	17	2	3	4	6	8	10	12	14	16	17	19	20	21
	19	2	3	4	5	7	9	11	12	14	15	16	17	19
	21	1	2	3	4	6	7	8	10	11	12	13	13	13
	23	1	1	2	2	3	4	5	6	6	6	6	6	6

5.4.3.4 FUEL MODEL 4

SPREAD Ch/hr		Effective Windspeed(EWS), mph *Use 20ft/FCST wind only if EWS = MFWS and assumes unsheltered wind adjustment (0.5)												
*20ft/FCST		NWNS-0	Back - ½	Flank - 1	4	8	12	16	20	24	28	32	36	40
EWS					2	4	6	8	10	12	14	16	18	20
1-hr Moisture, %; (Woody moisture 120% - 80%)	1	5-6	8-11	13-18	27-37	65-88	111-151	165-224	225-306	290-394	359-489	433-589	511-695	593-807
	3	4-6	7-9	11-16	24-32	56-76	97-132	144-195	196-266	253-343	313-425	378-513	446-605	517-702
	5	4-5	6-8	10-14	21-29	51-69	88-118	130-176	178-239	229-309	284-383	343-462	404-545	469-632
	7	4-5	6-8	10-13	20-27	48-64	83-110	122-163	167-222	215-286	267-355	322-429	380-506	440-587
	9	3-4	6-7	9-12	19-25	46-61	79-104	118-155	160-211	206-271	256-337	309-406	365-479	423-556
	11	3-4	5-7	9-12	19-24	44-58	76-100	113-148	154-201	199-259	247-322	298-388	351-458	408-531
	13	3-4	5-7	8-11	17-23	41-55	71-95	105-140	143-191	184-246	229-306	276-369	325-435	377-504
	15	2-4	4-6	6-10	13-21	30-50	52-87	77-129	105-175	135-226	167-281	202-338	238-399	276-463
	17	1-3	2-5	3-8	6-16	14-38	25-65	37-96	50-130	65-168	80-209	97-252	114-297	133-344
	19	1	1	2	3-4	8-10	14-17	20-25	27-34	35-44	44-55	53-66	62-78	72-90

FLAME feet		Effective Windspeed(EWS), mph *Use 20ft/FCST wind only if EWS = MFWS and assumes unsheltered wind adjustment (0.5)												
20ft/FCST		NWNS-0	Back - ½	Flank - 1	4	8	12	16	20	24	28	32	36	40
EWS					2	4	6	8	10	12	14	16	18	20
1-hr Moisture, %; (Woody moisture 120% - 80%)	1	6-7	8-9	10-11	13-16	20-24	26-30	31-36	36-42	40-47	44-52	48-57	52-61	56-66
	3	5-6	7-8	9-10	12-14	18-21	23-27	27-32	32-37	36-42	39-46	43-50	46-54	49-58
	5	5-6	6-7	8-9	11-13	16-19	21-25	25-30	29-34	33-38	36-42	39-46	43-50	46-53
	7	5	6-7	8-9	10-12	16-18	20-23	24-28	28-32	31-36	34-40	37-43	40-47	43-50
	9	5	6-7	7-8	10-12	15-17	19-22	23-27	27-31	30-35	33-38	36-42	39-45	42-48
	11	4-5	6-6	7-8	10-11	15-17	19-22	23-26	26-30	29-34	32-37	35-40	38-44	41-47
	13	4-5	5-6	7-8	9-11	14-16	18-21	21-25	24-29	28-32	30-36	33-39	36-42	38-45
	15	3-5	4-6	5-7	7-10	10-15	13-19	16-23	18-27	21-30	23-33	25-36	27-39	29-42
	17	2-3	2-3	3-6	4-8	5-12	7-15	8-18	9-21	11-23	12-25	13-28	14-30	15-32
	19	1	1	2	2	3	4	5	5-6	6-7	7	7-8	8-9	9

5.4.3.5 FUEL MODEL 5

SPREAD Ch/hr		**Effective Windspeed(EWS), mph** *Use 20ft/FCST wind only if EWS = MFWS and assumes unsheltered wind adjustment (0.4)												
*20ft/FCST		**NWNS-0**	**Back - ½**	**Flank - 1**	5	10	15	20	25	30	35	40	45	50
EWS					**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**
1-hr Moisture, %; (Woody moisture 120% - 80%)	**1**	1–2	2-3	4-6	8-12	20-28	34-48	50-70	67-95	86-122	107-151	128-181	151-214	175-247
	3	1-2	2-3	3-5	7-11	17-25	28-43	42-63	57-86	73-110	90-136	109-164	128-193	148-223
	5	1	2-3	3-5	5-10	13-23	22-40	32-59	44-79	56-102	70-126	84-152	98-178	114-206
	7	<1	1-2	1-4	3-9	6-22	10-37	15-54	20-74	22-95	22-117	22-141	22-165	22-191
	9	<1	1-2	1-4	2-8	6-18	10-32	14-47	19-63	20-81	20-100	20-120	20-142	20-164
	11	<1	1	1-2	2-4	5-9	9-16	14-23	19-32	19-41	19-46	19-46	19-46	19-46
	13	<1	1	1	2-3	5-7	9-12	13-17	17-22	17-22	17-22	17-22	17-22	17-22
	15	<1	<1	1	2-3	5-6	8-10	11-15	12-16	12-16	12-16	12-16	12-16	12-16
	17	<1	<1	<1	1-2	3-5	6-8	7-9	7-9	7-9	7-9	7-9	7-9	7-9
	19	<1	<1	<1	1	1-2	1-2	1-2	1-2	1-2	1-2	1-2	1-2	1-2

FLAME feet		**Effective Windspeed(EWS), mph** *Use 20ft/FCST wind only if EWS = MFWS and assumes unsheltered wind adjustment (0.4)												
*20ft/FCST		**NWNS-0**	**Back - ½**	**Flank - 1**	5	10	15	20	25	30	35	40	45	50
EWS					**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**
1-hr Moisture, %; (Woody moisture 120% - 80%)	**1**	2	2-3	3	4-5	6-7	8-9	9-11	11-13	12-14	13-16	14-17	15-19	17-20
	3	1-2	2	3	4	5-7	7-9	8-10	9-12	10-13	11-14	12-16	13-17	14-18
	5	1-2	2	2-3	3-4	4-6	5-8	6-10	7-11	8-12	9-14	10-15	10-16	11-17
	7	1-2	1-2	1-3	1-4	2-6	3-7	3-9	4-10	4-12	4-13	4-14	4-15	4-16
	9	1	1-2	1-2	1-3	2-5	3-7	3-8	3-9	3-10	3-11	3-12	3-13	3-14
	11	1	1	1	1-2	2-3	2-4	3-4	3-5	3-5	3-6	3-6	3-6	3-6
	13	1	1	1	1	2	2-3	3	3-4	3-4	3-4	3-4	3-4	3-4
	15	0-1	1	1	1	2	2	2-3	3	3	3	3	3	3
	17	<1	0-1	0-1	1	1	2	2	2	2	2	2	2	2
	19	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1

5.4.3.6 FUEL MODEL 6

SPREAD **Ch/hr**		**Effective Windspeed(EWS), mph** *Use 20ft/FCST wind only if EWS = MFWS and assumes unsheltered wind adjustment (0.4)												
*20ft/FCST		NWNS/0	Back - ½	Flank - 1	5	10	15	20	25	30	35	40	45	50
EWS					2	4	6	8	10	12	14	16	18	20
1-hr Moisture, %	1	3	5	9	19	42	71	103	138	175	215	257	300	345
	3	2	4	7	15	34	56	82	110	139	171	204	239	274
	5	2	4	6	12	28	47	68	91	115	141	168	197	226
	7	2	3	5	10	24	40	58	78	99	121	145	169	181
	9	1	3	5	9	21	36	52	69	88	108	129	150	150
	11	1	2	4	8	19	33	47	63	81	99	118	132	132
	13	1	2	4	8	18	30	44	59	75	92	109	120	120
	15	1	2	4	7	17	28	41	55	70	85	102	109	109
	17	1	2	3	7	15	26	38	50	64	78	93	96	96
	19	1	2	3	6	14	23	33	45	57	70	78	78	78
	21	1	1	3	5	12	19	28	38	48	55	55	55	55
	23	1	1	2	4	9	15	21	29	31	31	31	31	31
	25	<1	1	1	2	5	9	10	10	10	10	10	10	10

FLAME **feet**		**Effective Windspeed(EWS), mph** *Use 20ft/FCST wind only if EWS = MFWS and assumes unsheltered wind adjustment (0.4)												
*20ft/FCST		NWNS/0	Back - ½	Flank - 1	5	10	15	20	25	30	35	40	45	50
EWS					2	4	6	8	10	12	14	16	18	20
1-hr Moisture, %	1	5	8	10	12	14	15	17	18	19	21	5	8	10
	3	5	7	8	10	11	13	14	15	16	17	5	7	8
	5	4	6	7	9	10	11	12	13	14	15	4	6	7
	7	4	5	7	8	9	10	11	12	13	13	4	5	7
	9	3	5	6	7	8	9	10	11	12	12	3	5	6
	11	3	5	6	7	8	9	10	10	11	11	3	5	6
	13	3	4	6	7	7	8	9	10	10	10	3	4	6
	15	3	4	5	6	7	8	9	10	10	10	3	4	5
	17	3	4	5	6	7	8	8	9	9	9	3	4	5
	19	3	4	5	5	6	7	8	8	8	8	3	4	5
	21	2	3	4	5	5	6	6	6	6	6	2	3	4
	23	2	3	3	4	4	4	4	4	4	4	2	3	3
	25	1	2	2	2	2	2	2	2	2	2	1	2	2

5.4.3.7 FUEL MODEL 7

SPREAD Ch/hr		**Effective Windspeed(EWS), mph** *Use 20ft/FCST wind only if EWS = MFWS and assumes unsheltered wind adjustment (0.4)												
*20ft/FCST		NWNS-0	Back - ½	Flank - 1	5	10	15	20	25	30	35	40	45	50
EWS					**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**
1-hr Moisture, %; (Woody moisture 120% - 80%)	**3**	1-2	3	5-6	10-12	23-28	38-47	56-68	74-91	94-115	116-141	138-168	161-197	185-226
	6	1	2-3	4-5	9-10	20-24	33-40	48-58	64-78	81-99	100-121	119-144	139-169	160-194
	9	1	2-3	4-5	8-9	17-21	29-35	42-51	57-68	72-87	88-106	105-127	123-148	141-170
	12	1	2	3-4	7-8	16-19	26-32	38-46	51-62	65-78	80-96	95-114	112-134	119-147
	15	1	2	3-4	6-8	15-17	25-29	36-42	48-57	60-72	74-88	88-105	103-123	105-129
	18	1	2	3	6-7	14-16	23-27	33-40	45-53	57-68	70-83	83-99	96-115	96-117
	21	1	2	3	6-7	13-15	22-26	32-37	42-50	54-64	66-78	79-93	89-108	89-108
	24	1	2	3	5-6	12-15	21-24	30-35	40-47	51-60	63-74	75-88	82-100	82-100
	27	1	1-2	2-3	5-6	12-14	19-23	28-33	38-44	48-56	59-69	70-83	74-91	74-91

FLAME feet		**Effective Windspeed(EWS), mph** *Use 20ft/FCST wind only if EWS = MFWS and assumes unsheltered wind adjustment (0.4)												
*20ft/FCST		NWNS-0	Back - ½	Flank - 1	5	10	15	20	25	30	35	40	45	50
EWS					**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**
1-hr Moisture, %; (Woody moisture 120% - 80%)	**3**	2-2	2	3	4-4	6-6	7-8	8-9	10-11	11-12	12-13	13-14	14-15	15-16
	6	1-2	2	2-3	3-4	5-6	6-7	8-8	9-10	10-11	11-12	11-13	12-14	13-14
	9	1-1	2	2-3	3-3	5-5	6-6	7-8	8-9	9-10	10-11	10-12	11-12	12-13
	12	1-1	2	2	3-3	4-5	5-6	6-7	7-8	8-9	9-10	10-11	10-11	11-12
	15	1-1	2	2	3-3	4-4	5-6	6-7	7-8	8-9	9-9	9-10	10-11	10-11
	18	1-1	2	2	3-3	4-4	5-5	6-6	7-7	7-8	8-9	9-10	9-10	9-11
	21	1-1	1-2	2	3-3	4-4	5-5	6-6	6-7	7-8	8-9	9-9	9-10	9-10
	24	1-1	1-2	2	2-3	4-4	5-5	5-6	6-7	7-8	8-8	8-9	9-10	9-10
	27	1-1	1	2	2-3	3-4	4-5	5-6	6-7	7-7	7-8	8-9	8-9	8-9

5.4.3.8 FUEL MODEL 8

SPREAD Ch/hr		**Effective Windspeed(EWS), mph** *Use 20ft/FCST wind only if EWS = MFWS and assumes sheltered wind adjustment (0.2)												
*20ft/FCST		NWNS/0	Back - ½	Flank - 1	10	20	30	40	50	60	70	80	90	100
EWS					**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**
1-hr Moisture, %	**1**	0	1	1	1	3	4	6	9	11	13	13	13	13
	3	0	<1	1	1	2	3	5	7	8	8	8	8	8
	5	0	<1	<1	1	2	3	4	6	6	6	6	6	6
	7	0	<1	<1	1	1	2	4	4	4	4	4	4	4
	9	0	0	<1	1	1	2	3	3	3	3	3	3	3
	11	0	0	<1	1	1	2	3	3	3	3	3	3	3
	13	0	0	<1	0	1	2	3	3	3	3	3	3	3
	15	0	0	<1	0	1	2	2	2	2	2	2	2	2
	17	0	0	0	0	1	2	2	2	2	2	2	2	2
	19	0	0	0	0	1	1	2	2	2	2	2	2	2
	21	0	0	0	0	1	1	2	2	2	2	2	2	2
	23	0	0	0	0	1	1	1	1	1	1	1	1	1

FLAME feet		**Effective Windspeed(EWS), mph** *Use 20ft/FCST wind only if EWS = MFWS and assumes sheltered wind adjustment (0.2)												
*20ft/FCST		NWNS/0	Back - ½	Flank - 1	10	20	30	40	50	60	70	80	90	100
EWS					**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**
1-hr Moisture, %	**1**	1	1	1	1	1	2	2	2	3	3	3	3	3
	3	1	1	1	1	1	2	2	2	2	2	2	2	2
	5	0	1	1	1	1	1	2	2	2	2	2	2	2
	7	0	<1	1	1	1	1	1	2	2	2	2	2	2
	9	0	<1	1	1	1	1	1	1	1	1	1	1	1
	11	0	<1	<1	1	1	1	1	1	1	1	1	1	1
	13	0	<1	<1	1	1	1	1	1	1	1	1	1	1
	15	0	<1	<1	1	1	1	1	1	1	1	1	1	1
	17	0	<1	<1	0	1	1	1	1	1	1	1	1	1
	19	0	<1	<1	0	1	1	1	1	1	1	1	1	1
	21	0	<1	<1	0	1	1	1	1	1	1	1	1	1
	23	0	<1	<1	0	1	1	1	1	1	1	1	1	1

5.4.3.9 FUEL MODEL 9

SPREAD **Ch/hr**		**Effective Windspeed(EWS), mph** *Use 20ft/FCST wind only if EWS = MFWS and assumes prtly shelterd wind adjustment (0.3)												
***FCST/20ft**		**NWNS-0**	**Back - ½**	**Flank - 1**	7	13	20	27	33	40	47	53	60	67
EWS					**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**
1-hr Moisture, %	**1**	**1**	**2**	**2**	**4**	**11**	**20**	**33**	**47**	**64**	**83**	**104**	**127**	**152**
	3	**1**	**1**	**2**	**3**	**8**	**16**	**25**	**36**	**49**	**64**	**80**	**98**	**118**
	5	**1**	**1**	**2**	**3**	**7**	**13**	**20**	**29**	**40**	**52**	**65**	**79**	**95**
	7	**1**	**1**	**1**	**2**	**6**	**11**	**17**	**25**	**34**	**44**	**55**	**67**	**80**
	9	**1**	**1**	**1**	**2**	**5**	**10**	**15**	**22**	**30**	**39**	**49**	**60**	**71**
	11	**1**	**1**	**1**	**2**	**5**	**9**	**14**	**20**	**27**	**36**	**45**	**54**	**65**
	13	**1**	**1**	**1**	**2**	**4**	**8**	**13**	**19**	**25**	**33**	**41**	**50**	**60**
	15	**1**	**1**	**1**	**2**	**4**	**7**	**12**	**17**	**23**	**30**	**38**	**46**	**56**
	17	**0**	**1**	**1**	**1**	**4**	**7**	**11**	**15**	**21**	**27**	**34**	**42**	**48**
	19	**0**	**1**	**1**	**1**	**3**	**6**	**9**	**13**	**18**	**23**	**29**	**33**	**33**
	21	**0**	**<1**	**1**	**1**	**2**	**4**	**7**	**10**	**13**	**17**	**17**	**17**	**17**
	23	**0**	**<1**	**<1**	**1**	**1**	**2**	**4**	**4**	**4**	**4**	**4**	**4**	**4**

FLAME **feet**		**Effective Windspeed(EWS), mph** *Use 20ft/FCST wind only if EWS = MFWS and assumes prtly shelterd wind adjustment (0.3)												
***FCST/20ft**		**NWNS-0**	**Back - ½**	**Flank - 1**	7	13	20	27	33	40	47	53	60	67
EWS					**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**
1-hr Moisture, %	**1**	**2**	**2**	**2**	**3**	**4**	**5**	**6**	**8**	**9**	**10**	**11**	**12**	**13**
	3	**1**	**1**	**2**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
	5	**1**	**1**	**1**	**2**	**3**	**4**	**4**	**5**	**6**	**7**	**8**	**8**	**9**
	7	**1**	**1**	**1**	**2**	**2**	**3**	**4**	**5**	**5**	**6**	**7**	**7**	**8**
	9	**1**	**1**	**1**	**1**	**2**	**3**	**4**	**4**	**5**	**6**	**6**	**7**	**7**
	11	**1**	**1**	**1**	**1**	**2**	**3**	**3**	**4**	**5**	**5**	**6**	**6**	**7**
	13	**1**	**1**	**1**	**1**	**2**	**3**	**3**	**4**	**4**	**5**	**6**	**6**	**7**
	15	**1**	**1**	**1**	**1**	**2**	**3**	**3**	**4**	**4**	**5**	**5**	**6**	**6**
	17	**1**	**1**	**1**	**1**	**2**	**2**	**3**	**3**	**4**	**4**	**5**	**5**	**6**
	19	**1**	**1**	**1**	**1**	**2**	**2**	**3**	**3**	**3**	**4**	**4**	**5**	**5**
	21	**0**	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**3**	**3**	**3**	**3**	**3**
	23	**0**	**<1**	**<1**	**0**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**

5.4.3.10FUEL MODEL 10

SPREAD Ch/hr		Effective Windspeed(EWS), mph *Use 20ft/FCST wind only if EWS = MFWS and assumes prtly shelterd wind adjustment (0.3)												
*20ft/FCST		NWNS-0	Back - ½	Flank - 1	7	13	20	27	33	40	47	53	60	67
EWS					2	4	6	8	10	12	14	16	18	20
1-hr Moisture, %; (Woody moisture 120% - 80%)	1	1	1-2	2	3-4	8-10	13-17	19-25	25-33	33-43	41-53	49-64	58-76	67-88
	3	1	2	2	3-4	7-9	11-15	16-22	22-29	29-38	35-47	43-56	50-66	59-77
	5	1	1	1-2	3-3	6-8	10-13	15-19	20-26	26-34	32-42	38-50	45-59	52-69
	7	1	1	1-2	2-3	5-7	9-12	13-18	18-24	24-31	29-38	35-46	42-54	48-63
	9	1	1	1-2	2-3	5-7	9-11	13-16	17-22	22-29	27-36	33-43	39-51	45-59
	11	1	1	1-2	2-3	5-6	8-11	12-16	16-21	21-27	26-34	32-41	37-48	43-56
	13	1	1	1-2	2-3	5-6	8-10	12-15	16-20	20-26	25-32	30-39	36-46	41-53
	15	1	1	1	2-3	4-6	8-10	11-14	15-19	19-25	24-31	29-37	34-43	40-50
	17	1	1	1	2	4-5	7-9	11-13	14-18	18-23	23-29	28-34	33-41	38-47
	19	<1	1	1	2	4-5	7-8	10-12	13-16	17-21	21-26	25-32	30-37	35-43
	21	<1	1	1	1-2	3-4	5-7	8-11	11-14	14-19	17-23	21-28	25-33	29-38

FLAME feet		Effective Windspeed(EWS), mph *Use 20ft/FCST wind only if EWS = MFWS and assumes prtly shelterd wind adjustment (0.3)												
*20ft/FCST		NWNS-0	Back - ½	Flank - 1	7	13	20	27	33	40	47	53	60	67
EWS					2	4	6	8	10	12	14	16	18	20
1-hr Moisture, %; (Woody moisture 120% - 80%)	1	2	2-3	3	4	5-6	7-8	8-9	9-11	11-12	12-13	13-15	14-16	15-17
	3	2	2	3	3-4	5-6	6-7	7-8	8-10	9-11	10-12	11-13	12-14	13-15
	5	2	2	2-3	3-4	4-5	6	7-8	8-9	9-10	9-11	10-12	11-13	12-14
	7	2	2	2-3	3	4-5	5-6	6-7	7-8	8-9	9-10	10-11	10-12	11-13
	9	1-2	2	2	3	4	5-6	6-7	7-8	8-9	8-10	9-11	10-11	11-12
	11	1-2	2	2	3	4	5-6	6-7	7-8	7-8	8-9	9-10	10-11	10-12
	13	1-2	2	2	3	4	5	6	6-7	7-8	8-9	9-10	9-11	10-11
	15	1-2	2	2	2-3	4	5	5-6	6-7	7-8	8-9	8-10	9-10	10-11
	17	1	2	2	2-3	3-4	4-5	5-6	6-7	7-8	7-8	8-9	9-10	9-10
	19	1	1-2	2	2	3-4	4-5	5	6	6-7	7-8	8	8-9	9-10
	21	1	1	1-2	2	3	3-4	4-5	5-6	5-6	6-7	6-8	7-8	7-9

5.4.3.11FUEL MODEL 11

SPREAD **Ch/hr**		**Effective Windspeed(EWS), mph** ***Use 20ft/FCST wind only if EWS = MFWS and assumes unsheltered wind adjustment (0.4)**												
***20ft/FCST**		**NWNS/0**	**Back - ½**	**Flank - 1**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**
EWS					**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**
1-hr Moisture, %	**1**	**1**	**2**	**2**	**4**	**8**	**12**	**16**	**20**	**25**	**29**	**34**	**39**	**43**
	3	**1**	**1**	**2**	**3**	**6**	**9**	**13**	**16**	**20**	**23**	**27**	**31**	**35**
	5	**1**	**1**	**2**	**3**	**5**	**8**	**11**	**14**	**17**	**20**	**23**	**26**	**30**
	7	**1**	**1**	**1**	**2**	**5**	**7**	**10**	**12**	**15**	**18**	**21**	**24**	**27**
	9	**<1**	**1**	**1**	**2**	**4**	**7**	**9**	**11**	**14**	**17**	**19**	**22**	**25**
	11	**<1**	**1**	**1**	**2**	**4**	**6**	**8**	**10**	**12**	**15**	**17**	**19**	**22**
	13	**<1**	**1**	**1**	**2**	**3**	**5**	**6**	**8**	**10**	**12**	**14**	**16**	**16**
	15	**<1**	**<1**	**1**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**7**	**7**	**7**

FLAME **feet**		**Effective Windspeed(EWS), mph** ***Use 20ft/FCST wind only if EWS = MFWS and assumes unsheltered wind adjustment (0.4)**												
***20ft/FCST**		**NWNS/0**	**Back - ½**	**Flank - 1**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**
EWS					**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**
1-hr Moisture, %	**1**	**2**	**2**	**3**	**3**	**4**	**5**	**6**	**7**	**7**	**8**	**9**	**9**	**10**
	3	**1**	**2**	**2**	**3**	**4**	**4**	**5**	**6**	**6**	**7**	**7**	**8**	**8**
	5	**1**	**2**	**2**	**2**	**3**	**4**	**5**	**5**	**6**	**6**	**6**	**7**	**7**
	7	**1**	**1**	**2**	**2**	**3**	**4**	**4**	**5**	**5**	**6**	**6**	**6**	**7**
	9	**1**	**1**	**2**	**2**	**3**	**4**	**4**	**5**	**5**	**5**	**6**	**6**	**6**
	11	**1**	**1**	**2**	**2**	**3**	**3**	**4**	**4**	**5**	**5**	**5**	**6**	**6**
	13	**1**	**1**	**1**	**2**	**2**	**3**	**3**	**4**	**4**	**4**	**4**	**5**	**5**
	15	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**2**	**3**	**3**	**3**	**3**	**3**

5.4.3.12 FUEL MODEL 12

SPREAD **Ch/hr**		**Effective Windspeed(EWS), mph** *Use 20ft/FCST wind only if EWS = MFWS and assumes unsheltered wind adjustment (0.4)												
*20ft/FCST		**NWNS-0**	**Back - ½**	**Flank - 1**	5	10	15	20	25	30	35	40	45	50
EWS					**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**
1-hr Moisture, %	**1**	2	4	5	9	17	25	34	43	52	62	72	82	92
	3	2	3	4	7	14	20	28	35	43	50	58	66	75
	5	2	2	4	6	11	17	23	30	36	43	50	56	63
	7	1	2	3	5	10	15	21	26	32	38	44	50	56
	9	1	2	3	5	9	14	19	24	29	34	40	45	51
	11	1	2	3	5	9	13	17	22	27	32	37	42	47
	13	1	2	3	4	8	12	16	21	25	30	34	39	44
	15	1	2	2	4	7	11	15	19	23	27	31	36	40
	17	1	1	2	3	6	10	13	17	20	24	28	31	35
	19	1	1	2	3	5	8	11	14	16	19	23	26	29
	21	1	1	1	2	4	6	8	10	12	14	16	18	21
	23	<1	<1	1	1	2	3	4	5	6	7	8	9	9

FLAME **ft**		**Effective Windspeed(EWS), mph** *Use 20ft/FCST wind only if EWS = MFWS and assumes unsheltered wind adjustment (0.4)												
*20ft/FCST		**NWNS-0**	**Back - ½**	**Flank - 1**	5	10	15	20	25	30	35	40	45	50
EWS					**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**
1-hr Moisture, %	**1**	4	5	6	8	10	12	14	16	17	19	20	21	22
	3	3	4	5	7	9	11	12	14	15	16	17	18	19
	5	3	4	5	6	8	9	11	12	13	14	15	16	17
	7	3	4	4	5	7	9	10	11	12	13	14	15	16
	9	3	3	4	5	7	8	9	10	11	12	13	14	15
	11	3	3	4	5	6	8	9	10	11	12	13	13	14
	13	2	3	4	5	6	7	9	10	10	11	12	13	14
	15	2	3	3	4	6	7	8	9	10	11	11	12	13
	17	2	3	3	4	5	6	7	8	9	10	10	11	12
	19	2	2	3	3	5	5	6	7	8	8	9	9	10
	21	1	2	2	3	3	4	5	5	6	6	7	7	7
	23	1	1	1	1	2	2	2	3	3	3	3	4	4

5.4.3.13 FUEL MODEL 13

SPREAD Ch/hr		Effective Windspeed(EWS), mph *Use 20ft/FCST wind only if EWS = MFWS and assumes unsheltered wind adjustment (0.5)												
*20ft/FCST		NWNS-0	Back - ½	Flank - 1	4	8	12	16	20	24	28	32	36	40
EWS					2	4	6	8	10	12	14	16	18	20
1-hr Moisture, %	1	3	5	6	11	20	30	41	52	63	75	86	98	111
	3	2	4	5	9	16	25	34	43	52	61	71	81	91
	5	2	3	5	7	14	21	28	36	44	52	60	69	77
	7	2	3	4	6	12	18	25	31	38	45	52	60	67
	9	2	2	4	6	11	16	22	28	34	41	47	54	60
	11	1	2	3	5	10	15	20	26	32	37	43	49	55
	13	1	2	3	5	9	14	19	24	29	35	40	46	51
	15	1	2	3	5	9	13	18	23	27	33	38	43	48
	17	1	2	3	4	8	12	17	21	26	30	35	40	45
	19	1	2	2	4	8	11	15	19	24	28	32	37	42
	21	1	2	2	4	7	10	14	18	21	25	29	33	37
	23	1	1	2	3	6	9	12	15	18	22	25	29	32
	25	1	1	2	3	5	7	10	12	15	18	21	23	26
	27	1	1	1	2	3	5	7	9	11	13	15	17	19
	29	<1	<1	<1	1	2	3	4	5	6	7	8	9	10

FLAME feet		Effective Windspeed(EWS), mph *Use 20ft/FCST wind only if EWS = MFWS and assumes unsheltered wind adjustment (0.5)												
*20ft/FCST		NWNS-0	Back - ½	Flank - 1	4	8	12	16	20	24	28	32	36	40
EWS					2	4	6	8	10	12	14	16	18	20
1-hr Moisture, %	1	5	7	8	10	13	16	18	20	22	24	26	27	29
	3	5	6	7	9	11	14	16	18	19	21	22	24	25
	5	4	5	6	8	10	12	14	16	17	19	20	21	22
	7	4	5	5	7	9	11	13	14	16	17	18	19	20
	9	4	4	5	6	9	10	12	13	15	16	17	18	19
	11	3	4	5	6	8	10	11	13	14	15	16	17	18
	13	3	4	5	6	8	9	11	12	13	14	15	16	17
	15	3	4	5	6	8	9	10	12	13	14	15	16	17
	17	3	4	4	5	7	9	10	11	12	13	14	15	16
	19	3	3	4	5	7	8	10	11	12	13	13	14	15
	21	3	3	4	5	6	8	9	10	11	12	13	13	14
	23	2	3	3	4	6	7	8	9	10	10	11	12	13
	25	2	2	3	4	5	6	7	7	8	9	9	10	11
	27	2	2	2	3	4	4	5	6	6	7	7	8	8
	29	1	1	1	2	2	2	3	3	3	4	4	4	4

5.4.4 Surface Fire Behavior Nomographs & Nomograms For 13 Standard Fuel Models;

5.4.4.1 Primary References

Scott, Joe H. 2007. Nomographs for estimating surface fire behavior characteristics. Gen. Tech. Rep. RMRS-GTR-192. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 119 p... http://www.fs.fed.us/rm/pubs/rmrs_gtr192.pdf

Rothermel, Richard C. 1992. Fire behavior nomograms. Appendix A excerpted from How to Predict the Spread and Intensity of Forest and Range Fuels. PMS 436-3, NFES 2220. Boise, ID: National Wildfire Coordinating Group. 28 p.
http://www.nwccweb.us/content/products/fwx/publications/Fire%20Behavior%20Nomograms.pdf

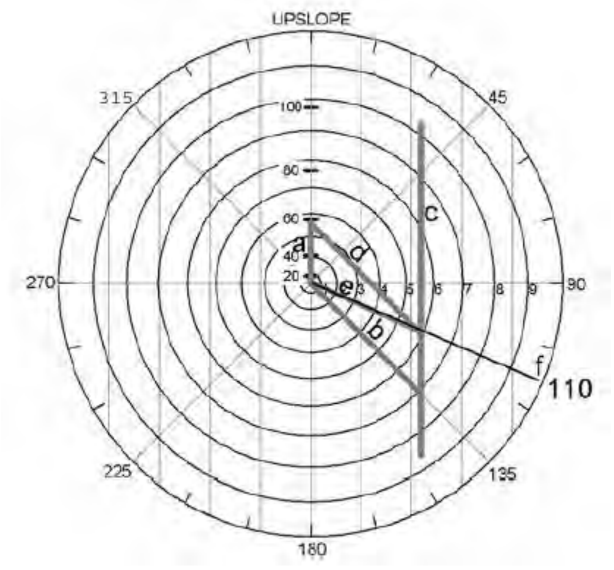
5.4.4.2 Instructions for Nomograph Use

Each fuel model includes a duplicate set of effective windspeed protractor and fire behavior nomograph, one for ***low wind speeds*** and ***one for high wind speeds***. Select the one with applicable windspeeds.

Inputs Required

- Fuel Model
- Midflame Windspeed & direction, azimuth clockwise from upslope
- Slope %
- Dead and Live Fuel Moistures.

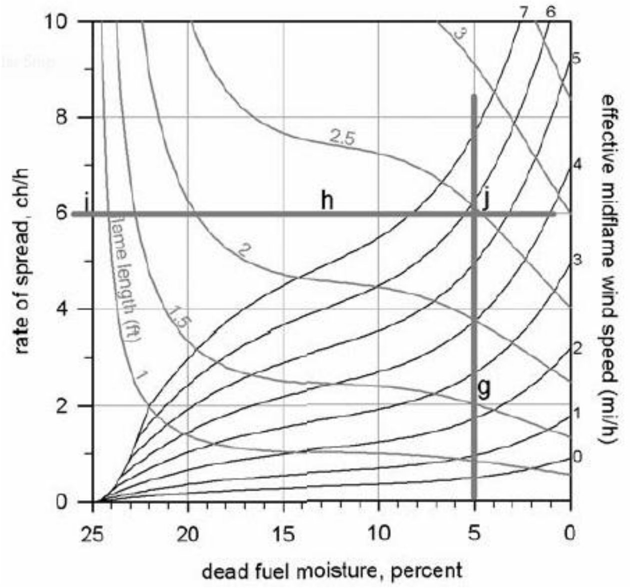
Determine Effective Windspeed (EWS) - low or high
Use the vectoring process identified in 5.1.4.1 and shown here if the situation includes cross slope winds



- plot the slope vector (a) in the upslope direction to the hash representing the slope %. Interpolate if necessary
- Plot the wind vector (b) using the concentric circle to for the input windspeed and the azimuth above for direction.
- Plot parallel vectors (c&d) and resultant vector (e). Read resulting windspeed (e) & direction (f).

Estimate Head Fire Rate Of Spread & Flame Length

If the fuel model includes a live fuel component, use the nomograph that references the input live fuel moisture. Otherwise, there is only one nomograph.



- Using the input dead fuel moisture, draw vertical line (g) to the estimated EWS curve.
- Read the ***flame length*** from the embedded curves at the intersection (j). Interpolate between lines if necessary.
- Draw horizontal line (h) to the left axis and read the Rate of Spread at intersection (i)

Estimate Flanking and Backing Fire Behavior Outputs from table in section 5.4.5.

5.4.4.3 *Instructions for Using Nomograms*

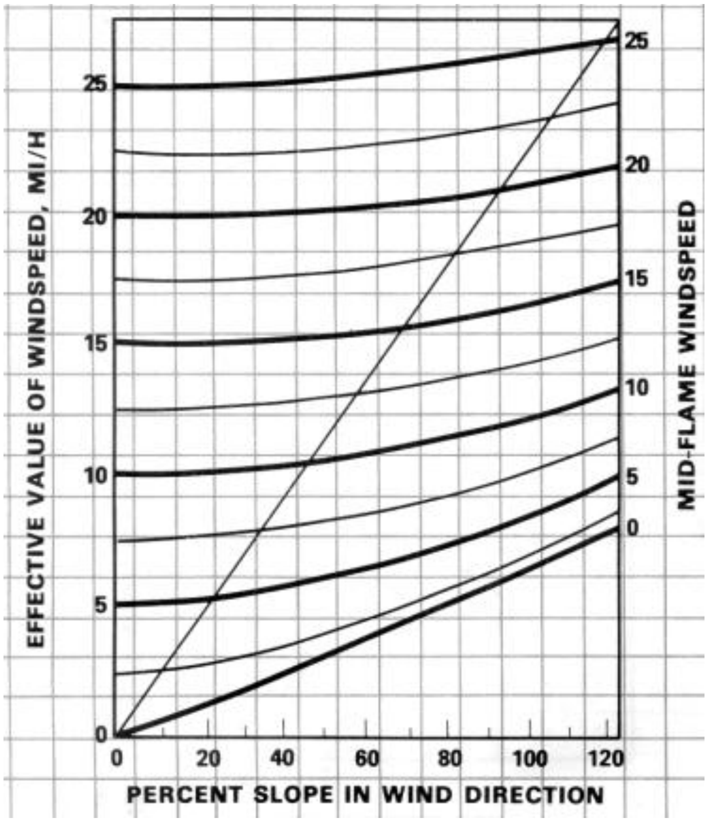
Unlike the newer Nomographs, the original surface fire behavior nomograms have several limitations:

- They are only available for the original 13 fuel models. Nomographs are available for all models.
- They are intended for use with wind blowing within ±30° of upslope. Use in vectoring is possible, though it is not outlined here.

Inputs required include , fuel model, midflame windspeed, percent slope, dead fuel moisture (use 1-hr), and live fuel moisture for fuel models 2, 4, 5, 7, & 10. Select the appropriate windspeed (Low/High) nomogram.

Part I: Effective Windspeed (for all fuel models)

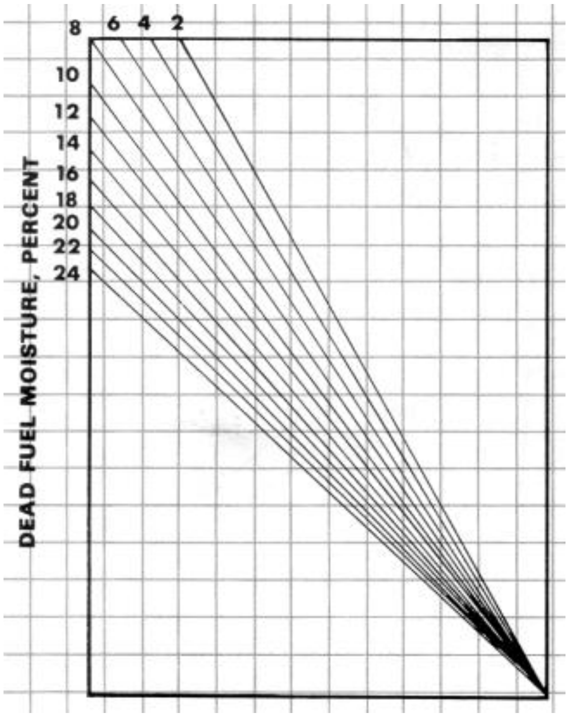
- In lower left quadrant, draw vertical line from percent slope value to intersect midflame windspeed curve. Draw horizontal line to left axis and read ***effective windspeed***.



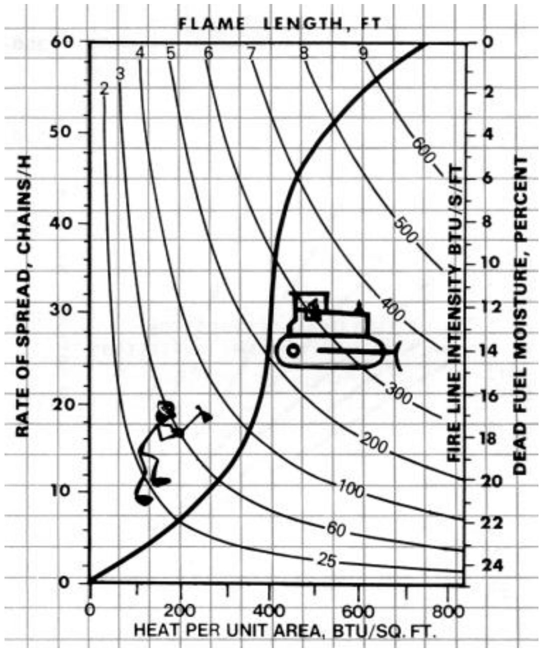
- In lower right quadrant, identify and highlight the appropriate effective windspeed line. Interpolate by adding line for effective windspeed from 1 above if it is between existing lines.

Part II: Fuel Moisture

For FM 1, 3, 6, 8, 9, 11, 12, 13 with only dead fuel

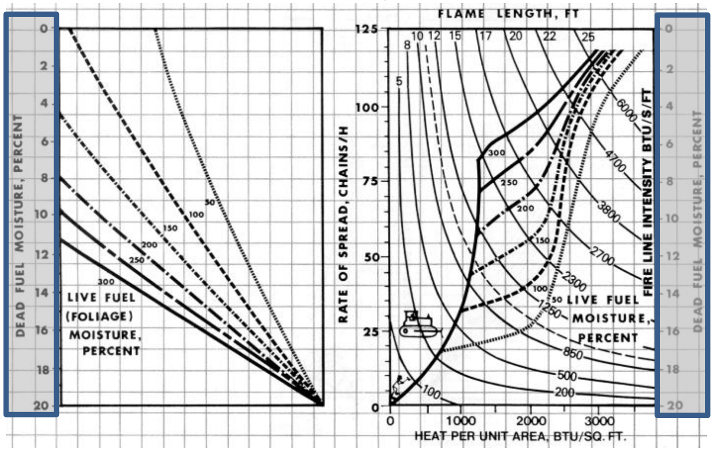


- In the upper left quadrant, identify and highlight the appropriate dead fuel moisture line based on the input value provided. Interpolate by drawing new line between existing lines if necessary.



At this point, including the S-curve in the upper right quadrant and the default corner to corner line in the lower left, turning lines have been identified in all 4 quadrants, preparing the nomogram for Part III.

For FM 2, 4, 5, 7, 10 with live fuel



- Using the two upper quadrants, locate the appropriate dead fuel moisture value on the two outer vertical axes (highlighted) Connect with a horizontal line.
- Connect the point where the horizontal line intersects the live fuel curve in the upper left quadrant to the origin point, creating a straight line.
- Using the input live fuel moisture provided, identify and highlight the appropriate S-curve in the upper right quadrant. Interpolate by adding a new line between existing lines if necessary.

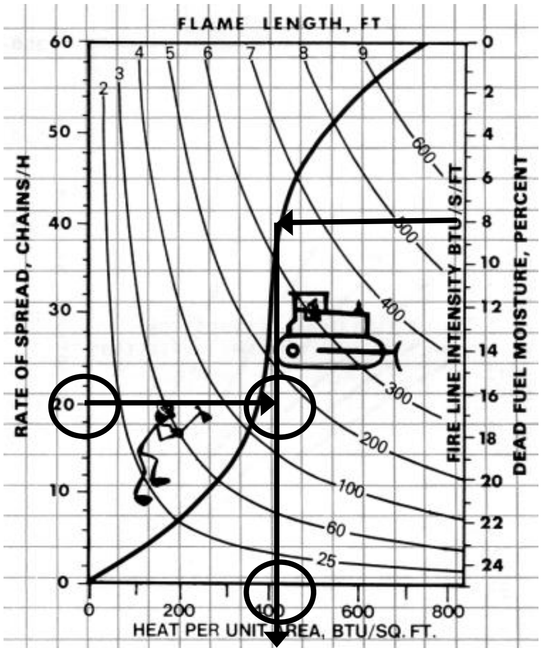
At this point, including the S-curve in the upper right quadrant and the default corner to corner line in the lower left, turning lines have been identified in all 4 quadrants, preparing the nomogram for Part III.

Part III: Estimating Fire Behavior

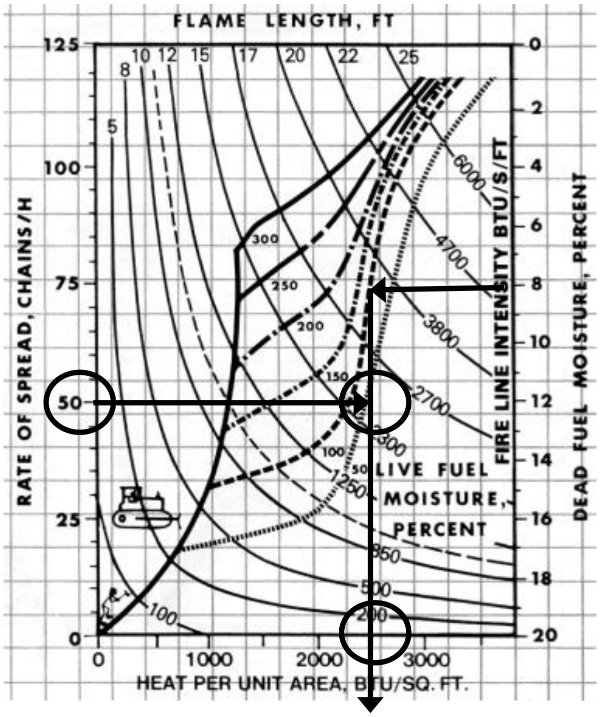
With the preparations in parts I and II, "turning" lines have been highlighted in the two lower quadrants and the upper left quadrant.

1. Begin in the upper right quadrant. Draw horizontal line from dead fuel moisture to the highlighted turning line,
2. From intersection, draw vertical line down to the turning line in the lower right quadrant.
3. From intersection with turning line in the lower right, draw horizontal line to the turning line in the lower left quadrant.
4. From intersection with the turning line in the lower left quadrant, draw vertical line up to the turning line in the upper left quadrant.
5. From intersection with turning line in the upper left quadrant, draw horizontal line to the right until it intersects the vert. line drawn in step 2.

Part IV: Reading Fire Behavior Outputs



6. Read ***Heat Per Unit Area*** where vertical line from step 2 intersects its axis in the upper right quadrant.
7. Read ***Rate of Spread*** where horizontal line from step 5 intersects its axis in the upper right quadrant.
8. Read ***Flame Length*** and ***Fireline Intensity*** at the final intersection produced in step 5.

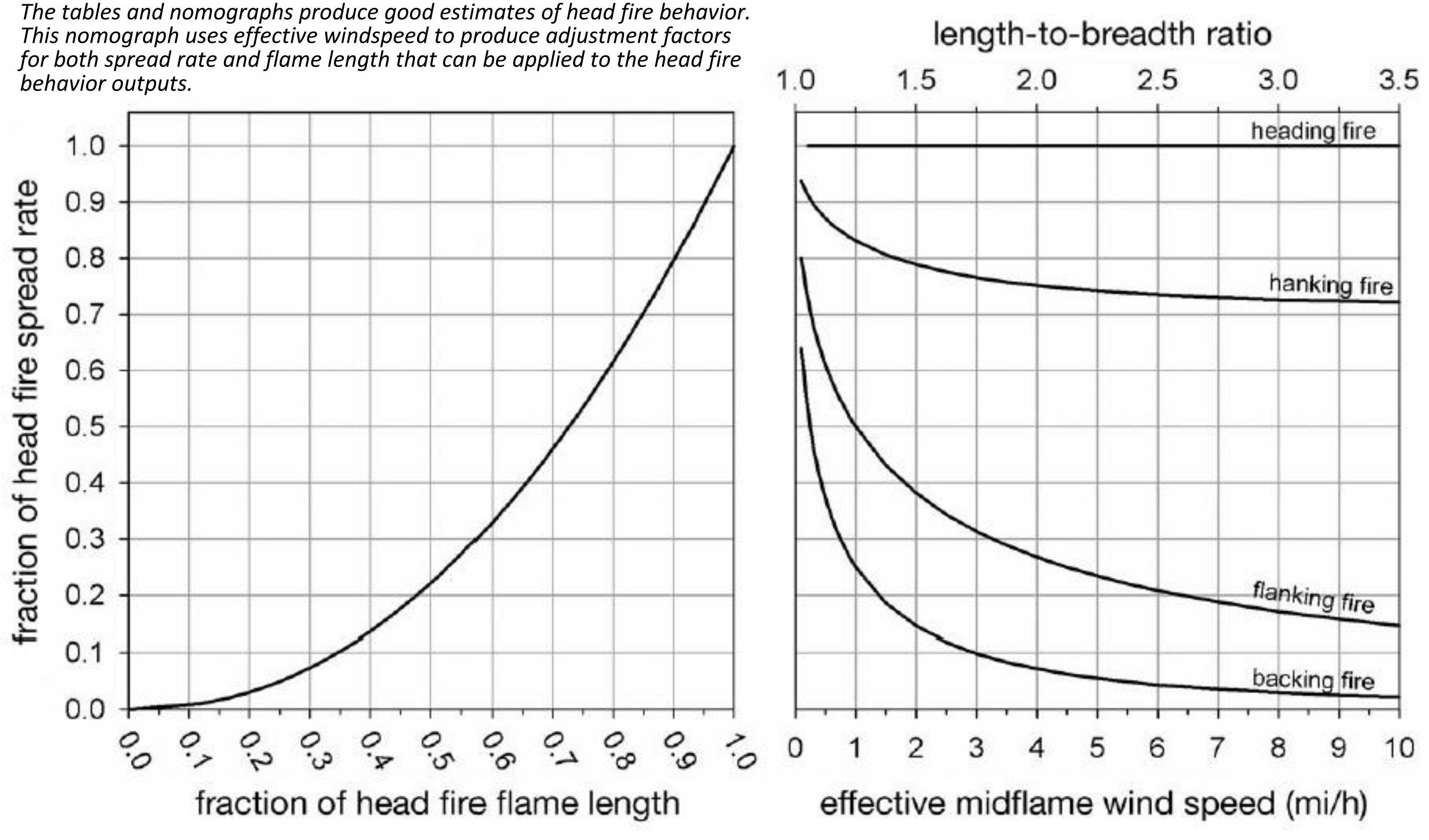


Part V: Flanking and Backing Fire Behavior Outputs

from table in section 5.4.5

5.4.5 Flanking and Backing Fire Behavior

The tables and nomographs produce good estimates of head fire behavior. This nomograph uses effective windspeed to produce adjustment factors for both spread rate and flame length that can be applied to the head fire behavior outputs.

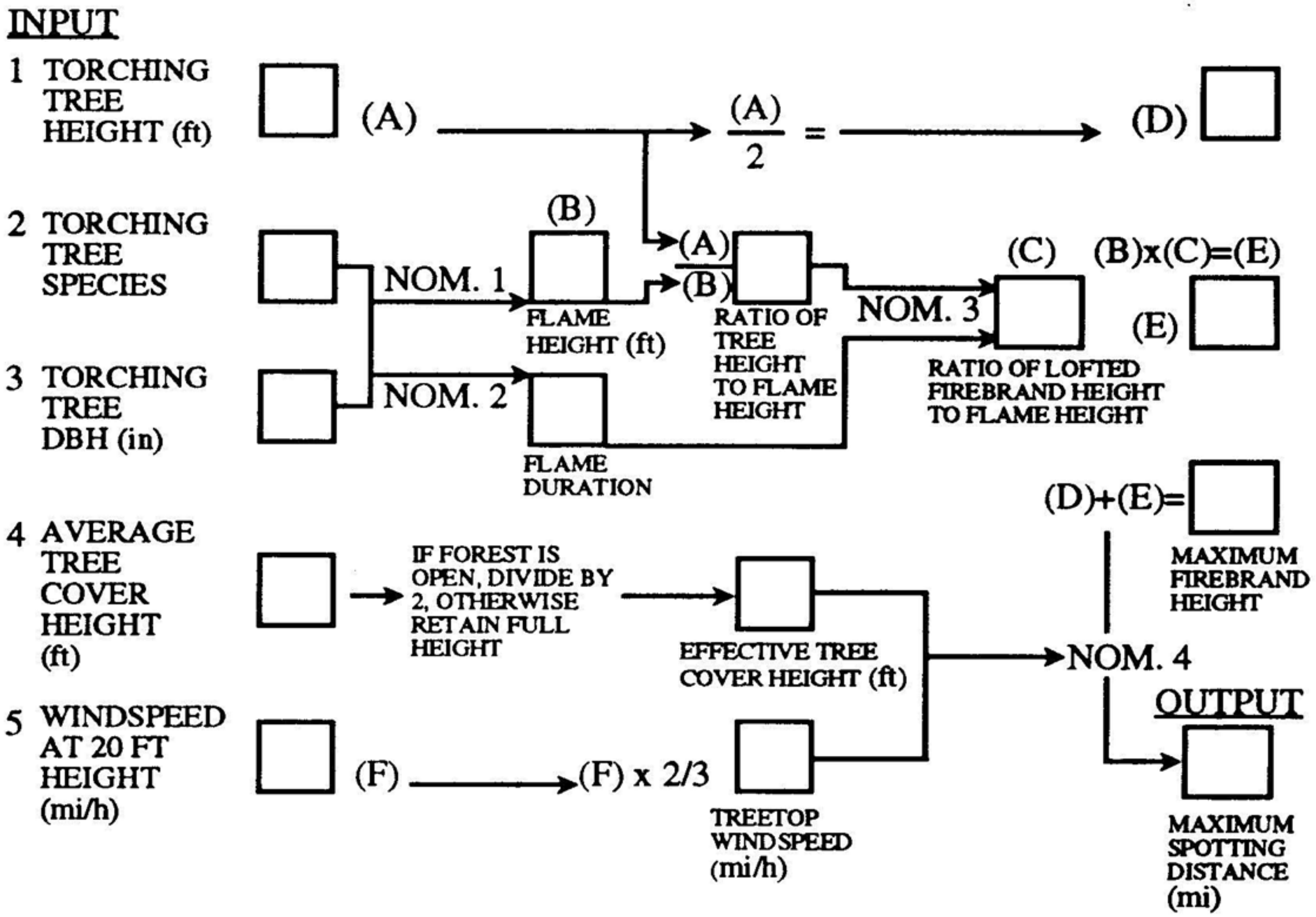


1. *Begin with the EWS at the base of the right hand chart, draw vertical line to intersect desired spread direction and the axis at top to read the length to breadth ratio.*
2. *Draw horizontal line from intersection at desired spread direction into and across the left hand chart to intersect the left axis. Read the fraction from left axis and apply it to the headfire ROS to obtain the spread rate in the assumed direction.*
3. *Draw vertical line down from where horizontal line intersected curve in left hand chart to bottom axis. Read the fraction from this bottom axis and apply it to the headfire flame length estimate to obtain the flame length in the spread direction assumed.*

5.5 Crown Fire Behavior

5.5.1 Spotting and Crownfire Worksheet

Incident/Project:____________________________**Observer/Analyst:**_______________**Date:**______________



Incident/Project: **Observer/Analyst:** **Date:**

Time and Place					Notes
1	Projection Point Identifier				
2	Projection Month/Day				
3	Projection Hour of the Day				
4	Burn Period/Duration, hr or min				
Crown Fire Assessment Inputs					
5	Surface Fire Intensity (flame, ft)				
6	20 Ft Windspeed (mph)				
7	Rate of Spread (FM 10, WAF=.4)				
8	**Canopy Base Height (ft)**				
9	**Canopy Bulk Density (lb/ft^3)**				
Crown Fire Assessment Outputs					
10	Threshold Surface FLI or FL				
11	Crown Fire Initiation? (Y/N)				
12	Threshold Crown Fire ROS				
13	Est. Crown Fire ROS (3.34* Line 7)				
14	Active Crown Fire? (Y/N)				
15	Fire Type (Surface, Passive, Active)				

5.5.2 Maximum Spotting Distance Nomograms

Instructions (Rothermel, 1983), Use worksheet (5.5.1) to document work

Inputs Required:

- Torching Tree: Species, Height, DBH
- Open 20 ft Windspeed
- Downwind Average Tree Height (Divide by 2 for open stands)

Nomogram 1(Flame Height) & Nomogram 2 (Flame Duration)

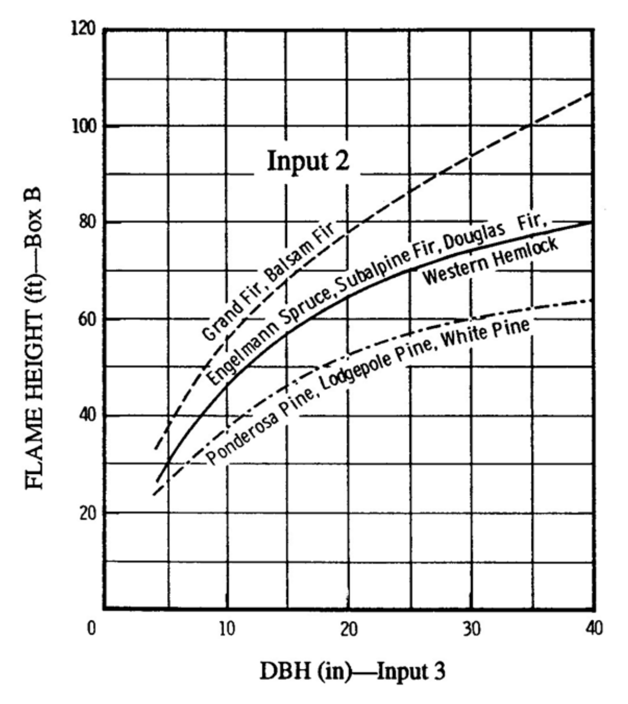
Start with input DBH, draw vertical line to interest curve for input torching tree species, turn and draw horizontal line to determine flame height in Nom 1 and flame duration in Nom 2.

Nomogram 3 (Firebrand Lofting): Divide Flame Height (Nom 1) by the input torching tree height and use that value to select the curve in Nom 3. Using the flame duration (Nom 2), draw a vertical line from the bottom axis to intersect the selected curve. From that intersection, draw a horizontal line to determine ratio for calculating firebrand height.

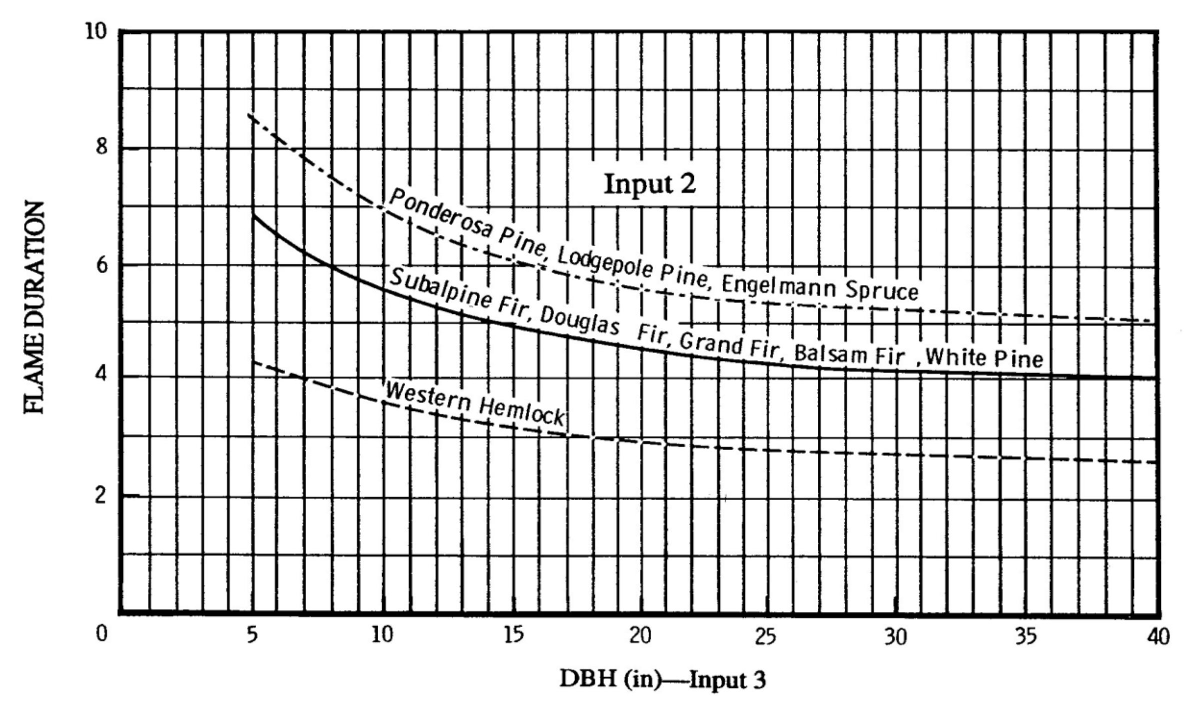
Multiply ratio from Nom 3 by flame height to determine firebrand height

Nomogram 4: Using the estimated firebrand ht., draw vertical line from bottom axis on right to intersect curve for selected downwind tree ht. From intersection draw horizontal line to line for input windspeed, then down to spot distance.

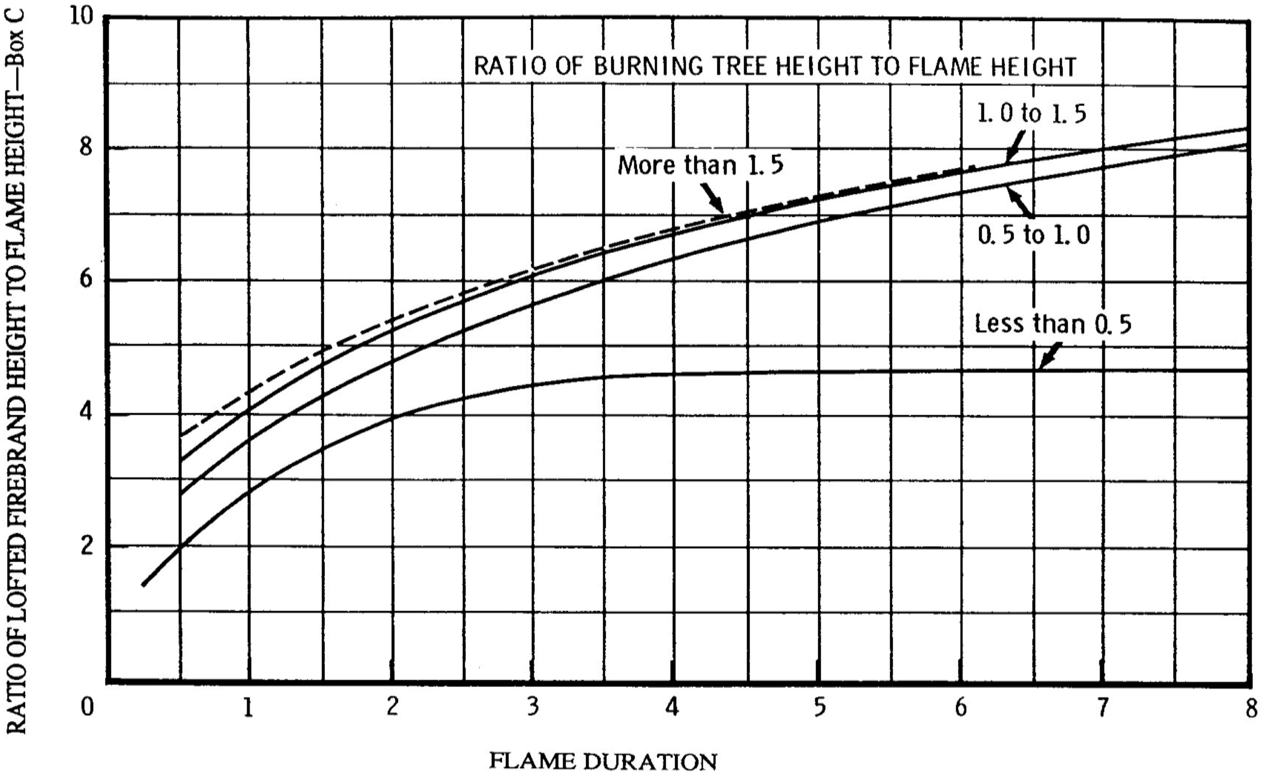
5.5.2.1 Spot Distance Nomogram 1: Estimating Flame Height



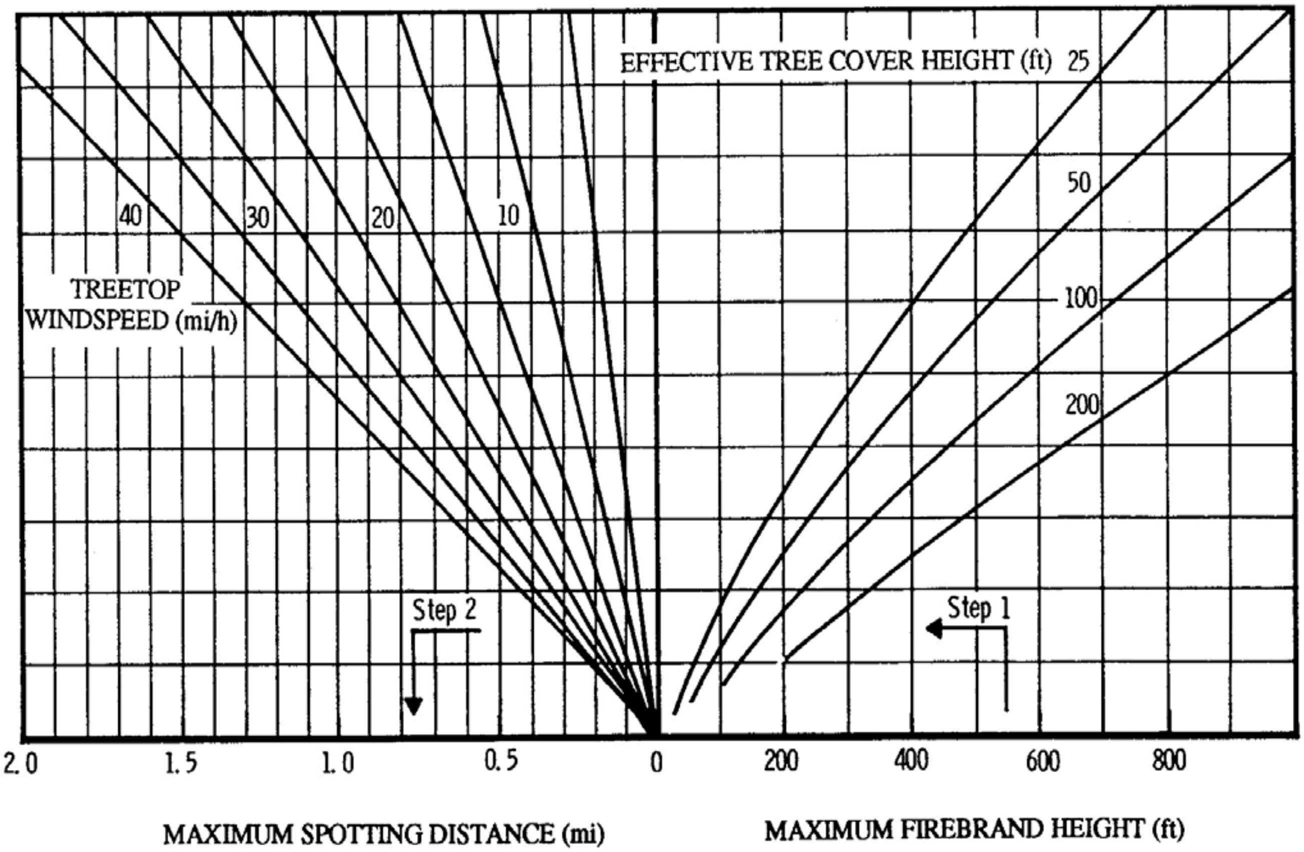
5.5.2.2 Spot Distance Nomogram 2: Estimating Flame Duration



5.5.2.3 Spot Distance Nomogram 3: Firebrand Lofting



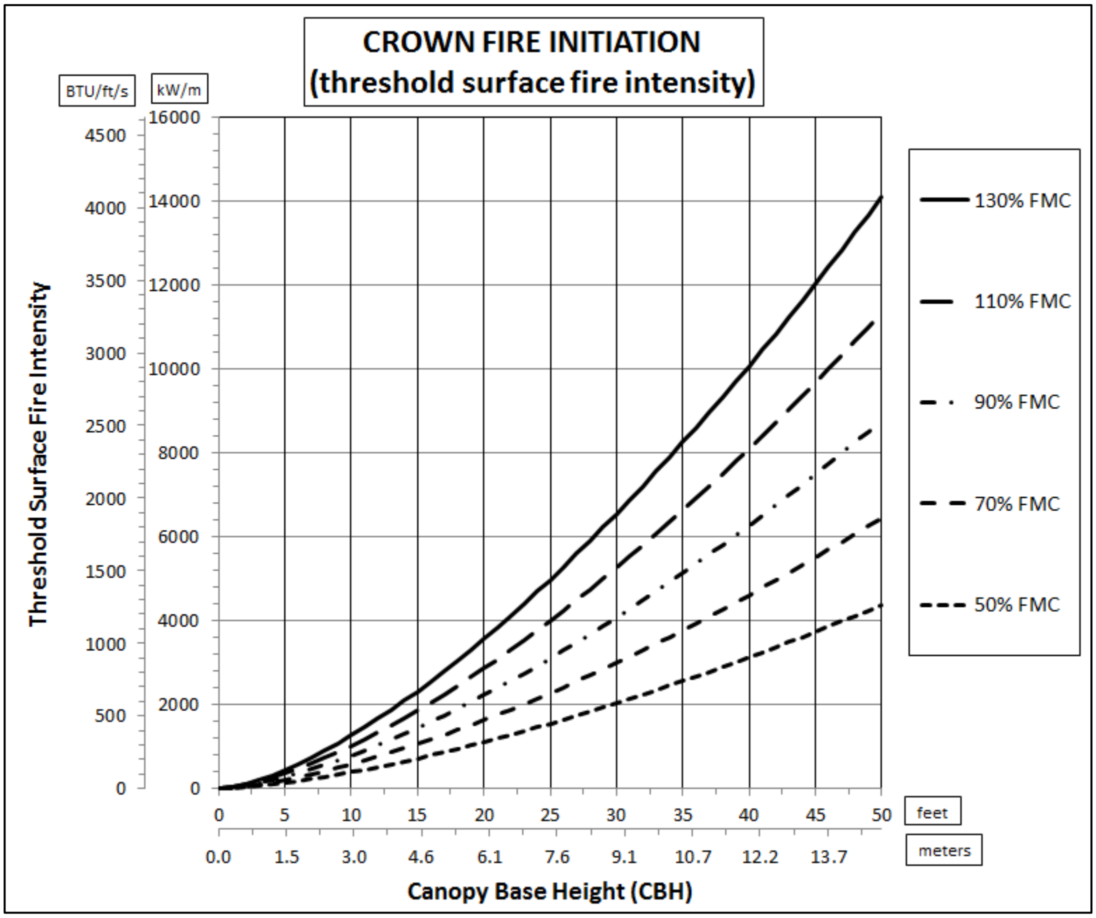
5.5.2.4 Spot Distance Nomogram 4: Maximum Spotting Distance

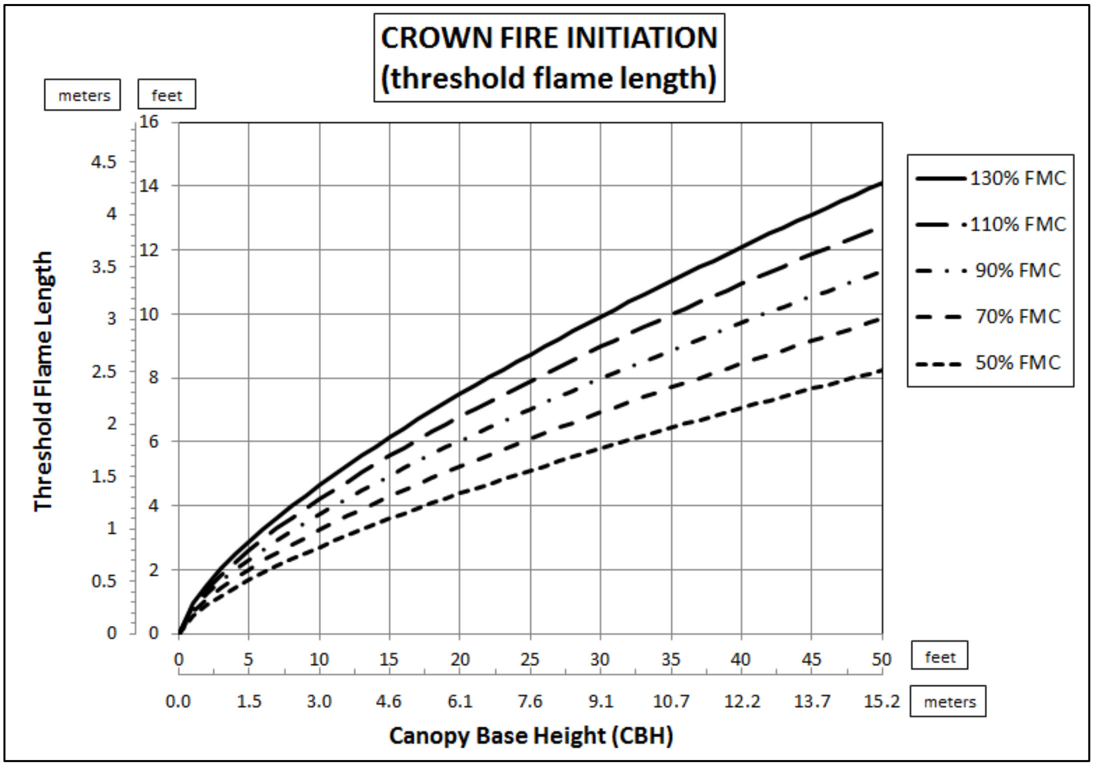


5.5.3 Crown Fire Behavior

5.5.3.1 Crown Fire Initiation

These two graphs identify the height to live crowns (CBH) and the canopy foliar moisture content (FMC) as critical factors, along with the surface fire intensity or flame length, in the evaluation of crown fire potential.





<u>Fire Type: Crown Fire</u>

This assessment only determines whether surface fire behavior is sufficient to initiate crown combustion. Both ***passive*** and ***active*** crown fire are possible if this threshold is met. See the criteria for active crown fire in section 5.5.3.2 to differentiate those conditions.

<u>Threshold Evaluation</u>

- Determine the current and/or expected surface intensity (FLI or FL) for that landscape.
- Estimate the CBH and FMC for the landscape you are evaluating for crown fire potential.
- Lookup the threshold surface intensity from either graph here.
- Compare the two intensities. If the projected intensity is greater than the threshold value, crown fire is expected.
- A ratio of projected over threshold provides a confidence value.

5.5.3.2 Active Crown Fire Propagation & Crowning Index

Crown Fire Spread (R_{act})

Surface rate of spread for fuel model 10 ($R_{FM10,WAF.4}$), using observed or forecasted conditions to determine fuel moistures and winds adjusted to 40% of the 20-ft wind, is the basis for estimating active crown fire spread rate (R_{act}) using the Rothermel model:

$$R_{act} = 3.34 * R_{FM10,WAF.4}$$

This calculation does not predict potential for active crown fire, only the ROS if there is an active crown fire.

Fire Type: Active Crown Fire

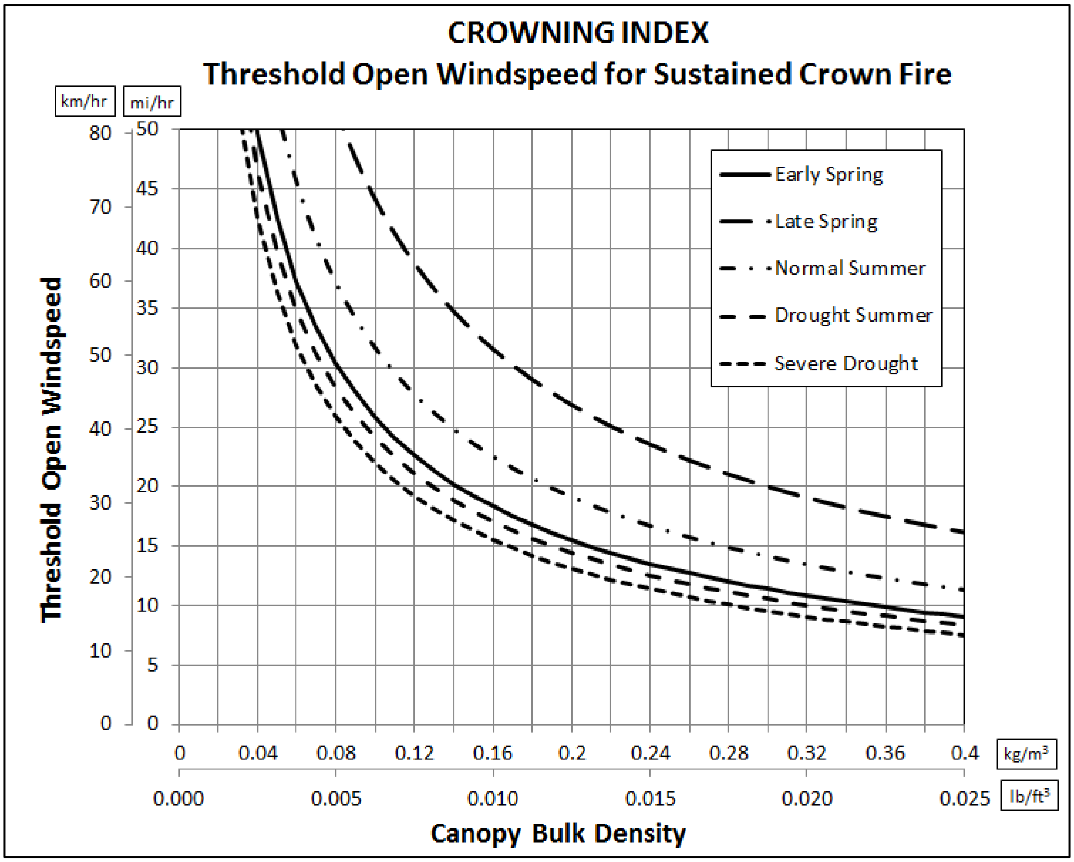
According to Van Wagner (1977), to determine if active crown fire (R_{act}) is expected, threshold conditions for canopy fuel density are necessary to sustain it. And since there is only a single crown fire fuel model, that threshold can be converted into a threshold windspeed or "crowning index" or ***CI***

The table and graph to the right provide threshold values for both R_{act} and open 20 ft windspeed.

Threshold Evaluation

For a given CBD, if observed or forecast 20 ft wind or projected R_{act} are larger than these threshold values, sustained active crown fire is expected. A ratio of estimate/threshold provides a confidence value.

Canopy Bulk Density		Threshold Crown Fire Rate of Spread			
Kg/meter^3	Lb/ft^3	Meters/min	Feet/min	Miles/hr	Chains/hr
0.02	0.0012	150.0	492	5.59	447
0.04	0.0025	75.0	246	2.80	224
0.06	0.0037	50.0	164	1.86	149
0.08	0.0050	37.5	123	1.40	112
0.1	0.0062	30.0	98	1.12	89
0.12	0.0075	25.0	82	0.93	75
0.14	0.0087	21.4	70	0.80	64
0.16	0.0100	18.8	62	0.70	56
0.18	0.0112	16.7	55	0.62	50
0.2	0.0125	15.0	49	0.56	45
0.22	0.0137	13.6	45	0.51	41
0.24	0.0150	12.5	41	0.47	37
0.26	0.0162	11.5	38	0.43	34
0.28	0.0175	10.7	35	0.40	32
0.3	0.0187	10.0	33	0.37	30
0.32	0.0200	9.4	31	0.35	28
0.34	0.0212	8.8	29	0.33	26
0.36	0.0225	8.3	27	0.31	25
0.38	0.0237	7.9	26	0.29	24
0.4	0.0250	7.5	25	0.28	22


CROWNING INDEX

Threshold Open Windspeed for Sustained Crown Fire

5.6 Using BehavePlus

5.6.1 Online Resources

Due to periodic updating, users should check the "Splash" information found in the help menu to determine the version currently installed. The latest version can be identified and downloaded, if necessary at http://www.firemodels.org . Install the latest version, as version 4 data files are compatible.

A collection of publications that support the BehavePlus, modeling system can be found at http://www.firemodels.org/index.php/behaveplus-introduction/behaveplus-publications

A comprehensive set of training resources can be found at http://www.firemodels.org/index.php/behaveplus-support/behaveplus-training

5.6.2 Creating A Workspace

To take full advantage of the BehavePlus system, users should consider recording their inputs, assumptions, and configurations within the BehavePlus file structure rather than on paper worksheets provided in the past. There are now enough options within the system that only knowing the fire environment inputs may not be sufficient to duplicate the results. Use these few guidelines to establish a BehavePlus Workspace and record all work, including documentation, by saving in the appropriate file format provided in the software.

In the BehavePlus "File" menu, the workspace submenu allows the user to open an existing workspace, create a new empty workspace, or clone the currently open workspace to a new location. The default workspace is located with the program files and is opened by default each time BehavePlus is opened.

Users should consider either creating a workspace on external storage (network folder or usb flash drive) or cloning the default workspace to one of those locations at the end of a work session when data files need to be shared, backed up, or archived.

There are individual folders for ***worksheet*** files, ***fuel model*** definition files, ***fuel moisture scenario*** files, individual ***run*** files that include system settings and modeling inputs,

5.6.3 Saving Worksheets, Fuel Models, Moisture Scenarios, and Runs in the Workspace

Worksheets: Regular users of BehavePlus should consider developing and saving a set of preconfigured worksheets for analyses that they frequently conduct. Within these worksheets, modules and how they are configured can be saved along with measurement units for each input and output, as well as settings for output tables and graphs. One may be selected as the default worksheet that is displayed whenever BehavePlus is opened.

Custom fuel models and **fuel moisture scenarios** can be saved and reused as long as they are stored in the active workspace.

Runs: These files document the modules, settings, inputs, and output formats If they are saved in the current workspace, they can be shared with others by cloning the current workspace to external storage.

5.6.4 Models & Tools Specific to BehavePlus

5.6.4.1 Two-Fuel Model projection

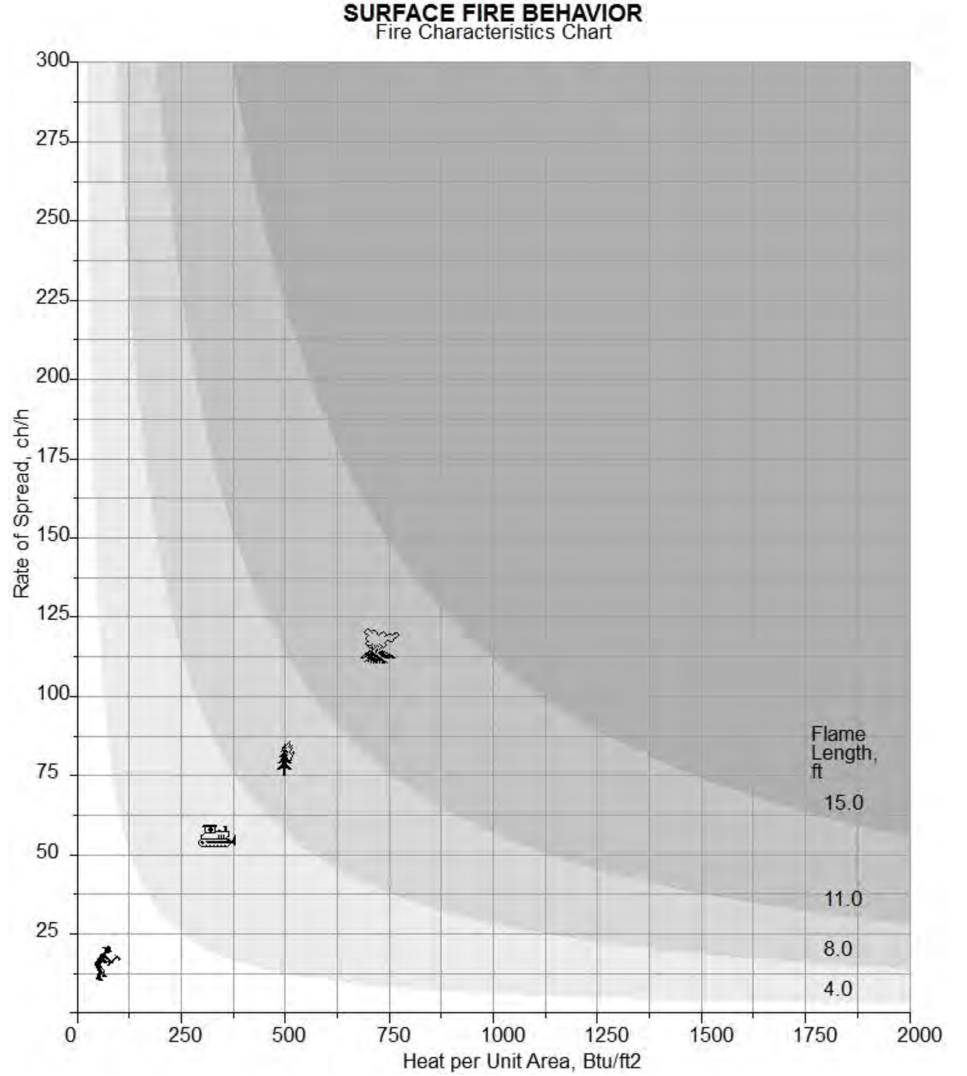
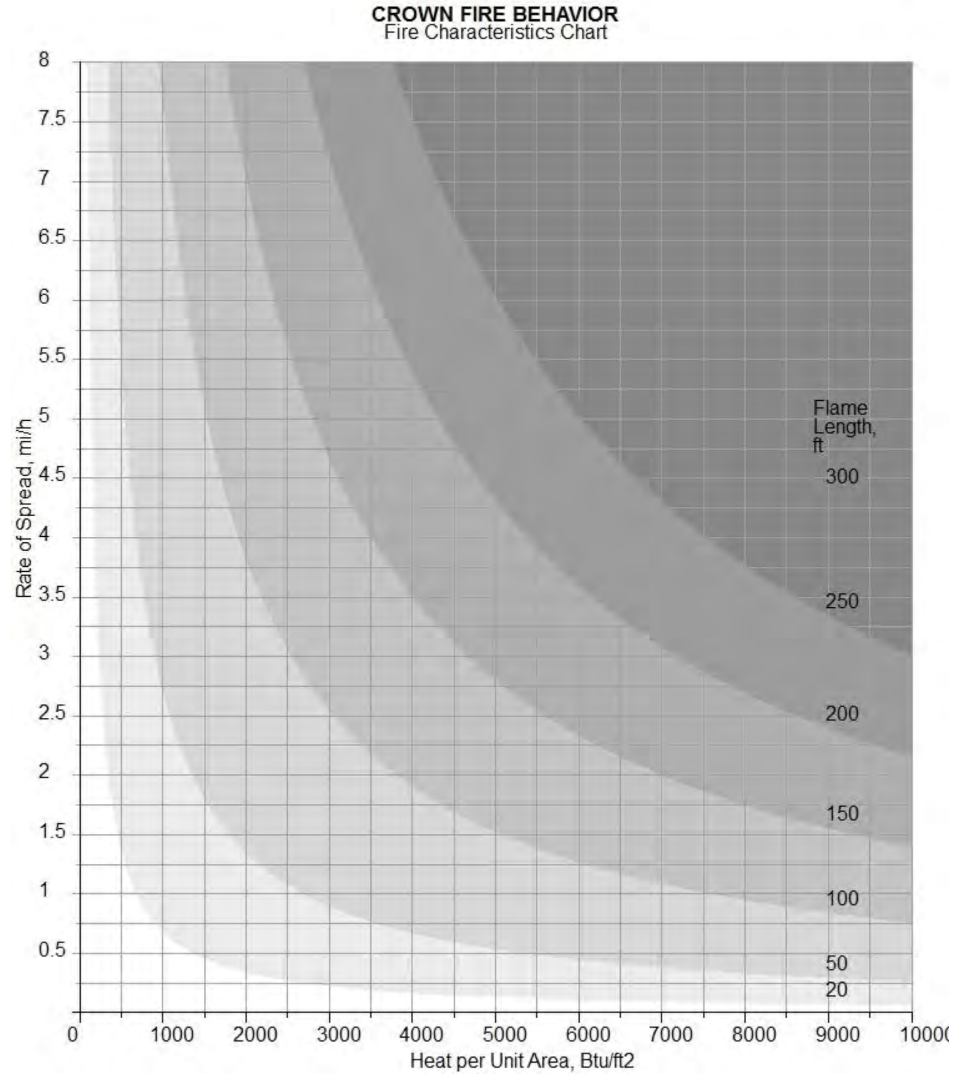
http://www.firemodels.org/downloads/behaveplus/tutorials/Modeling/8_TwoFuelModels/TwoFuel_Lesson.pdf

5.6.4.2 Tools Menu

Units Converter, Relative Humidity, Fine Dead Fuel Moisture, Slope from Map Inputs, and Sun-Moon Calendar

5.6.4.3 Special Case Fuel Models (Palmeto-Gallberry and Western Aspen)

5.7 Fire Behavior Interpretations (Hauling Charts)

	
Surface Fire Behavior Assessment • Probability of Ignition • Rate of Spread • Heat Per Unit Area • Fireline Intensity/Flame Length:	Crown Fire Assessment • Crown Fire Potential • Passive Crown Fire (Torching) • Active Crown Fire • Long Range Spotting and Ignition

References

Alexander, M.E. 1988. Help with making crown fire hazard assessments. in Fischer, W.C. and S.F. Arno (compilers), Protecting people and homes from wildfire in the interior west. USDA For. Serv. Gen. Tech. Rep. INT-251. pp. 147-156

Andrews, P. L.; Heinsch, F. A.; Schelvan, L. 2011. How to generate and interpret fire characteristics charts for surface and crown fire behavior. General Technical Report RMRS-GTR-253. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, 40p)

Bishop, Jim; The Fireline Assessment Method (FLAME): Part 1 – User's Guide & Part 2 - Technical Documentation; USDA Forest Service; Rocky Mountain Research Station, 75p

Finney, M.A. 1998. *FARSITE*: Fire Area Simulator-- Model Development and Evaluation. USDA For. Serv. Res. Pap. RMRS-RP-4.

Rothermel, R.C. 1983. How to predict the spread and intensity of forest and range fires. USDA For. Serv. Gen. Tech. Rep. INT-143.

Rothermel, R. C. 1991. Predicting behavior and size of crown fires in the Northern Rocky Mountains. Res. Pap. INT-438. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 46 p.

Scott, Joe H.; Reinhardt, Elizabeth D. 2001. Assessing crown fire potential by linking models of surface and crown fire behavior. Res. Pap. RMRS-RP-29. Fort Collins, CO: USDA, For. Serv 59 p.

Scott, J. H. 2007. Nomographs for estimating surface fire behavior characteristics. General Technical Report INT-192. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, 119p.)

Van Wagner, C. E. 1977. Conditions for the start and spread of crown fire. Canadian Journal of Forest Research. 7: 23–34.

6. FIRE SIZE & SHAPE

Contents

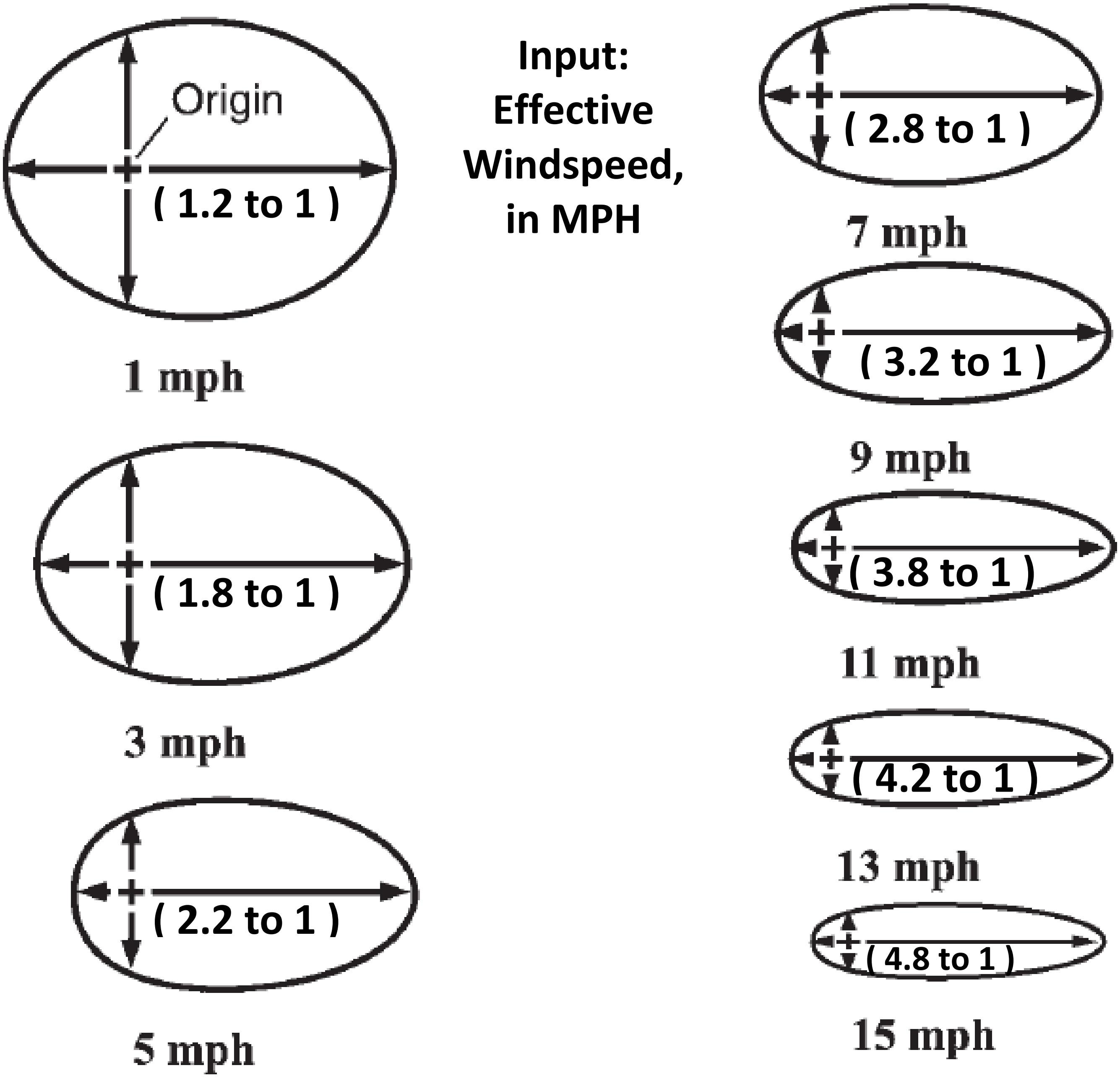
6.1 Estimating Fire Growth, Shape, and Size from Point Source

On initial attack, it is important to get a sense of the fire's growth by plotting its shape on a map and estimating its area and perimeter for increments of time during the first burn period.
Using these references, the required inputs for each increment include:

- Effective Windspeed, in MPH
- Total Spread Distance, in chains (estimated Rate of Spread, in ch/hr X Duration, in hours)

Results include the Shape & Length to Width Ratio, the Burned Area in Acres, and the Perimeter in Chains.

6.2 Fire Shapes & Length to Width Ratio



6.3 Burn Period

6.3.1 Definition

The duration of active fire spread within a 24 hour is generally known as the 'burn period'. Each fire growth projection, whether using non-spatial tools (BehavePlus) or spatial tools (WFDSS analyses NTFB and FSPro) specify a duration as the number of hours or minutes to obtain a resulting fire size and/or perimeter. Characterizing the duration as the number of hours or minutes in a day (burn period) for a projection allows the user to model growth for multiple days.

The NWCG Fire Glossary defines the burn period as that part of each 24-hour period when fires spread most rapidly; typically from 1000 to sundown. WFDSS Help offers “The default burn period in NTFB is 24 hours; however, modeling a fire overnight is generally not advised. NTFB, like FARSITE, has a tendency to over-predict overnight fire spread. For this reason, most analysts shorten the duration that the modeled fire is allowed to burn each day.”

Though it is not likely to be a common scenario, more than one burn period can be assigned for each day, if needed.

6.3.2 Factors that Affect Burning Period

Burn period can vary from day to day for a variety of reasons:

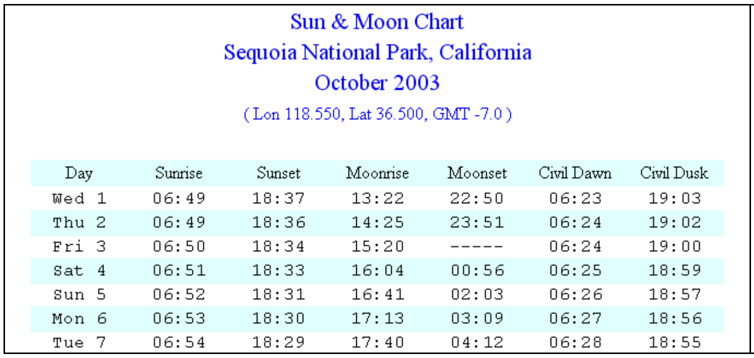
- ***Solar Radiation*** heats fuels as well as warming the air and lowering relative humidity. These influences lower fuel moisture, creating conditions favorable for active burning. Both day length and quality of sunlight are affected by the sun angle based on the time of year and latitude. Cloud cover and shading by canopy trees can further reduce the sun’s effect.
- ***Fuelbed characteristics*** can influence burn period as well. Moisture of light fuels, such as grasses, respond more quickly to changes in temperature and humidity.
- ***Diurnal fuel moisture trends*** are affected by the quality of night time humidity recovery and inversions. Slope/aspect and recent precipitation all affect the length of the burning period for a given situation.
- ***Drought*** can influence the length of the burn period through the heat produced in the burning of heavy fuels.
- ***Direction of Spread*** can be an important factor as well. Backing spread can start later and end earlier in the day for a given situation.

6.3.3 Sources of Information

- ***Fireline Observations*** are probably the first and most important source of information for determining the burn period. Try and get answers to specific questions as you pursue a reasonable estimate. When and where did fire begin to move and when did it slow down on previous days? Was there spread during the night? What were observed spread rates and when?

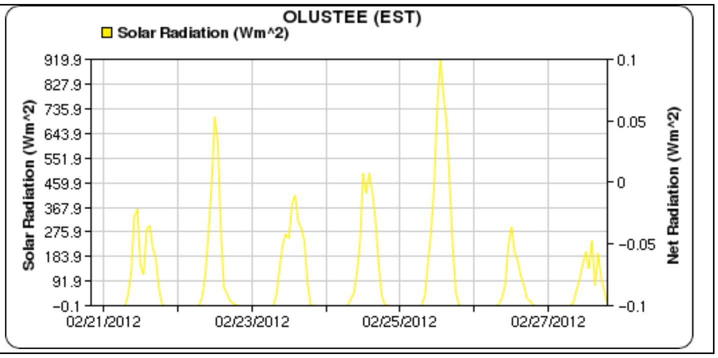
  Do these reports and modeled spread rates produce realistic spread predictions? Sometimes these reports are incomplete and need to be correlated to other information as suggested below. FSPro seeks burn period information for different types of days. These factors suggest that fireline observations should be reinforced with other information where possible.

- **Sunrise-Sunset Tables (time of year and latitude) from BehavePlus and solar radiation sensors** can show periodicity and suggest timing of beginning and end of active spread.

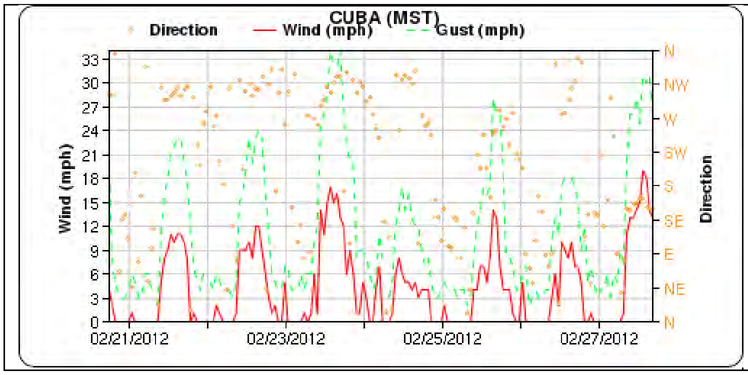


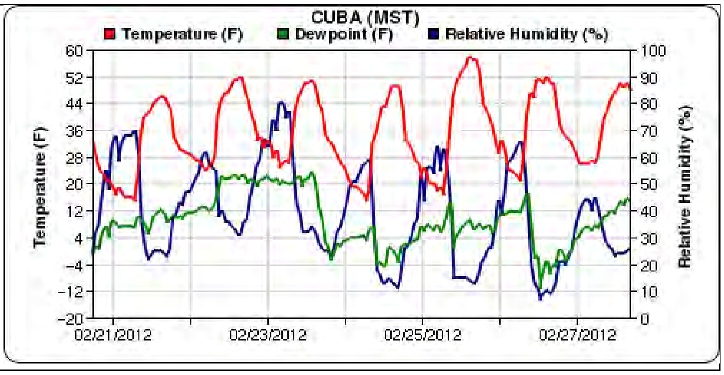
Sun & Moon Chart
Sequoia National Park, California
October 2003
(Lon 118.550, Lat 36.500, GMT -7.0)

Day	Sunrise	Sunset	Moonrise	Moonset	Civil Dawn	Civil Dusk
Wed 1	06:49	18:37	13:22	22:50	06:23	19:03
Thu 2	06:49	18:36	14:25	23:51	06:24	19:02
Fri 3	06:50	18:34	15:20	-----	06:24	19:00
Sat 4	06:51	18:33	16:04	00:56	06:25	18:59
Sun 5	06:52	18:31	16:41	02:03	06:26	18:57
Mon 6	06:53	18:30	17:13	03:09	06:27	18:56
Tue 7	06:54	18:29	17:40	04:12	06:28	18:55



- **Diurnal Wind, Weather and Fuel Moisture Trends** can similarly show a periodicity that can suggest timing of active spread.





- **Fire Progression Maps** suggest the overall daily spread around the fire, and with knowledge of weather conditions, fuels, slope and spread direction, can be compared to modeled growth.

6.3.4 Estimating Burning Period

A good starting point for estimating a burn period is to get information from the fireline to estimate the hours that the real-world fire is actively spreading. Ask about flanking and backing spread as well. Then buffer that burn period by an hour or two on each end. Doing so approximates the periods of slower burning and overnight backing fire growth. For example, if the fire you are modeling is actively burning (or anticipated to actively burn) from 1400 to 1800, a reasonable burn period for a first calibration run might be from 1300 to 1900. Without good fireline observations, start with a period between 1200 and sundown.

Using your first estimate, you may need to make adjustments based on the factors discussed above if they will produce different burning conditions than those reported from the field. Frequently, efforts to calibrate modeled growth to observed daily spread will incorporate adjustments to the burn period estimate.

6.4 Surface Fire Area for Point Source Fires, in Acres

Spread Distance, in Chains	Effective Windspeed, in mph									
	1	3	5	7	9	11	13	15	17	19
	Acres									
1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.4	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
3	1	1	0.3	0.3	0.2	0.2	0.2	0.2	0.1	0.1
4	2	1	1	1	0.4	0.3	0.3	0.3	0.2	0.2
5	3	1	1	1	1	1	1	0.4	0.4	0.3
6	4	2	1	1	1	1	1	1	1	1
7	5	3	2	2	1	1	1	1	1	1
8	6	4	3	2	2	1	1	1	1	1
9	8	4	3	3	2	2	2	1	1	1
10	10	5	4	3	3	2	2	2	2	1
11	12	7	5	4	3	3	2	2	2	2
12	14	8	6	4	4	3	3	2	2	2
13	17	9	7	5	4	4	3	3	3	2
14	19	11	8	6	5	4	4	3	3	3
15	22	12	9	7	6	5	4	4	3	3
16	25	14	10	8	7	6	5	4	4	4
17	28	16	11	9	7	6	6	5	4	4
18	32	18	13	10	8	7	6	6	5	5
19	35	20	14	11	9	8	7	6	6	5
20	39	22	16	12	10	9	8	7	6	6
21	43	24	17	14	11	10	8	8	7	6
22	48	26	19	15	12	11	9	8	7	7
23	52	29	21	16	13	12	10	9	8	7
24	57	31	22	18	15	13	11	10	9	8
25	61	34	24	19	16	14	12	11	10	9
26	66	37	26	21	17	15	13	11	10	9
28	77	43	31	24	20	17	15	13	12	11
30	88	49	35	28	23	20	17	15	14	13
32	101	56	40	31	26	22	20	17	16	14
34	114	63	45	35	29	25	22	20	18	16
36	127	70	50	40	33	28	25	22	20	18
38	142	78	56	44	37	31	28	24	22	20
40	157	87	62	49	41	35	30	27	24	22
42	173	96	69	54	45	38	34	30	27	25
44	190	105	75	59	49	42	37	33	30	27
46	208	115	82	65	54	46	40	36	32	29
48	226	125	90	71	59	50	44	39	35	32
50	245	135	97	77	64	54	48	42	38	35

6.4 Surface Fire Area for Point Source Fires, in Acres (Continued)

Spread Distance, in Chains	**Effective Windspeed, in mph**									
	1	**3**	**5**	**7**	**9**	**11**	**13**	**15**	**17**	**19**
	Acres									
52	266	146	105	83	69	59	51	46	41	38
54	286	158	113	89	74	63	55	49	44	40
56	308	170	122	96	80	68	60	53	48	44
58	330	182	131	103	85	73	64	57	51	47
60	353	195	140	110	91	78	68	61	55	50
62	377	208	149	118	98	84	73	65	59	53
64	402	222	159	125	104	89	78	69	62	57
66	428	236	169	133	111	95	83	74	66	60
68	454	250	180	142	117	100	88	78	71	64
70	481	265	190	150	124	106	93	83	75	68
72	509	281	201	159	132	113	99	88	79	72
74	538	297	213	168	139	119	104	93	83	76
76	567	313	224	177	147	126	110	98	88	80
78	597	330	236	186	154	132	116	103	93	84
80	628	347	249	196	162	139	122	108	98	89
82	660	364	261	206	171	146	128	114	103	93
84	693	382	274	216	179	153	134	119	108	98
86	726	401	287	227	188	161	141	125	113	103
88	760	419	301	237	197	168	147	131	118	107
90	795	439	315	248	206	176	154	137	123	112
92	831	458	329	259	215	184	161	143	129	117
94	868	479	343	271	224	192	168	149	135	123
96	905	499	358	282	234	200	175	156	140	128
98	943	520	373	294	244	209	183	162	146	133
100	982	542	389	306	254	217	190	169	152	139
105	1082	597	428	338	280	240	210	187	168	153
110	1188	655	470	371	307	263	230	205	184	168
115	1298	716	514	405	336	287	251	224	202	183
120	1414	780	559	441	366	313	274	244	219	200
125	1534	846	607	478	397	339	297	264	238	217
130	1659	915	657	518	429	367	321	286	258	234
135	1789	987	708	558	463	396	347	308	278	253
140	1924	1062	761	600	498	426	373	332	299	272
145	2064	1139	817	644	534	457	400	356	320	292
150	2209	1219	874	689	571	489	428	381	343	312
155	2359	1301	933	736	610	522	457	406	366	333
160	2513	1386	995	784	650	556	487	433	390	355
165	2673	1474	1058	834	691	591	518	460	415	378

6.5 Surface Fire Perimeter for Point Source Fires, in Chains

Spread Distance, in Chains	Effective Windspeed, in mph									
	1	3	5	7	9	11	13	15	17	19
	Acres									
1	4	3	2	2	2	2	2	2	2	2
2	7	6	5	5	5	4	4	4	4	4
3	11	8	7	7	7	7	6	6	6	6
4	14	11	10	9	9	9	9	9	8	8
5	18	14	12	12	11	11	11	11	11	10
6	21	17	15	14	14	13	13	13	13	13
7	25	19	17	16	16	15	15	15	15	15
8	28	22	20	19	18	18	17	17	17	17
9	32	25	22	21	20	20	19	19	19	19
10	35	28	25	23	23	22	22	21	21	21
11	39	30	27	26	25	24	24	23	23	23
12	43	33	30	28	27	26	26	26	25	25
13	46	36	32	30	29	29	28	28	27	27
14	50	39	35	33	32	31	30	30	30	29
15	53	41	37	35	34	33	32	32	32	31
16	57	44	40	37	36	35	35	34	34	34
17	60	47	42	40	38	37	37	36	36	36
18	64	50	45	42	41	40	39	38	38	38
19	67	52	47	44	43	42	41	41	40	40
20	71	55	50	47	45	44	43	43	42	42
21	74	58	52	49	47	46	45	45	44	44
22	78	61	55	51	50	48	48	47	46	46
23	82	64	57	54	52	51	50	49	49	48
24	85	66	60	56	54	53	52	51	51	50
25	89	69	62	59	56	55	54	53	53	52
26	92	72	65	61	59	57	56	55	55	54
28	99	77	70	66	63	62	61	60	59	59
30	106	83	74	70	68	66	65	64	63	63
32	113	88	79	75	72	70	69	68	68	67
34	121	94	84	80	77	75	73	73	72	71
36	128	99	89	84	81	79	78	77	76	75
38	135	105	94	89	86	84	82	81	80	80
40	142	110	99	94	90	88	86	85	84	84
42	149	116	104	98	95	92	91	90	89	88
44	156	122	109	103	99	97	95	94	93	92
46	163	127	114	108	104	101	99	98	97	96
48	170	133	119	112	108	106	104	102	101	101
50	177	138	124	117	113	110	108	107	106	105

6.5 Surface Fire Perimeter for Point Source Fires, in Chains (continued)

Spread Distance, in Chains	Effective Windspeed, in mph									
	1	3	5	7	9	11	13	15	17	19
	Acres									
52	184	144	129	122	117	114	112	111	110	109
54	191	149	134	126	122	119	117	115	114	113
56	199	155	139	131	126	123	121	119	118	117
58	206	160	144	136	131	128	125	124	122	122
60	213	166	149	140	135	132	130	128	127	126
62	220	171	154	145	140	136	134	132	131	130
64	227	177	159	150	144	141	138	137	135	134
66	234	182	164	154	149	145	143	141	139	138
68	241	188	169	159	153	150	147	145	144	142
70	248	193	174	164	158	154	151	149	148	147
72	255	199	179	169	162	158	156	154	152	151
74	262	204	184	173	167	163	160	158	156	155
76	269	210	189	178	171	167	164	162	160	159
78	277	215	194	183	176	172	169	166	165	163
80	284	221	199	187	180	176	173	171	169	168
82	291	227	204	192	185	180	177	175	173	172
84	298	232	209	197	189	185	182	179	177	176
86	305	238	214	201	194	189	186	183	182	180
88	312	243	219	206	198	194	190	188	186	184
90	319	249	223	211	203	198	194	192	190	189
92	326	254	228	215	207	202	199	196	194	193
94	333	260	233	220	212	207	203	200	199	197
96	340	265	238	225	217	211	207	205	203	201
98	347	271	243	229	221	216	212	209	207	205
100	355	276	248	234	226	220	216	213	211	210
105	372	290	261	246	237	231	227	224	222	220
110	390	304	273	257	248	242	238	235	232	230
115	408	318	286	269	259	253	249	245	243	241
120	425	331	298	281	271	264	259	256	253	251
125	443	345	310	293	282	275	270	267	264	262
130	461	359	323	304	293	286	281	277	275	272
135	479	373	335	316	304	297	292	288	285	283
140	496	387	348	328	316	308	303	299	296	293
145	514	401	360	339	327	319	313	309	306	304
150	532	414	372	351	338	330	324	320	317	314
155	550	428	385	363	350	341	335	331	327	325
160	567	442	397	374	361	352	346	341	338	335
165	585	456	410	386	372	363	357	352	348	346

6.6 Crown Fire Area, in acres

Spread Distance, in Miles	Maximum Sustained 20 ft Windspeed, in mph									
	10	15	20	25	30	35	40	45	50	60
	Area, in Acres									
0.25	14	11	9	8	7	6	5	5	4	4
0.5	56	44	36	30	26	23	21	19	17	15
1	223	175	144	122	106	94	84	76	69	59
1.5	503	393	323	274	238	210	188	171	156	133
2	894	699	574	487	423	374	335	303	277	237
2.5	1396	1093	898	762	661	584	524	474	433	370
3	2011	1574	1293	1097	952	842	754	683	624	532
3.5	2737	2142	1759	1493	1296	1146	1026	929	849	724
4	3574	2797	2298	1950	1693	1496	1340	1214	1109	946
4.5	4524	3540	2908	2468	2143	1894	1696	1536	1404	1198
5	5585	4371	3590	3046	2646	2338	2094	1897	1733	1478
5.5	6758	5289	4344	3686	3201	2829	2534	2295	2097	1789
6	8042	6294	5170	4387	3810	3367	3016	2731	2496	2129
8	14298	11190	9191	7799	6773	5985	5362	4856	4437	3785
10	22340	17484	14362	12186	10582	9352	8378	7587	6933	5914
12	32170	25176	20681	17547	15238	13466	12064	10926	9984	8516
14	43787	34268	28149	23884	20741	18329	16420	14871	13589	11591
16	57191	44758	36766	31195	27090	23940	21447	19423	17749	15139
18	72382	56647	46531	39481	34286	30300	27143	24583	22463	19160
20	89361	69935	57446	48742	42329	37407	33510	30349	27733	23654
22	108127	84621	69510	58978	51218	45262	40547	36722	33557	28622
24	128680	100706	82723	70189	60954	53866	48255	43703	39935	34062
30	201062	157353	129254	109670	95240	84165	75398	68285	62399	53222
35	273668	214175	175929	149273	129632	114559	102625	92944	84931	72441
40	357443	279738	229785	194969	169315	149627	134041	121396	110931	94617

6.7 Crown Fire Perimeter, in miles

Spread Distance, in Miles	Maximum Sustained 20 ft Windspeed, in mph									
	10	15	20	25	30	35	40	45	50	60
	Perimeter, In Miles									
0.25	1	1	1	0	0	0	0	0	0	0
0.5	1	1	1	1	1	1	1	1	1	1
1	2	2	2	2	2	2	2	2	2	2
1.5	3	3	3	3	3	3	3	3	3	3
2	5	4	4	4	4	4	4	4	4	4
2.5	6	5	5	5	5	5	5	5	4	4
3	7	6	6	6	6	6	5	5	5	5
3.5	8	7	7	7	7	7	6	6	6	6
4	9	8	8	8	8	7	7	7	7	7
4.5	10	10	9	9	9	8	8	8	8	8
5	11	11	10	10	10	9	9	9	9	9
5.5	12	12	11	11	10	10	10	10	10	10
6	14	13	12	12	11	11	11	11	11	11
8	18	17	16	16	15	15	15	14	14	14
10	23	21	20	20	19	19	18	18	18	18
12	27	25	24	23	23	22	22	22	21	21
14	32	30	28	27	27	26	26	25	25	25
16	36	34	32	31	30	30	29	29	29	28
18	41	38	36	35	34	34	33	33	32	32
20	45	42	40	39	38	37	37	36	36	35
22	50	47	44	43	42	41	40	40	39	39
24	54	51	48	47	46	45	44	43	43	42
30	68	64	61	59	57	56	55	54	54	53
35	79	74	71	68	67	65	64	63	63	61
40	91	85	81	78	76	75	73	72	71	70

7 MAPPING: SLOPE, SCALE, & GEOGRAPHY

Contents

7.1 Slope & Scale

Standard LANDFIRE slope themes are represented in units of degrees (°). Many locally produced landscapes over the year's stored slopes in percent (%). It is much easier to estimate slope in %, estimating the elevation change and the horizontal distance and calculating the ratio. BehavePlus, and BEHAVE tools before that, default to slope input in %.

Slope (Degrees)	Slope (Percent)
10º	17.6 %
20º	36.4 %
30º	57.7 %
40º	83.9 %
45º	100 %
50º	119.2 %
60º	173.2 %
70º	274.7 %
80º	567.1 %
90º	∞

To convert from slope in degrees (°) to slope in percent (%), a scientific calculator is needed.

- Enter the slope in degrees
- Press the Tangent button
- Multiply the result by 100 to get slope in %

7.1.1 Calculating slope from contour map measurements

See Firefighter Math (http://www.firefightermath.org) for additional explanation, examples, and exercises.

The process for directly calculating slope with measurements from a contour map:

1. Determine the contour interval. This is the elevation change between adjacent contour lines.

   Example: 40 ft.

2. Determine the map scale and conversion factor. The map scale must be found in terms of the number of feet that each inch on the map represents (ft/in).
   a. Map scales are usually given as the number of inches per mile, such as 2 in/mi, or as a representative fraction such as 1:31,680.
   b. Use the spacing of section lines to determine the map scale. Normally section line spacing is 1 mile; be careful of foreshortened sections; look around on the map and find square sections with equal spacing. Measure the distance with a ruler graduated in inches and tenths of inches. Divide 5,280 by the map distance between section lines.

Scale	Rep. fraction	Map (in/mi)	Map (in/ch)	Feet per map inch
1 : 253,440	253.44	0.25	0.0031	21120
1 : 126,720	126.72	0.50	0.0063	10560
1 : 63,360	63.36	1	0.0125	5280
1 : 62,500	62.5	1.01	0.0127	5188
1 : 31,680	31.68	2	0.025	2640
1 : 24,000	24	2.64	0.033	2000
1 : 21,120	21.12	3	0.0375	1760
1 : 15,840	15.84	4	0.05	1320
1 : 7,920	7.92	8	0.1	660

Example: Map dist. between section lines = 2.64 in
Map scale = 5,280/2.64 = 2,000 ft/in

3. Determine rise in elevation by counting contour intervals and convert to feet.

   Example: 11 contour intervals
   11 x 40 ft/contour interval = 440 ft.

4. Measure the horizontal distance with a ruler graduated in inches and tenths of inches, and convert to feet with the map scale from step 2.

   Example: Map dist. between section lines = 2.64 in
   Map scale = 5,280/2.64 = 2,000 ft/in

5. Determine rise in elevation by counting contour intervals and convert to feet.

   Example: 11 contour intervals
   11 x 40 ft/contour interval = 440 ft.

6. Measure the horizontal distance with a ruler graduated in inches and tenths of inches, and convert to feet with the map scale from step 2.

   Example: Map dist. of slope length = 1.2 in
   1.2 in x 2,640 ft/in = 3,168 ft.

7. Divide the rise in elevation from step 3 by the horizontal distance from step 4.

7.2 GPS Use for GIS Application

Set Up Before Going To The Field:

- Make Sure Fresh batteries are loaded and extra sets available.
- Transfer background maps using MapSource for the area of mapping (if available).
- Turn unit on to initialize and acquire satellites if you are in a new area or haven't used the unit in at least a week. This may take as long as 20 minutes in the open, away from buildings, canopy and obstructions.
- Download and clear old Waypoints and Tracks from memory. Download any data you don't need, make a copy and clean up waypoints in list and clear all saved tracks and active tracklogs.
- Turn off active tracklog. Set tracklog to the preferred Collection method (Time is best) and an appropriate logging rate for the data collection. 5 seconds works for most walking collection, but keep in mind the total storage capacity of the GPS.
- Ensure Simulator Mode is not ON when collecting data.
- Set unit time and date (Ensure Daylight Savings Time if needed).
- Check Interface Protocol is set properly.
- Set the Coordinate System (UTM or LAT/LONG) and Datum to ensure compatibility with any written coordinates you may need to navigate to or Map.
- Set Heading to Magnetic or True. If set to true, ensure compass has same declination.

Field – GPS Data Collection:

- Hold GPS antenna away from body with antenna up. Better yet, hold at, or above the head. Purchase an external antenna to free hands if needed or for better reception in vehicles.
- Mark (save) waypoints for point locations at beginning and ending of track log collections. Writing down a position is just backup.
- Most GPS units will collect data no matter what the GPS quality is. It's up to you to monitor the GPS Satellite Page continuously for anomalies and Accuracy.
- Collect only when "3D GPS" is shown. Do not collect data in 2D unless absolutely necessary.

Waypoints:

- Collect all waypoints in Averaged Position mode if you are standing still (when possible and if your receiver has that capability). Minimum of 10 positions, maximum of 20 minutes. Somewhere in between is enough to generate a quality position in most cases.
- Collect an instantaneous waypoint only when moving or in a hurry (or if using the eTrex line).
- Edit default waypoint numbers to letters or words that are more descriptive or make good field notes to ensure you remember what features are represented by which numbers.

Tracklogs:

- Use "Stop when Full" or "Fill" Record Mode rather than wrap to prevent overwriting tracklog points when Active Tracklog becomes full.
- Turn on Active Tracklog at start location and immediately begin moving.
- Stop Active Tracklog when movement is stopped temporarily or when mission is finished.
- Always Stop Active Track just shy of starting point when collecting an area (polygon). Overlapping with start point makes conversion to GIS more challenging.
- Always turn Active Tracklog to OFF when finished collecting or turn receiver off to avoid collecting unwanted positions after mission is complete.
- Use caution when saving an Active Tracklog. Garmin will generalize any active track to save space, thereby degrading data. If you save a track log and clear the active track, you won't be able to go back to the more detailed track log positions.

7.3 Average Latitude for Each State

Alabama	33
Alaska	65
Arizona	35
Arkansas	35
California	38
Colorado	39
Connecticut	41
Delaware	39
Florida	28
Georgia	33
Hawaii	21
Idaho	45
Illinois	40

Indiana	40
Iowa	42
Kansas	39
Kentucky	37
Louisiana	31
Maine	45
Maryland	39
Massachusetts	42
Michigan	43
Minnesota	46
Mississippi	32
Missouri	39

Montana	47
Nebraska	41
Nevada	39
New	44
New Jersey	40
New Mexico	34
New York	43
North	35
North	47
Ohio	40
Oklahoma	35
Oregon	44
Pennsylvania	41

Rhode Island	41
South Carolina	34
South Dakota	44
Tennessee	36
Texas	32
Utah	39
Vermont	44
Virginia	37
Washington	47
West Virginia	38
Wisconsin	44
Wyoming	43

7.4 GIS Data

7.4.1 Sources of Geographic Data

LANDFIRE Data Distribution Site: Raster Data for vegetation, fuels, & terrain (http://landfire.cr.usgs.gov/viewer/)

United States Geological Survey Rapid Data Delivery System (RDDS) (http://rmgsc.cr.usgs.gov/rdds/index.shtml)

This is a very functional, efficient, and reliable system from which to obtain geospatial information. A user can zoom to an area of interest or select *Quick Find* to view a fire location, define an area for data extraction, select products, specify a projection, and download the data. Products include vector and raster data, such as active and previous fires, moderate resolution imaging spectroradiometer (MODIS), Remote Automated Weather Stations (RAWS), roads, rivers, lakes, ownership, orthoimagery, digital raster graphics (DRG), and digital elevation models (DEM). UserID/Password

USFS ArcGIS Image Server (http://fsweb.rsac.fs.fed.us/imageserver/imageserver.html)
USFS Geodata Clearinghouse (http://svinetfc4.fs.fed.us/clearinghouse/index.html)
National Park Service (NPS) Data and Information (http://www.nps.gov/gis/data_info)
RSAC – USGS Monitoring Trends in Burn Severity (MTBS) Website (http://www.mtbs.gov)

National Weather Data in shapefile Format: http://www.srh.noaa.gov/gis/kml/shapepage.htm

7.4.2 Map Datum

Some common datums, or GCSs, used in North America follow:

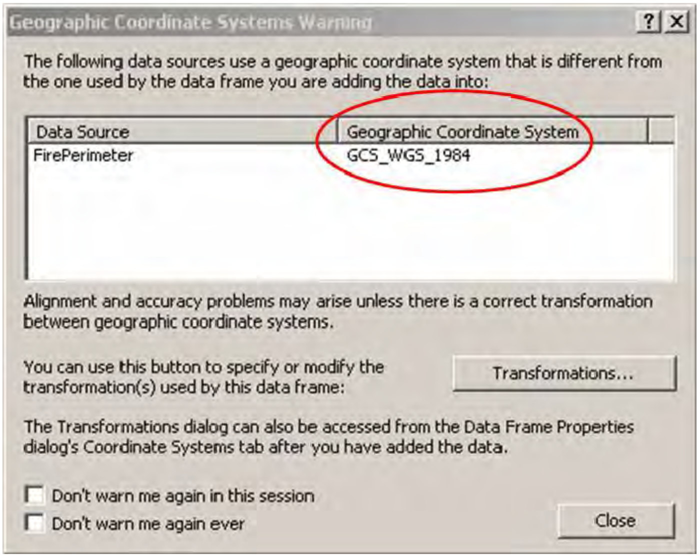
North American Datum of 1927 (NAD27)
Local datum well suited to the United States, Canada, Mexico, and the Carribean. Uses the Clarke 1866 spheroid.

North American Datum of 1983 (NAD83)
An earth-centered datum that corrects NAD27 coordinates based on both earth and satellite measurements. Uses the GRS 1980 spheroid. Coordinates are very similar to WGS84 coordinates and can be used interchangeably with them.

World Geodetic System of 1984 (WGS84)
Earth-centered datum common for datasets with a global extent. Uses the WGS 1984 spheroid. This is the datum that GPS coordinates are based on.

Geographic transformations

ArcGIS gives us a warning if we attempt to add data to our map that have a different GCS, or datum. For example if we have one layer depicting the 40 fire behavior fuel models. As with projection on-the-fly, the data frame's GCS defaults to that of the first layer added to the map, which is **North American 1983,.** If we then try to add a fire perimeter shapefile with the **WGS 1984** geographic coordinate system, we get a warning that a geographic transformation may be necessary. A **geographic transformation**, sometimes referred to as a datum transformation, is a set of mathematical formulas for converting coordinates from one datum to another. At this point, you may specify the transformation by clicking the transformations box in the warning dialog box



The following data sources use a geographic coordinate system that is different from the one used by the data frame you are adding the data into:

Data Source	Geographic Coordinate System
FirePerimeter	GCS_WGS_1984

Alignment and accuracy problems may arise unless there is a correct transformation between geographic coordinate systems.

You can use this button to specify or modify the transformation(s) used by this data frame:

The Transformations dialog can also be accessed from the Data Frame Properties dialog's Coordinate Systems tab after you have added the data.

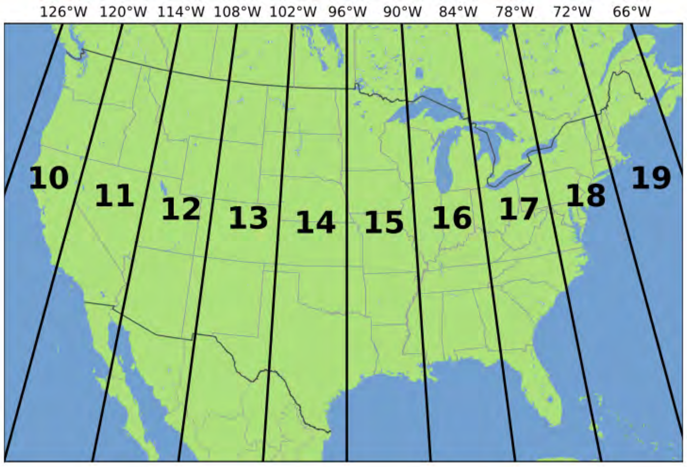
☐ Don't warn me again in this session
☐ Don't warn me again ever

7.4.3 Map Projections & Coordinate Systems

A projected coordinate system can reference the same geographic locations using a Cartesian system, which includes a uniform, linear unit of measure.

Universal Transverse Mercator (UTM)

The UTM system divides the earth into 60 zones, each six degrees of latitude wide. Figure 9 below depicts a simplified view of the UTM zones covering the conterminous United States.



State Plane Coordinate Systems

A good example of a PCS being independent of a particular map projection. **Lambert Conformal Conic** projections are used for greatest in east-west extent, **Transverse Mercator** projections are used for greatest in north-south extent, & the some use an oblique Mercator projection.

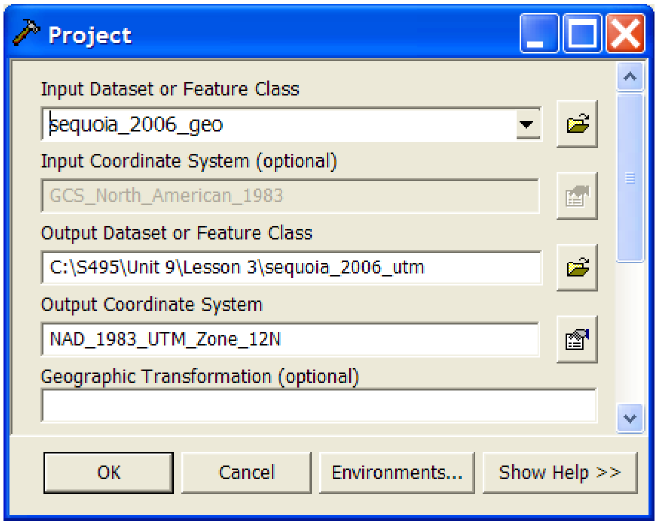
7.4.4 Reprojecting shapefile or arcgrid in ArcGIS

If a shapefile or ascii grid will not display as an overlay on a landscape (lcp) in FARSITE, FLAMMAP, it cannot be used or displayed by those systems. It is most likely using a different coordinate system than the lcp does.

In this case, the file (feature/shapefile or raster/ascii grid) can be re-projected to the same coordinate system so it can be displayed onscreen and used in reference by the landscape editor in FARSITE.

1. Open up a new ArcMap window and add the shapefile or raster file that is stored in the desired projection. *By adding the shapefile (or grid) with the desired projection first, the coordinate system of the Data Frame will default to the desired projection.*
2. Next, add the shapefile that is stored in the other projection.
3. If the ArcToolbox window is not already displayed, click on the ArcToolbox icon to show the ArcToolbox window.
4. In the ArcToolbox window, click on the plus sign next to "Data Management Tools" to expand the selection. Next, click on the plus sign next to "Projections and Transformations" to expand the selection. Next, click on the plus sign next to "Feature" (for shapefiles or "Raster" (for grids) to expand the selection. Double-click on "Project" to open up the tool.

5. In the Project window, under "Input Dataset or Feature Class," select the shapefile/raster grid that is currently stored in the wrong projection. The Input Coordinate System should automatically default to its projection." If none is displayed, that means that there is no prj file accompanying it. If known, it can be specified here.
6. Specify an output shapefile or raster grid under "Output Dataset or Feature Class." Click on the button next to "Output Coordinate System." In the "Spatial Reference Properties" window that pops up, click on the "Import" button. Navigate to and select the shapefile that is stored in desired coordinate system. The new projection properties will load into the "Spatial Reference Properties" window. Click "OK" on the "Spatial Reference Properties" window.



Input Dataset or Feature Class: sequoia_2006_geo
Input Coordinate System (optional): GCS_North_American_1983
Output Dataset or Feature Class: C:\S495\Unit 9\Lesson 3\sequoia_2006_utm
Output Coordinate System: NAD_1983_UTM_Zone_12N
Geographic Transformation (optional):

Click "OK" in the "Project" window to create a new shapefile that is stored in the chosen UTM projection.

If during the re-projection process, the user discovers that the feature or raster does not have a defined projection; one can be added by selecting "Define Projection", also found under "Projections and Transformations".

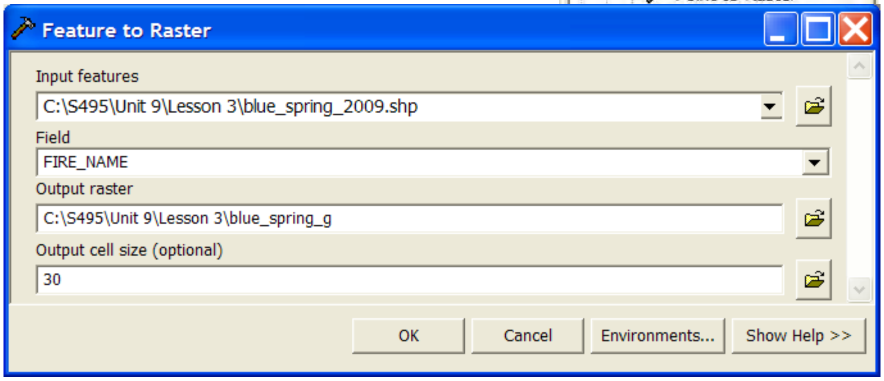
7.4.5 Convert a shapefile to an ASCII raster file

Understanding Raster Data; http://www.fire.org/niftt/released/RasterPrimer.pdf

While shapefiles can be displayed in both FLAMMAP and FARSITE, they cannot be used to make edits to an LCP using the FARSITE Landscape Calculator. In order to be used by the Calculator, a shapefile must be converted to an ASCII Raster. This is a two-step process and can be done in ArcGIS using the ArcToolbox. The first step is to convert the shapefile to a Raster GRID. The final step is to export the Raster GRID as an ASCII Raster.

Part A: Converting a shapefile to a Raster GRID file

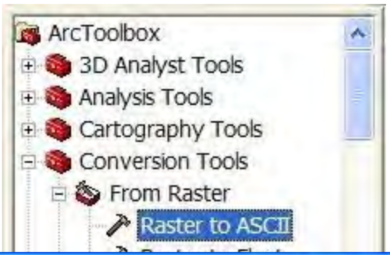
1. Within ArcMap or ArcCatalog, click on the ArcToolbox icon .
2. In ArcToolbox, click on the plus sign next to "Conversion Tools" to expand the selection. Next, click on the plus sign next to "To Raster" to expand the selection. Double-click on "Feature to Raster" to open up the tool.
3. In the "Feature to Raster" tool window, below "Input Features," select or navigate to the shapefile that you want to convert. Under "Field" select a non-numeric attribute field.
4. Below "Output Raster," specify the name and location of the output raster GRID file. Keep in mind that the names of raster GRID files have a maximum length of 13 characters.
5. Under "Output cell size," specify an output cell size of 30 meters so that the output grid resolution is consistent with the resolution of the FARSITE LCP. Click "OK" to create the raster GRID file.

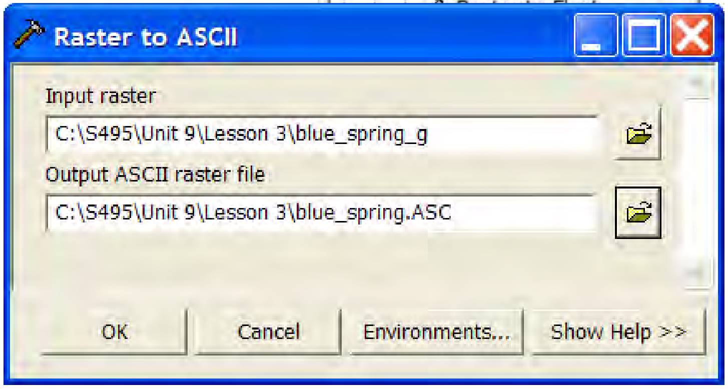


Input features
C:\S495\Unit 9\Lesson 3\blue_spring_2009.shp
Field
FIRE_NAME
Output raster
C:\S495\Unit 9\Lesson 3\blue_spring_g
Output cell size (optional)
30

Part B: Converting a Raster GRID to an ASCII Raster file

1. In ArcToolbox, click on the plus sign next to "Conversion Tools" to expand the selection. Next, click on the plus sign next to "From Raster" to expand the selection. Double-click on "Raster to ASCII" to open up the tool.
2. Below "Input raster," select the raster GRID file you created in Part A. Under "Output ASCII raster file," specify an output name and location. Be sure to specify the file type as .ASC. Click "OK" to create the ASCII Raster file.





Input raster
C:\S495\Unit 9\Lesson 3\blue_spring_g
Output ASCII raster file
C:\S495\Unit 9\Lesson 3\blue_spring.ASC

7.5 Google Earth Fire Applications

7.5.1 National Weather Service Data

The National Weather Service produces several data sets that are available in formats available to import into Geographic Information Systems (GIS). GIS is a collection of computer hardware, software, and geographic data for capturing, managing, analyzing, and displaying all forms of geographically referenced information. It takes the numbers and words from the rows and columns in databases and spreadsheets and puts them on a map

- NDFD Forecast Graphic: http://www.srh.noaa.gov/gis/kml/webpageforecast/coordinateforecast.kmz
- National Weather Data in KML/KMZ Format: http://www.srh.noaa.gov/gis/kml/index.htm

7.5.2 Geospatial Equipment and Technology Application (GETA) Group Common Operating Picture (COP)

The (GETA) Group is a growing circle of people who are interested in experiential training, incident management, and geospatial technology in general. Their website (http://geta.firenet.gov/) provides the user links within the Navigation Tabs to the left will navigate to sub-pages that go into further detail about the training and incident management applications provided.

- ***Common Operating Picture, or COP (http://geta.firenet.gov/incident-applications/c-c)***

  A Common Operating Picture is a single identical display of relevant operational information shared by more than one command. A COP facilitates collaborative planning and assists all incident responders to achieve situational awareness.

  Incident responders have the ability with networked mobile devices to show what they are seeing from an incident anywhere; terrain matched photos, video clips, incident specific locations (helispots, water sources, spot fires, dozer line, fire perimeter, etc.) and text messages all on a geospatial platform.

  Meanwhile all incident information is simultaneously viewed and updated at the Incident Command Post, helibase, and local unit offices or being able to brief the public using near real-time information.

  This page will outline ideas and working examples of how to use a Geospatial viewing platform as an incident management planning and operational tool.

  GETA Group focuses on a ground-up approach to developing a Common Operating Picture. In other words, we want incident responders to decide how the tool works best for them.

  For the last year GETA Group has worked with partners in the Northern Rockies, Pacific North-West, South-West, Southern Areas and the National Interagency Fire Center (NIFC) to develop the infrastructure for a Google Earth based National Fire COP.

  Included in the National Fire COP is the ability for Geographic Areas down to an individual unit to build or incorporate data that specifically pertains to the individual situation for those areas.

  In the National Fire COP users will find the:

  ✓ Northern Rockies COP
  ✓ Pacific Northwest COP
  ✓ Southwest COP
  ✓ Southern COP
  ✓ Texas Forest Service COP

  The National Fire COP can be downloaded by clicking HERE (http://sites.google.com/a/firenet.gov/cop/home/national-level/NationalFireCOPTestNetlink.kmz?attredirects=0).

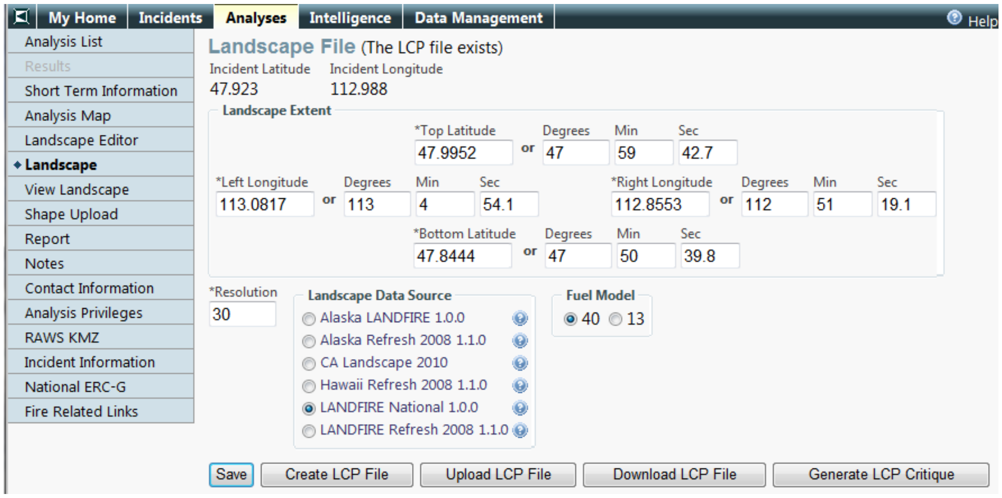
7.5.3 Finding a section, township, and range in Google Earth:

- ✓ Navigate to the Earth Point website (http://www.earthpoint.us/townships.aspx).
- ✓ Then scroll down to the middle of the page to the section called **Convert Township, Range, and Section to Latitude and Longitude**
- ✓ Select the appropriate state, meridian, township range and section from the drop-down menus.
- ✓ Click **Fly to on Google Earth**
- ✓ You can now view the terrain in the section of interest to gather information.

7.5.4 Overlay a GeoTIFF image

This handy trick allows the user to drape a georeferenced TIFF file over the 3D landscape displayed in Google Earth. The example here utilizes WFDSS to obtain the landscape file and its georeferencing coordinates and FLAMMAP to produce the TIFF image. A third tool, an image editor, is required to crop the image.

1. ***Obtain georeferenced landscape (lcp) file***. Login to WFDSS and navigate to an analysis that includes the landscape edits and analysis area of interest.



Landscape File (The LCP file exists)

Incident Latitude 47.923
Incident Longitude 112.988

Landscape Extent
*Top Latitude 47.9952 or Degrees 47 Min 59 Sec 42.7
*Left Longitude 113.0817 or Degrees 113 Min 4 Sec 54.1
*Right Longitude 112.8553 or Degrees 112 Min 51 Sec 19.1
*Bottom Latitude 47.8444 or Degrees 47 Min 50 Sec 39.8

*Resolution 30

Landscape Data Source
○ Alaska LANDFIRE 1.0.0
○ Alaska Refresh 2008 1.1.0
○ CA Landscape 2010
○ Hawaii Refresh 2008 1.1.0
● LANDFIRE National 1.0.0
○ LANDFIRE Refresh 2008 1.1.0

Fuel Model
● 40 ○ 13

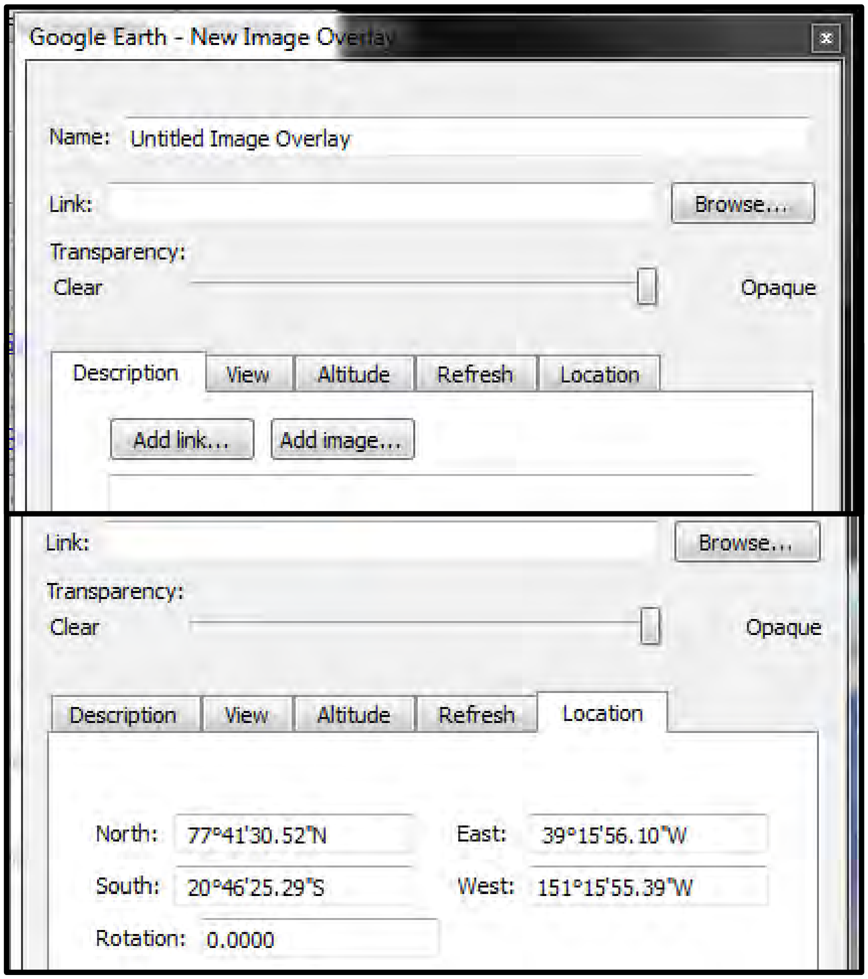
   - ✓ In the selected analysis, select "Landscape" on the left side menu.
   - ✓ Once the heading says "(The LCP file exists), click the Download LCP File button on the bottom row.
   - ✓ Note the top and bottom latitudes and the left and right longitudes from the Landscape File screen.
   - ✓ Also, note the resolution (30 m). If a larger area is needed, increase the resolution to 60 or 90 m. The larger the file, the more difficult it is for Google Earth and your computer to display the image.
2. ***Display the Landscape***. This example will use the fuel layer, but the process could be used to overlay any of the landscape themes. Simply choose to display the desired lcp them in the FLAMMAP window before continuing the process.
   - ✓ Open FLAMMAP and open the landscape just downloaded for display
   - ✓ Right-click on the displayed theme and select "full screen" from the menu that appears. It is important that the full extent is displayed to match the coordinates captured from WFDSS in step 1.
3. ***Save Display as a TIFF file.*** Right-click on the displayed theme again, this time choosing "Save as" and saving the file after selecting TIFF (*.TIF, *.TIFF) as the "Save as type".
4. ***Crop image to exclude white space on right side of image***.
   - ✓ Open the TIFF in an image editor, such as Microsoft Office Picture Manager.
   - ✓ Clip out the white area to the right. Crop it *as close as you can without clipping any of the fuel model image*. You may have to zoom in or crop it twice to be precise.

(Step 5 on next page)

5. ***Add TIFF to Google Earth as an Image Overlay*.**

- ✓ Open Google Earth.
- ✓ From the top line menu, select “Add” and choose “image overlay”.
- ✓ The dialog box to the right provides the opportunity to name the overlay
- ✓ Click on the “Browse…” button and Navigate to the saved TIFF file and open it.
- ✓ Slide the transparency slider bar to the middle of the range to allow the base Google Earth imagery to show through the overlay TIFF image.
- ✓ Click on the “Location” tab and enter the WFDSS coordinates captured earlier (North is “Top Latitude” | West is “Left Longitude” | etc.). Click “OK” when completed.

The image should now be displayed correctly. If you want to readjust the transparency, click on the image beneath “Places” (on the left), right-click, and select “Properties.”



Name: Untitled Image Overlay

Link:

North: 77°41'30.52"N

East: 39°15'56.10"W

South: 20°46'25.29"S

West: 151°15'55.39"W

Rotation: 0.0000

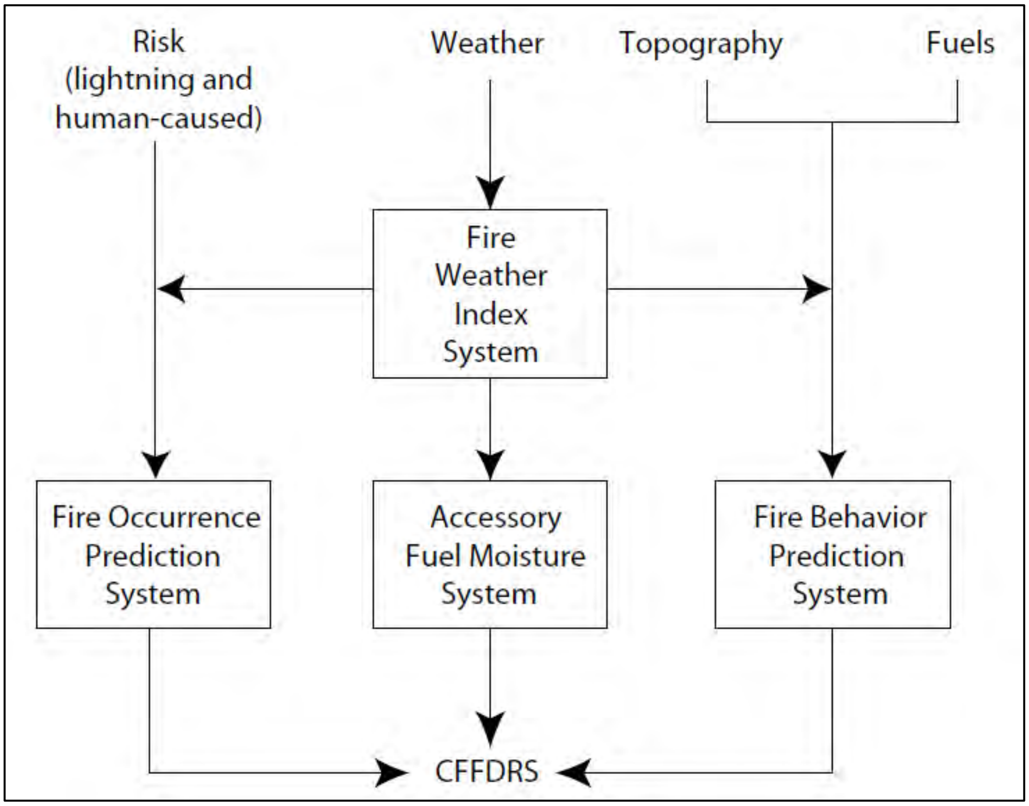
8 Assessment/Prescription/Fire Effects

9 Canadian Forest Fire Danger Rating System (CFFDRS)

Contents

9.1 CFFDRS System Overview

This guide is intended as a reference for US users who may have reason to work with the system in the United States, where English units are primarily used. Keep in mind that the Canadian Forest Service has produced the definitive selection of reference publications and tools.



The Canadian Forest Fire Danger Rating System (CFFDRS) was first conceived in 1968. The Fire Weather Index (FWI) system was the first developed and introduced across Canada in 1970. The Fire Behavior Prediction (FBP) system was first released in 1984. The Fire Occurrence Prediction (FOP) system and Accessory Fuel Moisture system are still in development, with several regional modules operational at this time.

Though this guide attempts to be faithful to the models embedded in CFFDRS, there are a number of adaptations to the standard depictions found in materials produced by the Canadian Forest Service.

Users are advised to review these important adaptations and to consider reviewing the source documentation from the Canadian Forestry Service to compare this guide with original intent.

- Most important among these is the use of English units instead of the standard metric units employed in the system internationally.
- CFFBP models and tools do not expressly identify the relationship between standard wind measurements (10 meters sensor height) used and field measurements at eye level. In this guide, the relationship is featured in the ISI/BISI (sections 9.2.5 and 9.2.6) tables and the area/perimeter tables in 9.3.18 and 9.3.19. The relationship between "airport", "forestry" and winds measured at other heights (e.g. 2m for eye level) is taken from Lawson & Armitage (2008). Relationship between 10-m and 20-ft winds is provided in table in section 9.3. Each user is encouraged to interpret the winds as measured and apply them appropriately for the model used.
- A major adaptation with uncertain validity is the use of flame length for fire intensity outputs in the fire behavior tables. FBP outputs (kW/m) were converted to BTU/ft/sec and then to flame length using the formula:

$$Flame\ Length = .45 * "BTU/Ft/Sec"\text{^}.46$$

The table below identifies the CFFBP Fire intensity thresholds in kW/m and the corresponding values in English units and flame length in feet. These thresholds are consistent with commonly held flame length thresholds for fire safety interpretations.

Fire Intensity		Flame Length
kW/m	BTU/ft/sec	Feet
10	3	1
500	145	4
2000	578	8
4000	1156	12
10000	2891	18

9 Canadian Forest Fire Danger Rating System (CFFDRS)

Most of these references, resources, and tools can be found at http://www.frames.gov/cffdrs.

9.1.1 Key References & Training Resources

Lawson, B.D.; Armitage, O.B. 2008. Weather guide for the Canadian Forest Fire Danger Rating System. Nat. Resour. Can., Can. For. Serv., North. For. Cent., Edmonton, AB.

Van Wagner, C.E. 1987. Development and structure of the Canadian Forest Fire Weather Index System. Canadian Forest Service, Ottawa, Ont. Forest Technical Report 35.

Taylor, Steve, Lawson, Bruce, and Sherman, Karen. Introduction to the Canadian Forest Fire Weather Index System, online video. Canadian Forest Service. 22 min.

Understanding the Fire Weather Index System Interactive Training and Reference, CD

Forestry Canada Fire Danger Group. 1992. Development and structure of the Canadian Forest Fire Behavior Prediction System. Information Report ST-X-3. Ottawa, Ontario, Canada: Forestry Canada, Science and Sustainable Development Directorate. 63 p.

Hirsch, K.G. 1996. Canadian Forest Fire Behavior Prediction (FBP) System User's Guide. Natural Resources Canada, Canadian Forest Service, Northern Forestry Centre Special Report 7. Edmonton, Alberta.

De Groot, W.J., 1993, Examples of Fuel Types in the Canadian Forest Fire Behavior Prediction (FBP) System, Forestry Canada. Poster.

Canadian Forest Fire Behavior Prediction System Interactive Training and Reference, CD,

Tymstra, C.; Bryce, R.W.; Wotton, B.M.; Taylor, S.W.; Armitage, O.B. 2010. Development and structure of Prometheus: the Canadian Wildland Fire Growth Simulation Model. Nat. Resour. Can., Can. For. Serv., North. For. Cent., Edmonton, AB. Inf. Rep. NOR-X-417

Wotton, B.M.; Alexander, M.E.; Taylor, S.W. 2009. Updates and Revisions to the 1992 Canadian Forest Fire Behavior Prediction System. Natural Resources Canada, Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario, Canada. Information Report GLC-X-10, 45p.

9.1.2 Operational Tools

Canadian Forestry Service. 1984. Tables for the Canadian Forest Fire Weather Index System. Environment Canada, Canadian Forestry Service, Forest Technical Report 25.

Taylor, S.W., Pike, R.G., Alexander, M.E. 1997. Field Guide to the Canadian Forest Fire Behavior Prediction (FBP) System. Fire Management Network, Canadian Forest Service, Northern Forestry Centre. Special Report 11.

Kidnie, S.M., Wotton, M.M., Droog, W.N. 2010. Field Guide for Predicting Fire Behaviour in Ontario’s Tallgrass Prairie.

RunCFFDRS.exe is a stand-alone executable file produced by the Canadian Forest Service that includes documentation and references for the entire system as well as basic calculators for the FWI and FBP systems.

Prometheus, the CFFDRS Geospatial Fire Growth Model, is supported by the Canadian Interagency Forest Fire Center(CIFFC) and its members. It includes a separate FWI/FBP calculator as part of its installation.

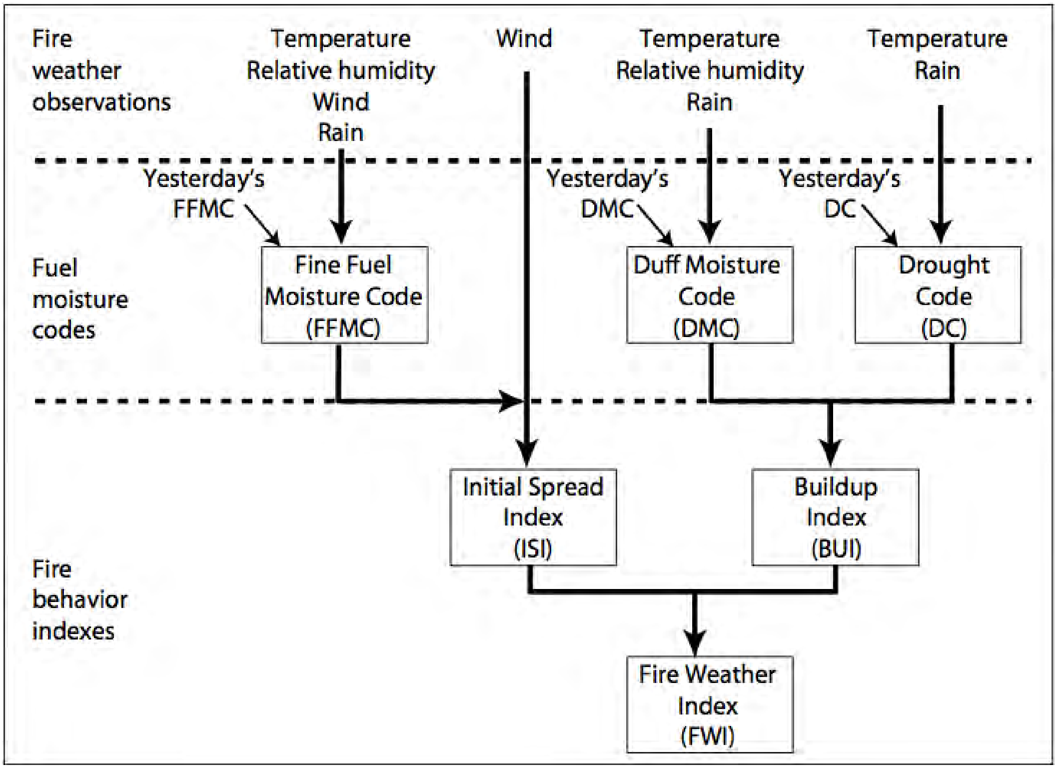
9.2 Fire Weather Index (FWI) System

9.2.1 System Overview and Structure

Analogous in concept to the National Fire Danger Rating System (NFDRS), the Fire Weather Index System depends solely on weather readings.

CFFDRS calculates FWI codes and indices based on a single "standard" fuel type that can be described as a generalized pine forest, most nearly jack pine and lodgepole pine.

Daily FWI weather inputs are collected at 1200 LST, with the calculated codes and indices intended to represent conditions at peak afternoon conditions.



There are three (3) ***fuel moisture codes*** calculated from these basic weather observations. Unlike the NFDRS fuel moistures, the FWI fuel moisture codes increase as fuels get drier. Like other accounting systems, the FWI system combines knowledge of yesterday's (or last hour's) fuel moisture conditions with the influence of air temperature, atmospheric moisture, wind, and precipitation since then.

- The ***Fine Fuel Moisture Code (FFMC)*** represents fuel moisture of forest litter fuels under the shade of a forest canopy. It is intended to represent moisture conditions for the equivalent of 16-hour timelag fuels. It ranges from 0-101. Subtracting the FFMC value from 100 can provide an estimate for the equivalent fuel moisture content, generally at the upper end when FFMC values are roughly above 80.
- The ***Duff Moisture Code (DMC)*** represents fuel moisture of decomposed organic material underneath the litter. System designers suggest that it is represents moisture conditions for the equivalent of 15-day (or 360 hr) timelag fuels. It is unitless and open ended. It may provide insight to live fuel moisture stress.
- The ***Drought Code (DC)***, much like the Keetch-Byrum Drought Index, represents drying deep into the soil. It approximates moisture conditions for the equivalent of 53-day (1272 hour) timelag fuels. It is unitless, with a maximum value of 1000. Extreme drought conditions in the Eastern Upper Peninsula have produced DC values near 650.

Similarly, there are three (3) ***fire behavior indices*** intended to represent spread, fuel consumption/heat release, and fire intensity.

- The ***Initial Spread Index (ISI)*** is analogous to the NFDRS Spread Component (SC). It integrates fuel moisture for fine dead fuels and surface windspeed to estimate a spread potential. It is unitless and open ended.
- The ***Buildup Index (BUI)*** is analogous to the NFDRS Energy Release Component (ERC). It combines the current DMC and DC to produce an estimate of potential heat release in heavier fuels. It is unitless and open ended.
- The ***Fire Weather Index (FWI)*** integrates current ISI and BUI to produce a unitless index of general fire intensity potential. Again, unitless and open ended. It is analogous to NFDRS Burning Index (BI).

9.2.2 Obtaining Fire Weather Index (FWI) Inputs

Fire Weather Index (FWI) Fine Fuel Moisture Code (FFMC), Initial Spread Index (ISI) and Buildup Index (BUI) are used as direct inputs to the Canadian Forest Fire Behavior Prediction (CFFBP) system. Because daily FWI codes and indices are calculated using standardized weather observations, collected consistently at fixed locations each day at 1200 Local Standard Time, they may not accurately reflect current conditions and the resulting fire behavior. However, in most cases, these daily values are starting points for local assessments.

Rather than provide detail on how to calculate these daily values, it makes more sense to identify ways to obtain current and forecast values from RAWS weather records and then to make adjustments for onsite conditions:

Sources of FWI Codes and Indices

In Alaska and in the Lake States, CFFDRS has been implemented for fire management users. A variety of weather and CFFDRS records are available publicly at the following locations:

- Alaska Interagency Coordination Center Fire Weather & Fuels/Fire Danger records are available at http://fire.ak.blm.gov/aicc.php.
- Michigan, Minnesota, and Wisconsin CFFDRS records can be found at http://glffc.utah.edu/.

If there is interest in calculating CFFDRS outputs in other areas, the user could consider obtaining weather records from appropriate RAWS or other data source and importing them into Firefamily Plus, where daily FWI codes and indices can be calculated, displayed and exported.

Adjusting FWI Outputs for local conditions

- ***Adjust FFMC*** for each location and time period of interest using Slope Adjustments in section 9.2.3 and Diurnal Adjustment in section 9.2.4. Tables and slope. Diurnal adjustments should be completed first.
- Using a moisture probe to evaluate 10 hr fuels in the field may provide an effective ***estimate for current FFMC***. Simply subtract the estimated fuel moisture from 100 to derive current FFMC.
- ***Adjust Initial Spread Index (ISI)*** for current conditions by using adjusted FFMC and current windspeed observation from the field using the table in section 9.2.5 for ISI and 9.2.6 for backing ISI.
- ***The Fire Weather Index (FWI)*** itself is highly dependent on windspeed and may also be adjusted, using the table in section 9.2.7.

Estimating Windspeed for CFFDRS Calculations

CFFDRS uses standard fire weather observations collected at 10 meters above prevailing cover. The following table, from the Field Guide for Predicting Fire Behavior in Ontario's Tallgrass Prairie (Kidnie et.al.2010), provides a means for converting the wind measurement or predictions to the "Forestry 10m winds" used in CFFDRS calculations.

Forestry 10 m winds (km/h)	Height of wind measurement (m)										Airport 10 m winds (km/h)
	1	2	3	4	5	6	7	8	9	10	
1	1	1	1	1	1	1	1	1	1	1	2
2	1	2	2	2	2	2	2	2	2	2	3
3	2	2	2	3	3	3	3	3	3	3	5
4	3	3	3	3	4	4	4	4	4	4	7
5	3	4	4	4	5	5	5	5	5	5	8
6	4	5	5	5	5	5	6	6	6	6	10
7	5	5	6	6	6	6	7	7	7	7	12
8	5	6	7	7	7	7	8	8	8	8	13
9	6	7	7	8	8	8	9	9	9	9	15
10	7	8	8	9	9	9	10	10	10	10	17
12	8	9	10	10	11	11	12	12	12	12	20
14	9	11	11	12	13	13	14	14	14	14	23
16	11	12	13	14	15	15	16	16	16	16	27
18	12	14	15	16	16	16	17	17	18	18	30
20	14	15	16	17	18	18	19	19	20	20	33
25	17	19	20	22	23	23	24	24	25	25	42
30	20	23	25	26	27	27	29	29	30	30	50
35	24	27	29	30	32	32	34	34	35	35	58
40	27	31	33	34	36	36	39	39	40	40	67
45	30	34	37	39	41	41	44	44	45	45	75
50	34	38	41	43	45	45	49	49	50	50	83

Eye level winds could be compared to those from the 2 m Height of wind measurement column. In the same way, winds recorded at airports and very large openings can be represented by the Airport 10m winds column on the right. Either can be converted by following the row to the left and reading the value in the "Forestry" column.

9.2.3 Slope Adjustments

Slope Equivalent windspeeds

		Slope, %					
Fuel Type		10	20	30	40	50	60
C-1		1	2	3	4	5	6
C-2		2	5	7	11	14	18
C-3		1	2	4	5	7	9
C-4		2	5	7	11	14	18
C-5		1	2	3	4	6	7
C-6		1	3	4	6	8	10
C-7		1	3	6	8	11	13
D-1		2	4	7	10	13	16
M-1		3	6	9	12	16	20
M-2		2	5	8	11	14	18
M 3	30%DF	2	4	7	10	13	16
	60%DF	2	5	8	11	15	20
	100%DF	2	6	9	13	18	25
M 4	30%DF	1	3	5	7	9	11
	60%DF	1	4	6	8	11	14
	100%DF	2	5	8	11	16	20
S-1		2	5	9	12	17	22
S-2		2	4	7	10	13	17
S-3		1	2	4	6	8	10
O-1a		2	5	8	11	15	20
O-1b		2	4	7	10	13	16

Find the fuel type identifier, and then move horizontally to the most appropriate slope column to read the **slope equivalent windspeed**. If the FFMC is ≥ 95 and slope is ≥ 50%, add 3 mph to the table value.

Slope equivalent windspeed varies with FFMC. Those given above are for FFMC 90 and are accurate to ± 1-2 mph of the true value for FFMC 90-96. The values for FFMC ≥ 95 and slope ≥ 50% may be underestimated by ≥ 3 mph.

M-1 and M-2 values are for 50:50 conifer/hardwood mixture. M-3 and M-4 modifiers are percent dead fir (%DF).

FFMC Slope-Aspect Adjustments

FFMC	1-15%				16-30%				31-45%				46-60%			
Flat	N	E	S	W	N	E	S	W	N	E	S	W	N	E	S	W
80	78	79	82	80	77	78	82	80	74	77	83	81	72	76	84	81
82	80	81	84	82	79	80	84	82	76	79	85	83	74	78	85	83
84	83	83	85	84	81	82	86	84	79	81	87	84	76	80	88	84
86	85	85	87	86	83	84	88	86	81	83	89	86	78	82	90	86
87	86	86	88	87	84	85	89	87	82	84	90	87	80	83	90	87
88	87	87	89	88	85	87	90	88	83	86	91	88	82	85	91	88
89	88	88	90	89	87	88	91	89	85	87	91	89	83	86	92	89
90	89	89	91	90	88	89	92	90	86	88	92	90	84	87	93	90
91	90	90	92	91	89	90	92	91	87	89	93	91	86	88	93	91
92	91	91	93	92	90	91	93	92	88	90	94	92	87	89	94	92
93	92	92	94	93	91	92	94	93	89	91	95	93	88	90	95	93
94	93	93	95	94	92	93	95	94	91	92	96	94	90	92	96	94

Determine the slope and aspect of the area you are projecting spread in, find the FFMC, then move horizontally to the column that best describes the prediction point and read adjusted FFMC. These adjustments should be used with caution as they have not been rigorously tested. They should only be applied in slash and open fuel types on clear days in March, April, August, September, or October between 1200 and 2000 LST.

9.2.4 Diurnal FFMC Adjustments

DIURNAL FFMC ADJUSTMENTS FOR 1300-0659 DAYLIGHT SAVINGS TIME

Local Daylight Time Today				STD FFMC	Local Daylight Time Today						Local Daylight Time Tomorrow							
1300	**1400**	**1500**	**1600**	**1700**	**1800**	**1900**	**2000**	**2100**	**2200**	**2300**	**0000**	**0100**	**0200**	**0300**	**0400**	**0500**	**0600**	**0659**
41	43	46	48	50	51	52	53	53	52	51	50	49	48	47	46	45	44	43
48	52	55	57	60	61	62	62	62	61	59	58	56	55	54	52	51	50	49
53	56	60	62	65	66	67	66	66	64	63	61	60	58	57	56	54	53	55
57	61	65	68	70	70	71	70	69	68	66	65	63	62	60	59	58	56	57
63	67	71	73	75	75	75	74	73	72	70	69	67	66	64	63	61	60	58
64	68	72	74	76	76	76	75	74	72	71	69	68	66	65	64	62	61	59
66	69	73	75	77	77	77	76	75	73	72	70	69	67	66	64	63	62	60
67	71	75	76	78	78	78	77	76	74	72	71	69	68	67	65	64	63	61
69	72	76	78	79	79	78	77	76	75	73	72	70	69	67	66	65	63	62
71	74	77	79	80	80	79	78	77	76	74	73	71	70	68	67	66	64	63
74	76	79	80	81	81	80	79	78	77	75	73	72	71	69	68	66	65	64
76	78	80	81	82	82	81	80	79	77	76	74	73	71	70	69	67	66	65
78	80	81	82	83	83	82	81	80	78	77	75	74	72	71	70	68	67	66
80	81	82	83	84	84	83	82	81	79	78	76	75	73	72	70	69	68	67
82	82	83	84	85	85	84	83	82	80	79	77	76	74	73	71	70	69	68
83	84	85	85	86	86	85	84	83	81	79	78	77	75	74	72	71	70	68
84	85	86	86	87	87	86	85	83	82	80	79	78	76	75	73	72	71	70
85	86	87	87	88	88	87	86	84	83	81	80	79	77	76	74	73	72	71
86	87	88	89	89	89	88	87	85	84	82	81	80	78	77	75	74	73	72
88	88	89	90	90	90	89	88	86	85	83	82	81	79	78	77	75	74	73
89	89	90	91	91	91	90	89	87	86	84	83	82	80	79	78	76	75	74
90	90	91	92	92	92	91	90	88	87	85	84	83	81	80	79	77	76	75
91	91	92	93	93	93	92	91	89	88	86	85	84	82	81	80	79	77	76
92	93	93	94	94	94	93	92	90	89	88	86	85	84	82	81	80	79	77
93	94	94	95	95	95	94	93	91	90	89	87	86	85	83	82	81	80	79
94	95	95	96	96	96	95	94	92	91	90	88	87	86	85	84	82	81	80
95	96	96	97	97	97	96	95	93	92	91	90	88	87	86	85	84	83	81
96	97	97	98	98	98	97	96	94	93	92	91	90	88	87	86	85	84	83
97	98	98	99	99	99	98	97	95	94	93	92	91	90	88	87	86	85	84
98	99	99	100	100	100	99	98	96	95	94	93	92	91	90	89	88	86	85
1300	**1400**	**1500**	**1600**	**1700**	**1800**	**1900**	**2000**	**2100**	**2200**	**2300**	**2400**	**0100**	**0200**	**0300**	**0400**	**0500**	**0600**	**0659**

DIURNAL FFMC ADJUSTMENT TABLE FOR 0700-1259 LOCAL DAYLIGHT SAVINGS TIME

Hour LDT	RH %	Yesterday's Standard Fine Fuel Moisture Code (FFMC)																									
		45-54	**58-62**	**63-67**	**68-72**	**73-75**	**76**	**77**	**78**	**79**	**80**	**81**	**82**	**83**	**84**	**85**	**86**	**87**	**88**	**89**	**90**	**91**	**92**	**93**	**94**	**95**	**96**
700	**<68**	54	57	59	62	65	66	66	67	68	69	69	70	71	72	73	74	75	76	78	79	80	81	83	84	86	87
	68-87	48	53	55	58	62	63	63	64	65	66	66	67	68	69	70	71	72	73	74	75	76	77	78	80	81	82
	>87	43	49	52	55	59	60	60	61	62	63	64	65	66	67	67	68	69	71	72	73	74	75	76	77	79	80
800	**<58**	56	60	62	64	67	68	69	69	70	71	72	72	73	74	75	76	77	78	79	80	81	83	84	85	87	88
	58-77	49	54	57	60	63	64	65	66	67	67	68	69	70	71	72	73	74	75	76	77	78	79	81	82	83	84
	>77	44	49	53	56	60	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	77	78	79	81	82
900	**<48**	59	63	65	67	70	70	71	72	72	73	74	75	75	76	77	78	79	80	81	82	83	84	85	86	88	89
	48-67	50	55	58	61	65	66	67	68	68	69	70	71	72	73	74	75	76	77	78	79	81	82	83	84	85	87
	>67	45	50	53	57	61	61	62	63	64	65	66	67	68	69	70	71	72	73	74	76	77	78	79	81	82	84
1000	**<43**	64	67	69	71	74	74	75	75	76	77	77	78	79	80	80	81	82	83	84	85	86	87	88	89	90	91
	43-62	56	60	63	66	69	70	71	72	72	73	74	75	76	77	77	78	79	80	81	82	83	85	86	87	88	89
	>62	51	56	58	62	65	66	66	67	68	69	70	70	71	72	73	74	75	76	77	78	79	80	82	83	84	85
1100	**<38**	70	72	74	76	78	78	79	79	80	81	81	82	82	83	84	85	85	86	87	88	89	90	91	92	93	94
	38-57	62	66	68	71	74	75	75	76	77	77	78	79	79	80	81	82	83	84	85	86	87	88	89	90	91	92
	>57	57	61	64	67	70	70	71	72	72	73	74	74	75	76	77	77	78	79	80	81	82	83	84	85	86	87
1200	**<35.5**	76	78	79	80	82	83	84	84	85	85	86	86	87	87	88	89	89	90	90	91	91	92	92	93	93	94
	35-54	69	72	74	76	79	80	80	81	82	82	83	83	84	85	85	86	87	87	88	88	89	89	90	91	91	92
	>54.5	64	68	70	72	75	76	76	77	77	78	78	79	80	80	81	81	82	82	83	84	84	85	85	86	86	87
1259	**<33**	82	83	84	85	87	87	88	88	88	89	89	89	90	90	90	91	91	91	92	92	92	92	93	93	93	94
	33-52	77	79	81	82	84	84	85	85	86	86	86	87	87	88	88	88	89	89	89	90	90	90	91	91	91	92
	>52	72	75	77	78	80	81	81	81	82	82	82	83	83	83	83	84	84	84	85	85	85	86	86	86	86	87

If Onsite weather is not consistent with that used to determine daily FWI codes & indices, or if weather changes significantly after daily observation, onsite measurement of 10 hour fuel moisture may be used as a reference to current FFMC. This table represents a comparison between calculated daily FFMC and manual NFDRS fuel stick weights from 7 NFDRS manual recording stations from Michigan prior to RAWS establishment.

10 Hr	5	6	7	8	9	10	11	12	13	14
FFMC	96	94	93	91	90	88	87	86	84	83

9.2.5 Initial Spread Index (ISI)

ISI		**Effective Windspeed** (in miles per hour) **EL Open** in at Eye Level in Open,																			
10 Meter		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
EL Open		1	1	2	3	3	4	5	5	6	7	7	8	9	9	10	11	11	12	13	13
FINE FUEL MOISTURE CODE (FFMC)	75	0.8	0.9	1	1.1	1.1	1.2	1.4	1.5	1.6	1.7	1.9	2	2.2	2.4	2.6	2.8	3	3.3	3.6	3.9
	76	0.9	1	1	1.1	1.2	1.3	1.4	1.6	1.7	1.8	2	2.2	2.3	2.5	2.7	3	3.2	3.5	3.8	4
	77	0.9	1	1.1	1.2	1.3	1.4	1.5	1.7	1.8	2	2.1	2.3	2.5	2.7	2.9	3.2	3.5	3.7	4	4
	78	1	1.1	1.2	1.3	1.4	1.5	1.7	1.8	2	2.1	2.3	2.5	2.7	2.9	3.2	3.4	3.7	4	4	5
	79	1.1	1.2	1.3	1.4	1.5	1.7	1.8	2	2.1	2.3	2.5	2.7	3	3.2	3.5	3.8	4	4	5	5
	80	1.2	1.3	1.5	1.6	1.7	1.8	2	2.2	2.4	2.6	2.8	3	3.3	3.5	3.8	4	5	5	5	6
	81	1.4	1.5	1.6	1.8	1.9	2.1	2.2	2.4	2.6	2.9	3.1	3.4	3.6	3.9	4	5	5	6	6	6
	82	1.5	1.7	1.8	2	2.1	2.3	2.5	2.7	3	3.2	3.5	3.8	4	4	5	5	6	6	7	7
	83	1.8	1.9	2.1	2.2	2.4	2.6	2.8	3.1	3.4	3.6	3.9	4	5	5	5	6	6	7	8	8
	84	2	2.2	2.3	2.5	2.8	3	3.2	3.5	3.8	4	5	5	5	6	6	7	7	8	9	9
	85	2.3	2.5	2.7	2.9	3.2	3.4	3.7	4	4	5	5	6	6	7	7	8	8	9	10	11
	86	2.6	2.8	3.1	3.3	3.6	3.9	4	5	5	5	6	6	7	8	8	9	10	10	11	12
	87	3	3.3	3.6	3.9	4	5	5	5	6	6	7	7	8	9	9	10	11	12	13	14
	88	3.5	3.8	4	5	5	5	6	6	7	7	8	9	9	10	11	12	13	14	15	16
	89	4	4	5	5	6	6	7	7	8	8	9	10	11	12	13	14	15	16	17	19
	90	5	5	6	6	6	7	8	8	9	10	11	11	12	13	15	16	17	19	20	22
	91	5	6	6	7	7	8	9	10	10	11	12	13	14	15	17	18	20	21	23	25
	92	6	7	7	8	9	9	10	11	12	13	14	15	16	18	19	21	23	25	27	29
	93	7	8	8	9	10	11	12	13	14	15	16	17	19	20	22	24	26	28	31	33
	94	8	9	10	10	11	12	13	14	16	17	18	20	22	24	26	28	30	33	35	38
	95	9	10	11	12	13	14	15	17	18	20	21	23	25	27	29	32	34	37	40	44
	96	11	12	13	14	15	16	18	19	21	22	24	26	29	31	34	36	39	43	46	50

9.2.6 Backing Initial Spread Index (BISI)

BISI		**Effective Windspeed** (in miles per hour) **EL Open** in at Eye Level in Open,																			
10 Meter		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
EL Open		**1**	**1**	**2**	**3**	**3**	**4**	**5**	**5**	**6**	**7**	**7**	**8**	**9**	**9**	**10**	**11**	**11**	**12**	**13**	**13**
FINE FUEL MOISTURE CODE (FFMC)	**75**	0.7	0.7	0.6	0.6	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	76	0.7	0.7	0.6	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2
	77	0.8	0.7	0.7	0.6	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2
	78	0.9	0.8	0.7	0.7	0.6	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2
	79	1	0.9	0.8	0.7	0.7	0.6	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.2
	80	1	1	0.9	0.8	0.8	0.7	0.6	0.6	0.6	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.2
	81	1.2	1.1	1	0.9	0.8	0.8	0.7	0.7	0.6	0.6	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3
	82	1.3	1.2	1.1	1	1	0.9	0.8	0.7	0.7	0.6	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3
	83	1.5	1.4	1.3	1.2	1.1	1	0.9	0.8	0.8	0.7	0.7	0.6	0.6	0.5	0.5	0.4	0.4	0.4	0.3	0.3
	84	1.7	1.6	1.4	1.3	1.2	1.1	1	1	0.9	0.8	0.8	0.7	0.6	0.6	0.5	0.5	0.5	0.4	0.4	0.4
	85	1.9	1.8	1.7	1.5	1.4	1.3	1.2	1.1	1	0.9	0.9	0.8	0.7	0.7	0.6	0.6	0.5	0.5	0.5	0.4
	86	2.2	2.1	1.9	1.8	1.6	1.5	1.4	1.3	1.2	1.1	1	0.9	0.8	0.8	0.7	0.7	0.6	0.6	0.5	0.5
	87	2.6	2.4	2.2	2	1.9	1.7	1.6	1.5	1.4	1.2	1.1	1.1	1	0.9	0.8	0.8	0.7	0.7	0.6	0.6
	88	3	2.7	2.5	2.3	2.2	2	1.8	1.7	1.6	1.4	1.3	1.2	1.1	1	1	0.9	0.8	0.8	0.7	0.6
	89	3.4	3.2	2.9	2.7	2.5	2.3	2.1	1.9	1.8	1.7	1.5	1.4	1.3	1.2	1.1	1	0.9	0.9	0.8	0.7
	90	4	3.6	3.4	3.1	2.9	2.6	2.4	2.2	2.1	1.9	1.8	1.6	1.5	1.4	1.3	1.2	1.1	1	0.9	0.9
	91	5	4	3.9	3.6	3.3	3	2.8	2.6	2.4	2.2	2	1.9	1.7	1.6	1.5	1.4	1.3	1.2	1.1	1
	92	5	5	5	4	3.8	3.5	3.2	3	2.8	2.5	2.3	2.2	2	1.8	1.7	1.6	1.4	1.3	1.2	1.1
	93	6	6	5	5	4	4	3.7	3.4	3.2	2.9	2.7	2.5	2.3	2.1	2	1.8	1.7	1.5	1.4	1.3
	94	7	6	6	6	5	5	4	4	3.7	3.4	3.1	2.9	2.6	2.4	2.3	2.1	1.9	1.8	1.6	1.5
	95	8	7	7	6	6	5	5	5	4	3.9	3.6	3.3	3	2.8	2.6	2.4	2.2	2	1.9	1.7
	96	9	8	8	7	7	6	6	5	5	4	4	3.8	3.5	3.2	3	2.7	2.5	2.3	2.1	2

9.2.7 Fire Weather Index (FWI)

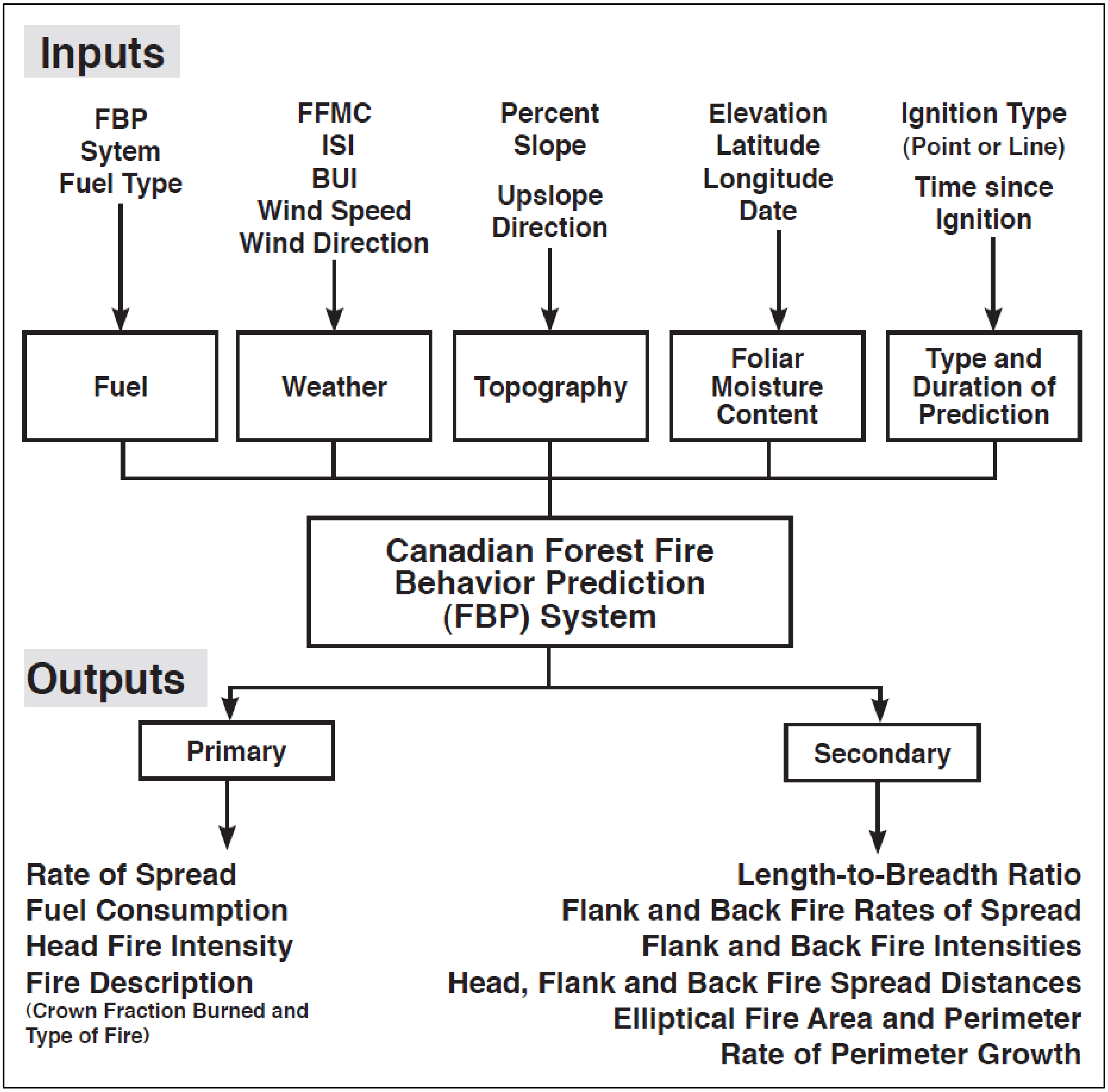
FWI		BUILDUP INDEX (BUI)																									
		1	5	8-12	13-17	18-22	23-27	28-32	33-37	38-42	43-37	48-52	53-57	58-62	63-67	68-72	73-77	78-84	85-94	95-104	105-114	115-124	125-134	135-144	145-154	155-164	165-174
INITIAL SPREAD INDEX (ISI)	**1**	0	0	1	1	1	1	2	2	2	3	3	3	3	4	4	4	4	5	5	5	6	6	6	6	6	7
	2	1	1	2	3	3	4	4	5	5	6	6	6	7	7	8	8	8	9	10	10	11	11	11	12	12	12
	3	1	2	3	4	5	6	6	7	8	8	9	9	10	10	11	11	12	12	13	14	15	15	15	16	16	16
	4	1	3	4	6	7	7	8	9	10	10	11	12	12	13	14	14	15	16	17	17	18	19	19	20	20	20
	5	2	4	5	7	8	9	10	11	12	13	13	14	15	15	16	17	17	18	19	20	21	22	22	23	23	24
	6	3	5	7	8	9	11	12	13	14	14	15	16	17	18	18	19	20	21	22	23	24	25	26	26	27	27
	7	3	5	7	9	11	12	13	14	15	16	17	18	19	20	21	21	22	23	25	26	27	28	28	29	30	30
	8	4	6	8	10	12	13	15	16	17	18	19	20	21	22	23	23	24	26	27	28	29	30	31	32	32	33
	9	4	7	9	11	13	15	16	17	18	20	21	22	23	24	25	25	26	28	29	31	32	33	34	34	35	35
	10	5	8	10	12	14	16	17	19	20	21	22	23	24	25	26	27	28	30	32	33	34	35	36	37	37	38
	11	5	8	11	13	15	17	18	20	21	23	24	25	26	27	28	29	30	32	34	35	36	37	38	39	40	40
	12	6	9	12	14	16	18	20	21	23	24	25	27	28	29	30	31	32	34	36	37	38	40	41	41	42	43
	13	6	10	13	15	17	19	21	22	24	25	27	28	29	30	32	33	34	36	38	39	41	42	43	44	44	45
	14	7	10	13	16	18	20	22	24	25	27	28	30	31	32	33	34	35	37	39	41	43	44	45	46	46	47
	15	7	11	14	17	19	21	23	25	27	28	30	31	32	34	35	36	37	39	41	43	44	46	47	48	48	49
	16	7	11	15	18	20	22	24	26	28	29	31	32	34	35	36	37	39	41	43	45	46	48	49	50	50	51
	17	8	12	16	18	21	23	25	27	29	31	32	34	35	36	38	39	40	42	45	46	48	49	51	52	52	53
	18	8	12	16	19	22	24	26	28	30	32	33	35	36	38	39	40	42	44	46	48	50	51	52	53	54	55
	19	9	13	17	20	23	25	27	29	31	33	35	36	38	39	41	42	43	46	48	50	52	53	54	55	56	57
	20	9	14	18	21	23	26	28	30	32	34	36	37	39	40	42	43	45	47	49	51	53	55	56	57	58	59
	21	9	14	18	21	24	27	29	31	33	35	37	39	40	42	43	45	46	49	51	53	55	56	58	59	60	60
	22	10	15	19	22	25	28	30	32	34	36	38	40	41	43	45	46	47	50	52	55	56	58	59	61	61	62
	23	10	15	19	23	26	29	31	33	35	37	39	41	43	44	46	47	49	51	54	56	58	60	61	62	63	64
	24	11	16	20	24	27	29	32	34	36	38	40	42	44	45	47	49	50	53	55	58	60	61	63	64	65	66
	25	11	16	21	24	27	30	33	35	37	39	41	43	45	47	48	50	51	54	57	59	61	63	64	65	66	67
	26	11	17	21	25	28	31	34	36	38	40	42	44	46	48	49	51	53	56	58	60	63	64	66	67	68	69
	27	12	17	22	26	29	32	35	37	39	41	43	45	47	49	51	52	54	57	60	62	64	66	67	68	70	70
	28	12	17	22	26	30	33	35	38	40	42	44	46	48	50	52	53	55	58	61	63	65	67	69	70	71	72
	29	12	18	23	27	30	33	36	39	41	43	45	47	49	51	53	55	56	59	62	65	67	69	70	71	73	73
	30	13	18	23	28	31	34	37	40	42	44	46	48	50	52	54	56	57	61	63	66	68	70	72	73	74	75

9.3 Fire Behavior Prediction (FBP) System

9.3.1 FBP System Overview and Structure

Though the basic categories of inputs to the system are similar to the US system of fire behavior models and tools, there are several important differences.

- Each CFFBP Fuel Type integrates the surface and canopy fuel characteristics, providing for evaluation of crown fire initiation and propagation without additional canopy characterizations. Only Foliar Moisture Content can be provided by the analyst
- Basic environmental inputs are produced by the Fire Weather Index (FWI) system. Fine Fuel Moisture Code (FFMC) estimates, both daily and hourly values, are estimated using FWI processes and combined with open 10 meter windspeeds to determine the Initial Spread Index (ISI), one of the key inputs. Buildup Index (BUI) is used to evaluate overall consumption and its contribution to spread and intensity estimates for all but the open fuels.
- Foliar Moisture content can be modeled according to phenology associated with elevation and Lat/Long.



9.3.2 Instructions for Estimating FBP Outputs

Once you have obtained current and/or forecasted FWI outputs (FFMC, ISI, BISI, BUI), fire behavior outputs may be determined using the following information and the fuel type specific tables on the following pages.

FUEL TYPE: Select appropriate fuel type(s) (Pages 13-15)

SPREAD DIRECTION: Select one or more of the following: (H)eadfire, (F)lanking fire, and (B)acking fire

RATE OF SPREAD & FLAME LENGTH

- Select appropriate Initial Spread Index ; ISI for head fire or BISI for backing fire
- Select appropriate Fuel Type specific table(s). (pages 16-29)
- To determine expected Headfire Rate of Spread and flame length, use current ISI and BUI and appropriate fuel model table from pages 16-29. Similarly, backing fire behavior uses BISI and BUI with the appropriate table from pages 16-29. Interpolate if necessary.
- ***Flanking Spread rate*** = (ROS + BROS)/(L:W ratio X 2). Length:Width Ratio found in table to the right.

TYPE OF FIRE
(Surface, Torching or Intermittent, Active Crown)
Fire Behavior tables for Conifer (C) and Mixedwood (M) fuels from pages 16-29 include shading and font colors that represent fire type***. Torching*** is determined by comparing surface flame length to the threshold flame length for each fuel.

Fuel Type	Torching Threshold (Flame Length)	
C-1	4.8 ft	
C-2	6.4 ft	
C-3	12.6 ft	
C-4	7.8 ft	
C-5	22 ft	
C-6	11.5 ft	
C-7	14.7 ft	
M	10.3 ft	

AREA & PERIMETER (from point source)

- Determine total spread distance (combine headfire and backing spread) for elapsed time from ignition.
- Select appropriate table; page 30 for Sheltered fuels (C, M, D, or S) or page 31 for Open Fuels(O-1a or O-1b)
- Reference appropriate windspeed and spread distance in both area and perimeter tables

Airport Winds mph	**Forestry Winds mph**		**Open Eye Level Winds mph**	**Fire Shape Length:Width Ratio**	
10m	**10m**	**20ft**		**Unshelt.**	**Shelt.**
1.0	**0.6**	**0.5**	**0.4**	**O-1a, O-1b**	**C,M,D ,S**
1	1	1	0	1.4	1.0
2	1	1	1	1.4	1.0
3	2	2	1	1.9	1.1
4	2	2	2	1.9	1.1
5	3	3	2	2.3	1.1
6	4	3	2	2.6	1.2
7	4	4	3	2.6	1.2
8	5	4	3	2.9	1.3
9	5	5	4	2.9	1.3
10	6	5	4	3.2	1.5
11	7	6	4	3.4	1.6
12	7	6	5	3.4	1.6
13	8	7	5	3.6	1.8
14	8	7	6	3.6	1.8
15	9	8	6	3.8	1.9
16	10	8	6	4.0	2.1
17	10	9	7	4.0	2.1
18	11	9	7	4.2	2.3
19	11	10	8	4.2	2.3
20	12	10	8	4.4	2.5
21	13	11	8	4.5	2.7
22	13	11	9	4.5	2.7
23	14	12	9	4.7	2.9
24	14	12	10	4.7	2.9
25	15	13	10	4.8	3.1
26	16	13	10	5.0	3.3
27	16	14	11	5.0	3.3
28	17	14	11	5.1	3.5
29	17	15	12	5.1	3.5
30	18	15	12	5.2	3.7
40	24	20	16	6.0	4.9
50	30	25	20	6.7	5.9

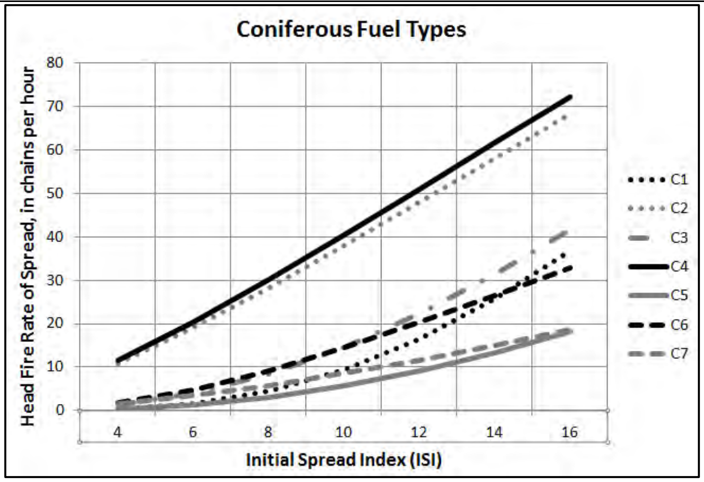
10 m winds are the most appropriate to use in determining Initial Spread Index (ISI) and making fire behavior predictions. However, many fire weather recording stations record windspeeds at **20 ft**. If you are taking eye level winds, working with a NWS forecast product, or obtaining 20 ft readings from our fire weather sites, the 10 m winds may be estimated from the chart above.

9.3.3 System Fuel Groups and Types

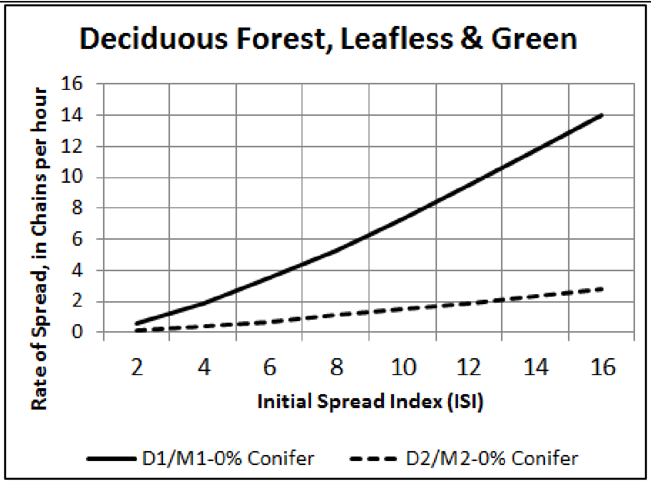
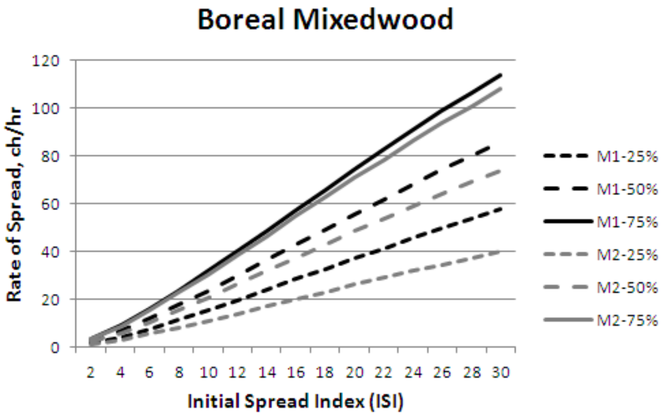
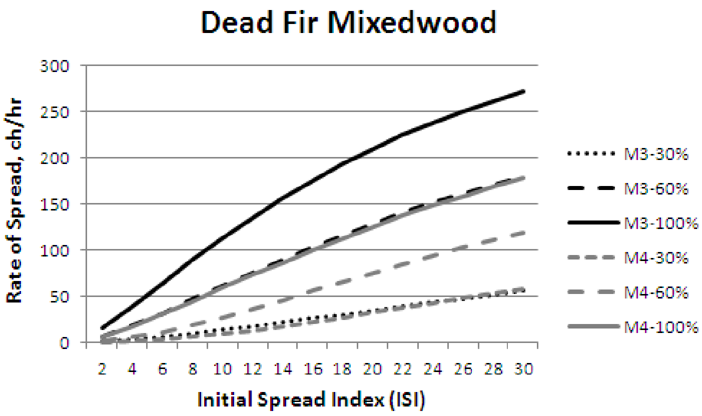
Designed specifically for use in predicting the full range of fire behavior in northern forest ecosystems, there are 16 fuel types among 5 fuel groups. The classification recognizes coarse vegetative cover and structure types:

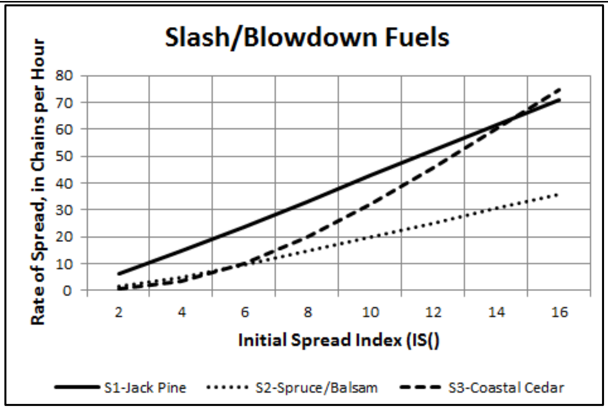
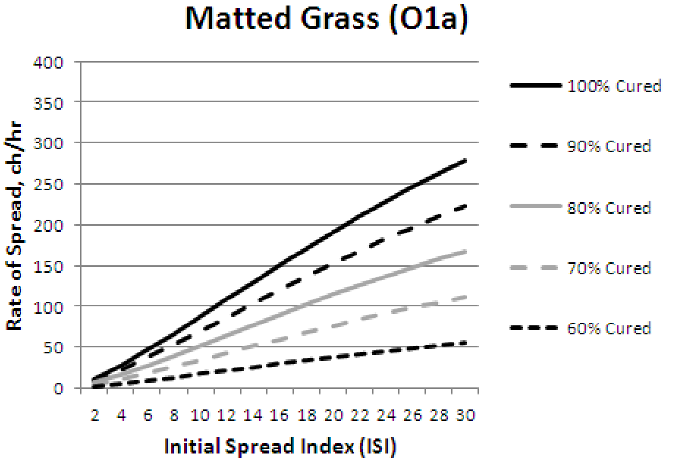
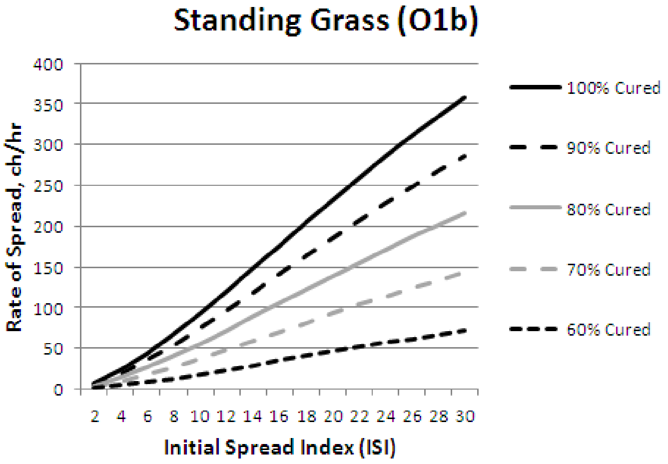
Coniferous Group

Fuel Type	CBH (m/ft)	CFL (kg/m2)
C-1	2	0.75
C-2	3	0.80
C-3	8	1.15
C-4	4	1.20
C-5	18	1.20
C-6	7(default)	1.80
C-7	10	0.50



FUEL TYPE	FOREST FLOOR /ORGANIC	SURFACE & LADDER FUEL	STRUCTURE COMPOSITION
C-1-Spruce Lichen Woodland	Continuous reindeer lichen; organic layer absent or shallow, uncompacted	Very sparse her/shrub cover and down woody fuels; tree crowns extend to ground	Open black spruce with dense clumps; assoc. sp. Jack pine, white birch; well drained upland sites.
C-2-Boreal Spruce	Continuous feather moss and/or Cladonia; deep, compacted organic layer.	Continuous shrub (e.g., Labrador tea); low to moderate down woody fuels,; tree crowns extend nearly to ground arboreal lichens, flaky bark	Moderately well stocked black spruce stands on both upland and lowland sites; Sphagnum bogs excluded.
C-3-Mature Jack or Lodgepole Pine	Continuous feather moss; moderately deep, compacted organic layer.	Sparse conifer understory may be present; sparse down woody fuels; tree crowns separated from the ground.	Fully stocked jack or lodgepole pine stands; mature.
C-4-Immature Jack or Lodgepole Pine	Continuous needle litter; moderately compacted organic layer.	Moderate shrub/herb cover; continuous vertical crown fuel continuity; heavy standing dead and down, dead woody fuel.	Dense jack or lodgepole pine stands; immature.
C-5-Red and White Pine	Continuous needle litter; moderately shallow organic layer	Moderate herb and shrub (e.g. hazel); moderate dense understory (e.g. red maple, balsam fir); tree crowns separated from ground.	Moderately well-stocked red and white pine stands; mature; assoc. sp. White spruce, white birch, and aspen.
C-6-Conifer Plantation	Continuous needle litter; moderately shallow organic layer	Absent herb/shrub cover; absent understory; tree crowns separated from ground	Fully stocked conifer plantations; complete crown closure regardless of mean stand height; mean stand crown base height controls ROS and crowning.
C-7-Ponderosa Pine /Douglas Fir	Continuous needle litter; absent to shallow organic layer	Discontinuous grasses, herbs, except in conifer thickets, where absent; light woody fuels; tree crowns separated from ground except in thickets.	Open ponderosa pine and Douglas-fir stands; mature uneven aged; assoc. sp. Western larch, lodgepole pine; understory conifer thickets.

<table>
<tr><td colspan="4"> </td></tr>
<tr><td>FUEL TYPE</td><td>FOREST FLOOR /ORGANIC</td><td>SURFACE & LADDER FUEL</td><td>STRUCTURE COMPOSITION</td></tr>
<tr><td>D-1-Leafless
D-2-Green</td><td>Continuous leaf litter; shallow, uncompacted organic layer.</td><td>Moderate medium to tall shrubs and herb layers; absent conifer understory; sparse, dead, down woody fuels.</td><td>Moderately well stocked trembling aspen stands; semimature; leafless (i.e., spring, fall or defoliated) and green (summer).</td></tr>
<tr><td colspan="2"> </td><td colspan="2"> </td></tr>
<tr><td>M-1-Boreal Mixedwood-leafless
M-2-Boreal Mixedwood-green</td><td>Continuous leaf litter in deciduous portions of stands; discontinuous feather moss and needle litter in conifer portions of stand; organic layers shallow, uncompacted to moderately compacted.</td><td>Moderate shrub and continuous herb layers; low to moderate dead, down woody fuels; conifer crowns extend nearly to ground; scattered to moderate conifer understory</td><td>Moderately well stocked mixed stand of boreal conifers (e.g., black/white spruce, balsam/sub-alpine fir) and deciduous species (e.g., trembling aspen, white birch). Fuel types are differentiated by season and percent conifer vs. deciduous sp. composition</td></tr>
<tr><td>M-3-Dead Fir Mixedwood-leafless
M-4-Dead Fir Mixedwood-green</td><td>Continuous leaf litter in deciduous portions of stands; discontinuous feather moss, needle litter, & hardwood leaves in mixed portions conifer portions of stands; organic layers moderately compacted, 8-10 cm.</td><td>Dense, continuous herbaceous cover after greenup; down woody fuels low initially, but becoming heavy several years after balsam mortality; ladder fuels dominated by dead balsam understory.</td><td>Moderately well stocked mixed stand of spruce, pine and birch with dead balsam fir, often as an understory. Fuel types differentiated by season and time since balsam mortality.</td></tr>
</table>

<table>
<tr><td colspan="4"> </td></tr>
<tr><td>FUEL TYPE</td><td>FOREST FLOOR /ORGANIC</td><td>SURFACE & LADDER FUEL</td><td>STRUCTURE COMPOSITION</td></tr>
<tr><td>S-1-Jack Pine Slash</td><td>Continuous feather moss; discontinuous needle litter; moderately deep, compacted organic layer.</td><td>Continuous slash, moderate loading and depth; high foliage retention; absent to sparse shrub and herb cover</td><td>Slash from clearcut logging; mature jack or lodgepole pine stands</td></tr>
<tr><td>S-2-White Spruce & Balsam Slash</td><td>Continuous feather moss and needle litter; moderately deep, compacted organic layer</td><td>Continuous to discontinuous slash (due to skidder trails); moderate foliage retention; moderate loading and depth; moderate shrub and herb cover.</td><td>Slash from clearcut logging; mature or overmature white spruce, subalpine fir or balsam fir stands.</td></tr>
<tr><td>S-3-Coastal Cedar, Hemlock & Doug-Fir Slash</td><td>Continuous feather moss or compacted old needle litter below fresh needle litter from slash; moderately deep to deep, compacted organic layer.</td><td>Continuous slash, high foliage retention (cedar), moderate for other species; heavy loading, deep slash; sparse to moderate shrub and herb cover</td><td>Slash from clearcut logging; mature to overmature cedar, hemlock, or Douglas-fir stands.</td></tr>
<tr><td colspan="2"> </td><td colspan="2"> </td></tr>
<tr><td>O-1a-Matted Grass
O-1b-Standing Grass</td><td>Continuous dead grass litter; organic layer absent to shallow and moderately compacted.</td><td colspan="2">Continuous standing grass (current year crop). Subtypes for both early spring matted grass and late summer standing cured grass are included.
Standard loading is 0.3 kg/m2, but other loading can be accommodated; percent cured or dead must be estimated.
Scattered trees, shrubs, and/or down woody fuel.</td></tr>
</table>

9.3.4 C-1 and C-2 Fire Spread and Flame Length Outputs

C-1 – Spruce Lichen Woodland

ROS ch/hr		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	0	0	0	0	0	0	0	0	0
	4	<1	<1	<1	<1	<1	<1	<1	<1	<1
	6	1	2	2	2	2	2	2	2	2
	8	3	4	5	5	5	5	5	5	5
	10	6	9	9	10	10	10	10	10	10
	12	11	15	16	17	17	17	18	18	18
	14	17	24	26	26	27	27	27	27	28
	16	24	***34***	***36***	***38***	***38***	***39***	***39***	***39***	***39***
	18	***32***	***45***	***49***	***50***	***51***	***52***	***52***	***52***	***52***
	20	***41***	***58***	***62***	***64***	***65***	***66***	***66***	***66***	***67***
	22	***50***	***71***	***76***	***78***	***79***	***80***	***81***	***81***	***82***
	24	***59***	***84***	***90***	***92***	***94***	***95***	***96***	***96***	***97***
	26	***68***	***97***	***104***	***107***	***109***	***110***	***111***	***111***	***112***
	28	***77***	***109***	***117***	***121***	***123***	***124***	***125***	***126***	***126***
	30	***85***	***121***	***130***	***134***	***136***	***138***	***139***	***140***	***140***

Torching ***Continuous Crown Fire***

FLAME LEN-ft		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	0	0	0	0	0	0	0	0	0
	4	1	1	2	2	2	2	2	2	2
	6	3	3	3	3	3	3	3	3	3
	8	4	5	5	5	5	5	5	5	5
	10	6	7	7	7	7	7	7	7	7
	12	7	8	9	9	9	9	9	9	9
	14	9	10	11	11	11	11	11	11	11
	16	10	***12***	***13***	***13***	***13***	***13***	***13***	***13***	***13***
	18	***12***	***14***	***14***	***15***	***15***	***15***	***15***	***15***	***15***
	20	***13***	***16***	***16***	***16***	***16***	***16***	***17***	***17***	***17***
	22	***15***	***17***	***18***	***18***	***18***	***18***	***18***	***18***	***18***
	24	***16***	***18***	***19***	***19***	***19***	***20***	***20***	***20***	***20***
	26	***17***	***20***	***20***	***21***	***21***	***21***	***21***	***21***	***21***
	28	***18***	***21***	***22***	***22***	***22***	***22***	***22***	***22***	***22***
	30	***19***	***22***	***23***	***23***	***23***	***23***	***23***	***23***	***23***

C-2 – Boreal Spruce

ROS ch/hr		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	1	3	4	4	5	5	5	5	5
	4	3	8	11	12	12	13	13	13	14
	6	5	15	19	21	22	23	23	24	24
	8	7	22	28	31	***32***	***34***	***34***	***35***	***35***
	10	9	29	***37***	***41***	***43***	***45***	***46***	***47***	***48***
	12	11	***37***	***47***	***52***	***55***	***57***	***58***	***59***	***60***
	14	14	***45***	***57***	***63***	***66***	***69***	***70***	***72***	***73***
	16	16	***52***	***66***	***74***	***78***	***81***	***83***	***84***	***85***
	18	18	***60***	***76***	***84***	***89***	***93***	***95***	***97***	***98***
	20	21	***68***	***86***	***95***	***101***	***104***	***107***	***109***	***111***
	22	23	***75***	***95***	***106***	***112***	***116***	***119***	***121***	***123***
	24	25	***83***	***105***	***116***	***123***	***127***	***130***	***133***	***135***
	26	27	***90***	***114***	***126***	***133***	***138***	***142***	***144***	***146***
	28	29	***97***	***122***	***136***	***144***	***149***	***153***	***155***	***158***
	30	31	***103***	***131***	***145***	***153***	***159***	***163***	***166***	***168***

Torching ***Continuous Crown Fire***

FLAME LEN-ft		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	2	4	6	7	7	8	8	9	9
	4	3	7	10	11	12	13	14	14	14
	6	3	10	13	15	16	17	18	19	19
	8	4	12	16	18	***20***	***21***	***22***	***23***	***23***
	10	4	14	***18***	***21***	***23***	***24***	***25***	***26***	***26***
	12	5	***16***	***20***	***23***	***25***	***27***	***28***	***29***	***30***
	14	5	***18***	***22***	***26***	***28***	***29***	***31***	***31***	***32***
	16	6	***19***	***24***	***28***	***30***	***32***	***33***	***34***	***35***
	18	6	***20***	***26***	***29***	***32***	***34***	***35***	***36***	***37***
	20	7	***21***	***27***	***31***	***34***	***36***	***37***	***38***	***39***
	22	8	***23***	***29***	***32***	***35***	***37***	***39***	***40***	***41***
	24	8	***24***	***30***	***34***	***37***	***39***	***41***	***42***	***43***
	26	9	***24***	***31***	***35***	***38***	***40***	***42***	***43***	***44***
	28	10	***25***	***32***	***36***	***40***	***42***	***44***	***45***	***46***
	30	10	***26***	***33***	***38***	***41***	***43***	***45***	***46***	***47***

9.3.5 C-3 and C-4 Fire Spread and Flame Length Outputs

C-3 - Mature Jack or Lodgepole Pine

ROS ch/hr		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	0	<1	<1	<1	<1	<1	<1	<1	<1
	4	0	1	1	2	2	2	2	2	2
	6	1	3	4	4	5	5	5	5	5
	8	3	7	8	9	9	10	10	10	10
	10	5	12	14	16	16	17	17	17	18
	12	7	18	22	24	25	26	26	27	27
	14	10	25	31	33	35	36	37	37	38
	16	13	34	41	44	***46***	***48***	***49***	***49***	***50***
	18	16	43	52	***56***	***59***	***61***	***62***	***63***	***63***
	20	20	52	***63***	***69***	***72***	***74***	***76***	***77***	***78***
	22	24	62	***75***	***82***	***86***	***88***	***90***	***91***	***92***
	24	28	72	***87***	***95***	***99***	***102***	***104***	***106***	***107***
	26	32	***82***	***100***	***108***	***113***	***117***	***119***	***121***	***122***
	28	35	***92***	***112***	***121***	***127***	***131***	***133***	***135***	***137***
	30	39	***102***	***124***	***134***	***141***	***145***	***148***	***150***	***152***

Torching ***Continuous Crown Fire***

FLAME LEN-ft		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	0	1	1	2	2	2	2	2	2
	4	0	2	3	4	4	5	5	5	5
	6	1	3	5	6	7	8	8	8	9
	8	1	4	7	8	10	11	11	12	12
	10	1	5	8	11	12	14	15	16	16
	12	2	6	10	13	16	18	19	20	20
	14	2	7	12	17	20	22	23	24	24
	16	2	9	15	20	***23***	***25***	***26***	***27***	***28***
	18	2	9	19	***23***	***26***	***28***	***29***	***30***	***31***
	20	3	10	***21***	***26***	***28***	***31***	***32***	***33***	***34***
	22	3	11	***23***	***28***	***31***	***33***	***35***	***36***	***37***
	24	3	12	***25***	***30***	***33***	***36***	***37***	***39***	***40***
	26	3	***15***	***27***	***32***	***35***	***38***	***40***	***41***	***42***
	28	3	***19***	***28***	***33***	***37***	***40***	***42***	***43***	***45***
	30	3	***22***	***30***	***35***	***39***	***42***	***44***	***46***	***47***

C-4 – Immature Jack or Lodgepole Pine

ROS ch/hr		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	2	4	4	5	5	5	5	5	5
	4	5	10	11	12	13	13	13	13	13
	6	8	17	20	21	22	23	23	23	24
	8	12	26	30	32	33	***34***	***34***	***35***	***35***
	10	16	34	***40***	***42***	***44***	***45***	***46***	***46***	***47***
	12	21	43	***50***	***54***	***55***	***57***	***58***	***58***	***59***
	14	25	***52***	***61***	***65***	***67***	***69***	***70***	***70***	***71***
	16	29	***61***	***71***	***76***	***79***	***80***	***82***	***83***	***83***
	18	33	***70***	***82***	***87***	***90***	***92***	***94***	***95***	***96***
	20	38	***79***	***92***	***98***	***101***	***104***	***105***	***107***	***107***
	22	42	***88***	***102***	***109***	***112***	***115***	***117***	***118***	***119***
	24	46	***96***	***112***	***119***	***123***	***126***	***128***	***129***	***131***
	26	50	***104***	***121***	***129***	***134***	***137***	***139***	***140***	***142***
	28	53	***112***	***130***	***139***	***144***	***147***	***149***	***151***	***152***
	30	57	***120***	***139***	***148***	***154***	***157***	***160***	***161***	***163***

Torching ***Continuous Crown Fire***

FLAME LEN-ft		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	1	3	5	6	7	8	8	9	9
	4	1	5	8	10	12	13	14	14	15
	6	2	6	11	14	16	17	18	19	20
	8	2	8	15	18	20	***21***	***22***	***23***	***24***
	10	2	11	***17***	***20***	***23***	***24***	***26***	***27***	***27***
	12	3	14	***20***	***23***	***25***	***27***	***29***	***30***	***30***
	14	3	***16***	***22***	***25***	***28***	***30***	***31***	***32***	***33***
	16	3	***18***	***23***	***27***	***30***	***32***	***34***	***35***	***36***
	18	3	***19***	***25***	***29***	***32***	***34***	***36***	***37***	***38***
	20	3	***21***	***26***	***30***	***34***	***36***	***38***	***39***	***40***
	22	4	***22***	***27***	***32***	***35***	***38***	***40***	***41***	***42***
	24	4	***23***	***29***	***33***	***37***	***39***	***41***	***43***	***44***
	26	4	***24***	***30***	***35***	***38***	***41***	***43***	***44***	***46***
	28	4	***24***	***31***	***36***	***39***	***42***	***44***	***46***	***47***
	30	4	***25***	***32***	***37***	***41***	***44***	***46***	***47***	***49***

9.3.6 C-5 and C-7 Fire Spread and Flame Length Outputs

C-5 – Red and White Pine

ROS ch/hr		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	0	0	0	<1	<1	<1	<1	<1	<1
	4	0	<1	<1	<1	<1	<1	<1	<1	<1
	6	1	1	1	1	1	1	1	1	1
	8	1	3	3	3	3	3	3	3	3
	10	2	5	6	6	6	6	6	6	7
	12	4	8	9	10	10	10	10	11	11
	14	5	11	13	14	15	15	15	15	15
	16	7	15	18	19	20	20	21	21	21
	18	9	20	23	24	25	26	26	27	27
	20	11	24	28	30	31	32	32	32	33
	22	14	29	33	35	37	37	38	38	39
	24	16	33	38	41	42	43	44	44	45
	26	18	37	43	46	47	48	49	50	50
	28	19	41	47	51	52	54	54	55	55
	30	21	44	52	55	57	58	59	60	60

Torching ***Continuous Crown Fire***

FLAME LEN-ft		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	0	0	0	1	1	1	1	1	1
	4	0	1	1	2	2	2	2	2	3
	6	0	1	2	3	4	4	4	5	5
	8	1	2	4	5	5	6	7	7	7
	10	1	3	5	6	7	8	9	9	10
	12	1	4	6	8	9	10	11	12	12
	14	1	4	7	9	11	12	13	14	14
	16	1	5	8	11	12	14	15	16	16
	18	1	6	9	12	14	16	17	18	18
	20	1	6	10	13	15	17	18	19	20
	22	2	7	11	14	17	18	20	21	22
	24	2	7	11	15	18	20	21	23	24
	26	2	7	12	16	19	21	23	25	26
	28	2	8	13	16	19	22	25	27	28
	30	2	8	13	17	20	23	27	28	29

C-7 – Ponderosa Pine / Douglas-fir

ROS ch/hr		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	<1	<1	<1	1	1	1	1	1	1
	4	1	2	2	2	2	2	2	2	2
	6	2	3	3	4	4	4	4	4	4
	8	3	5	6	6	6	6	6	6	7
	10	4	8	9	9	9	9	9	10	10
	12	6	10	12	12	12	13	13	13	13
	14	8	13	15	16	16	16	16	17	17
	16	10	17	18	19	20	20	20	21	21
	18	12	20	22	23	24	24	24	25	25
	20	13	23	26	27	28	28	28	29	29
	22	15	26	29	31	32	32	33	33	33
	24	17	30	33	35	36	36	37	37	37
	26	19	33	37	39	40	40	41	41	41
	28	21	37	41	43	44	44	45	45	46
	30	23	40	44	46	48	48	49	49	50

Torching ***Continuous Crown Fire***

FLAME LEN-ft		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	2	2	2	2	3	3	3	3	3
	4	3	4	4	4	5	5	5	5	5
	6	4	5	6	6	6	7	7	7	7
	8	5	7	8	8	8	8	8	9	9
	10	6	8	9	9	10	10	10	10	10
	12	7	9	10	11	11	11	12	12	12
	14	8	11	12	12	13	13	13	13	13
	16	8	12	13	13	14	14	14	15	15
	18	9	13	14	15	15	16	16	16	16
	20	10	14	15	16	17	17	17	17	18
	22	10	14	16	17	18	18	19	19	19
	24	11	15	17	19	19	20	20	20	20
	26	11	17	19	20	20	21	21	21	21
	28	12	17	20	21	21	22	22	22	22
	30	12	18	20	21	22	23	23	23	23

9.3.7 C-6 Fire Spread and Flame Length Outputs

C-6 – Pine Plantation (6 ft Canopy Base Height)

ROS ch/hr		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	0	<1	<1	<1	<1	<1	<1	<1	<1
	4	1	2	2	2	2	3	4	4	4
	6	2	4	7	12	14	15	16	17	17
	8	4	8	24	29	32	33	33	34	34
	10	6	20	43	47	49	50	51	51	52
	12	8	42	60	64	65	66	67	67	67
	14	11	61	74	77	***78***	***79***	***79***	***79***	***80***
	16	13	76	86	***88***	***89***	***89***	***90***	***90***	***90***
	18	16	88	96	***97***	***98***	***98***	***98***	***98***	***99***
	20	18	98	104	***105***	***105***	***106***	***106***	***106***	***106***
	22	20	107	111	***112***	***112***	***112***	***112***	***112***	***112***
	24	22	114	117	***117***	***118***	***118***	***118***	***118***	***118***
	26	24	120	122	***123***	***123***	***123***	***123***	***123***	***123***
	28	25	125	127	***127***	***127***	***127***	***127***	***127***	***127***
	30	26	129	131	***131***	***131***	***131***	***131***	***131***	***131***

Torching ***Continuous Crown Fire***

FLAME LEN-ft		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	0	1	1	2	2	2	2	2	2
	4	<1	2	3	4	5	6	7	8	8
	6	1	3	5	9	12	13	14	15	16
	8	1	4	11	15	18	20	21	22	23
	10	1	7	16	20	23	25	26	27	28
	12	1	13	20	24	27	29	30	31	32
	14	1	17	23	27	***30***	***32***	***33***	***34***	***35***
	16	2	20	26	***29***	***32***	***34***	***35***	***37***	***38***
	18	2	22	27	***31***	***33***	***36***	***37***	***38***	***39***
	20	2	24	29	***32***	***35***	***37***	***39***	***40***	***41***
	22	2	25	30	***33***	***36***	***38***	***40***	***41***	***42***
	24	2	26	30	***34***	***37***	***39***	***41***	***42***	***43***
	26	2	27	31	***34***	***37***	***40***	***41***	***43***	***44***
	28	2	28	32	***35***	***38***	***40***	***42***	***43***	***45***
	30	2	28	32	***36***	***39***	***41***	***43***	***44***	***45***

C-6 – Pine Plantation (20 ft Canopy Base Height)

ROS ch/hr		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	0	<1	<1	<1	<1	<1	<1	<1	<1
	4	1	2	2	2	2	2	2	2	2
	6	2	4	5	5	5	5	5	6	6
	8	4	8	9	10	10	16	20	22	24
	10	6	12	14	17	32	38	42	43	45
	12	8	17	20	44	54	58	60	62	63
	14	11	23	32	64	71	74	76	76	77
	16	13	28	59	80	85	87	***87***	***88***	***88***
	18	16	33	78	92	95	***96***	***97***	***97***	***98***
	20	18	38	92	102	***104***	***105***	***105***	***105***	***105***
	22	20	42	103	109	***111***	***111***	***112***	***112***	***112***
	24	22	46	111	***116***	***117***	***117***	***117***	***118***	***118***
	26	24	50	***118***	***122***	***122***	***122***	***123***	***123***	***123***
	28	25	53	***124***	***126***	***127***	***127***	***127***	***127***	***127***
	30	26	56	***128***	***131***	***131***	***131***	***131***	***131***	***131***

Torching ***Continuous Crown Fire***

FLAME LEN-ft		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	0	1	1	2	2	2	2	2	2
	4	<1	2	3	4	4	5	5	5	6
	6	1	3	4	6	7	8	8	9	9
	8	1	4	6	8	9	13	15	17	18
	10	1	4	7	10	17	21	23	25	26
	12	1	5	9	18	23	26	28	30	31
	14	1	6	11	23	28	30	32	34	35
	16	2	6	18	27	31	33	***35***	***36***	***37***
	18	2	7	22	29	33	***35***	***37***	***38***	***39***
	20	2	7	25	31	***34***	***37***	***38***	***40***	***41***
	22	2	8	27	32	***35***	***38***	***39***	***41***	***42***
	24	2	8	29	***33***	***36***	***39***	***40***	***42***	***43***
	26	2	8	***30***	***34***	***37***	***39***	***41***	***43***	***44***
	28	2	9	***31***	***35***	***38***	***40***	***42***	***43***	***44***
	30	2	9	***31***	***35***	***38***	***41***	***43***	***44***	***45***

9.3.8 D-1 and D-2 Fire Spread and Flame Length Outputs

D-1-Leafless Hardwoods

ROS ch/hr		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	0	1	1	1	1	1	1	1	1
	4	1	2	2	2	2	2	2	2	2
	6	1	3	3	4	4	4	4	4	4
	8	2	5	5	6	6	6	6	6	6
	10	3	6	7	8	8	8	8	8	8
	12	4	8	9	10	10	11	11	11	11
	14	5	10	12	12	13	13	13	13	14
	16	6	12	14	15	15	16	16	16	16
	18	7	14	16	17	18	18	18	19	19
	20	8	16	18	20	20	21	21	21	22
	22	9	18	21	22	23	23	24	24	24
	24	9	20	23	24	25	26	26	27	27
	26	10	22	25	27	28	29	29	29	30
	28	11	24	27	29	30	31	32	32	32
	30	12	26	30	32	33	34	34	34	35

FLAME LEN-ft		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	1	1	2	2	2	2	2	2	2
	4	1	2	3	3	3	3	4	4	4
	6	1	3	4	4	4	5	5	5	5
	8	2	3	4	5	5	5	6	6	6
	10	2	4	5	6	6	6	7	7	7
	12	2	5	6	6	7	7	7	7	8
	14	2	5	6	7	8	8	8	8	8
	16	3	5	7	8	8	8	9	9	9
	18	3	6	7	8	9	9	9	10	10
	20	3	6	8	9	9	10	10	10	10
	22	3	7	8	9	10	10	11	11	11
	24	3	7	9	10	10	11	11	11	11
	26	3	7	9	10	11	11	12	12	12
	28	3	7	9	10	11	12	12	12	12
	30	4	8	10	11	12	12	12	13	13

D-2-Summer Hardwoods

ROS ch/hr		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	0	<1	<1	<1	<1	<1	<1	<1	<1
	4	<1	<1	<1	<1	<1	<1	<1	<1	<1
	6	<1	1	1	1	1	1	1	1	1
	8	<1	1	1	1	1	1	1	1	1
	10	1	1	1	2	2	2	2	2	2
	12	1	2	2	2	2	2	2	2	2
	14	1	2	2	3	3	3	3	3	3
	16	1	2	3	3	3	3	3	3	3
	18	1	3	3	3	4	4	4	4	4
	20	2	3	4	4	4	4	4	4	4
	22	2	4	4	4	5	5	5	5	5
	24	2	4	5	5	5	5	5	5	5
	26	2	4	5	5	6	6	6	6	6
	28	2	5	6	6	6	6	6	6	6
	30	2	5	6	6	7	7	7	7	7

FLAME LEN-ft		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	0	1	1	1	1	1	1	1	1
	4	1	1	1	1	2	2	2	2	2
	6	1	1	2	2	2	2	2	2	2
	8	1	2	2	2	3	3	3	3	3
	10	1	2	2	3	3	3	3	3	3
	12	1	2	3	3	3	3	4	4	4
	14	1	2	3	3	4	4	4	4	4
	16	1	3	3	4	4	4	4	4	4
	18	1	3	3	4	4	4	4	5	5
	20	1	3	4	4	4	5	5	5	5
	22	1	3	4	4	5	5	5	5	5
	24	2	3	4	5	5	5	5	5	5
	26	2	3	4	5	5	5	6	6	6
	28	2	4	4	5	5	6	6	6	6
	30	2	4	5	5	6	6	6	6	6

9.3.9 M-1 and M-2 (25% Conifer) Fire Spread and Flame Length Outputs

M-1-Boreal Mixedwood-Leafless; 25% Conifer

ROS ch/hr		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	**2**	1	1	2	2	2	2	2	2	2
	4	2	4	4	5	5	5	5	5	5
	6	3	7	8	8	8	9	9	9	9
	8	5	10	11	12	13	13	13	13	13
	10	6	13	15	16	17	17	18	18	18
	12	8	17	20	21	22	22	23	23	23
	14	10	21	24	26	26	27	27	28	28
	16	12	24	28	30	31	32	32	33	33
	18	13	28	33	35	36	37	37	38	38
	20	15	32	37	39	41	42	***42***	***43***	***43***
	22	17	36	41	***44***	***46***	***47***	***47***	***48***	***48***
	24	19	39	46	***49***	***50***	***51***	***52***	***53***	***53***
	26	20	43	***50***	***53***	***55***	***56***	***57***	***58***	***58***
	28	22	46	***54***	***57***	***59***	***61***	***62***	***62***	***63***
	30	24	50	***58***	***61***	***64***	***65***	***66***	***67***	***67***

Torching ***Continuous Crown Fire***

FLAME LEN-ft		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	**2**	1	2	3	3	4	4	4	4	4
	4	2	4	5	5	6	6	6	6	6
	6	2	5	6	7	7	8	8	8	8
	8	3	6	7	8	9	9	10	10	10
	10	3	6	8	9	10	11	11	11	11
	12	3	7	9	10	11	12	12	13	13
	14	4	8	10	11	12	13	13	14	14
	16	4	9	11	12	13	14	14	15	15
	18	4	9	12	13	14	15	15	16	16
	20	4	10	12	14	15	16	***16***	***17***	***17***
	22	5	10	13	***15***	***16***	***17***	***17***	***18***	***18***
	24	5	11	14	***15***	***17***	***17***	***18***	***18***	***19***
	26	5	11	***14***	***16***	***17***	***18***	***19***	***19***	***20***
	28	5	11	***15***	***17***	***18***	***19***	***19***	***20***	***20***
	30	5	12	***15***	***17***	***18***	***19***	***20***	***21***	***21***

M-2-Boreal Mixedwood-Green; 25% Conifer

ROS ch/hr		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	**2**	1	1	1	1	1	1	1	1	1
	4	1	3	3	3	4	4	4	4	4
	6	2	5	6	6	6	6	6	6	7
	8	3	7	8	9	9	9	9	10	10
	10	5	10	11	12	12	13	13	13	13
	12	6	12	14	15	16	16	16	16	16
	14	7	15	17	18	19	19	20	20	20
	16	8	17	20	21	22	23	23	23	23
	18	9	20	23	25	25	26	26	27	27
	20	11	22	26	28	29	29	30	30	30
	22	12	25	29	31	32	33	33	34	34
	24	13	27	32	34	35	36	36	37	37
	26	14	30	35	37	38	39	***40***	***40***	***40***
	28	15	32	37	40	41	42	***43***	***43***	***44***
	30	16	34	40	42	44	45	***46***	***46***	***47***

Torching ***Continuous Crown Fire***

FLAME LEN-ft		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	**2**	1	2	3	3	3	3	3	3	4
	4	1	3	4	5	5	5	5	5	6
	6	2	4	5	6	6	7	7	7	7
	8	2	5	6	7	8	8	8	8	9
	10	3	6	7	8	9	9	9	10	10
	12	3	6	8	9	10	10	10	11	11
	14	3	7	9	10	11	11	11	12	12
	16	3	7	9	10	11	12	12	13	13
	18	4	8	10	11	12	13	13	14	14
	20	4	8	10	12	13	13	14	14	15
	22	4	9	11	12	13	14	15	15	15
	24	4	9	11	13	14	15	15	16	16
	26	4	9	12	13	15	15	***16***	***16***	***17***
	28	4	10	12	14	15	16	***16***	***17***	***17***
	30	5	10	13	14	16	16	***17***	***17***	***18***

9.3.10 M-1 and M-2 (50% Conifer) Fire Spread and Flame Length Outputs

M-1-Boreal Mixedwood-Leafless; 50% Conifer

ROS ch/hr		BUILDUP INDEX (BUI)								
		10	**30**	**50**	**70**	**90**	**110**	**130**	**150**	**170**
INITIAL SPREAD INDEX (ISI)	**2**	1	2	2	3	3	3	3	3	3
	4	3	6	7	7	7	8	8	8	8
	6	5	10	12	13	13	13	14	14	14
	8	7	15	18	19	19	20	20	20	21
	10	10	20	24	25	26	27	27	27	28
	12	12	26	30	32	33	34	34	35	35
	14	15	31	36	39	***40***	***41***	***42***	***42***	***43***
	16	18	37	43	***46***	***47***	***48***	***49***	***50***	***50***
	18	20	42	***49***	***53***	***54***	***56***	***57***	***57***	***58***
	20	23	***48***	***56***	***59***	***61***	***63***	***64***	***65***	***65***
	22	25	***53***	***62***	***66***	***68***	***70***	***71***	***72***	***72***
	24	28	***59***	***68***	***73***	***75***	***77***	***78***	***79***	***80***
	26	30	***64***	***74***	***79***	***82***	***84***	***85***	***86***	***87***
	28	33	***69***	***80***	***85***	***88***	***90***	***92***	***93***	***94***
	30	35	***74***	***86***	***91***	***95***	***97***	***98***	***99***	***100***

Torching ***Continuous Crown Fire***

FLAME LEN-ft		BUILDUP INDEX (BUI)								
		10	**30**	**50**	**70**	**90**	**110**	**130**	**150**	**170**
INITIAL SPREAD INDEX (ISI)	**2**	1	3	4	4	5	5	5	5	6
	4	2	5	6	7	8	8	8	9	9
	6	3	6	8	9	10	11	11	11	12
	8	3	8	10	11	12	13	14	14	14
	10	4	9	11	13	14	15	16	16	17
	12	4	10	13	15	16	17	18	18	19
	14	5	11	15	17	***18***	***19***	***20***	***20***	***20***
	16	5	12	16	***18***	***19***	***20***	***21***	***22***	***22***
	18	6	13	***17***	***19***	***21***	***22***	***23***	***23***	***24***
	20	6	***14***	***18***	***20***	***22***	***23***	***24***	***24***	***25***
	22	6	***15***	***19***	***21***	***23***	***24***	***25***	***26***	***26***
	24	6	***16***	***20***	***22***	***24***	***25***	***26***	***27***	***27***
	26	7	***17***	***21***	***23***	***25***	***26***	***27***	***28***	***28***
	28	7	***18***	***22***	***24***	***26***	***27***	***28***	***29***	***30***
	30	7	***18***	***22***	***25***	***27***	***28***	***29***	***30***	***30***

M-2-Boreal Mixedwood-Green; 50% Conifer

ROS ch/hr		BUILDUP INDEX (BUI)								
		10	**30**	**50**	**70**	**90**	**110**	**130**	**150**	**170**
INITIAL SPREAD INDEX (ISI)	**2**	1	2	2	2	2	3	3	3	3
	4	2	5	6	6	7	7	7	7	7
	6	4	9	10	11	12	12	12	12	12
	8	6	13	15	16	17	17	18	18	18
	10	9	18	21	22	23	23	24	24	24
	12	11	23	26	28	29	30	30	30	31
	14	13	27	32	34	35	36	36	37	37
	16	15	32	37	40	***41***	***42***	***43***	***43***	***44***
	18	18	37	43	***46***	***47***	***48***	***49***	***50***	***50***
	20	20	42	***48***	***51***	***53***	***55***	***55***	***56***	***57***
	22	22	46	***54***	***57***	***59***	***61***	***62***	***62***	***63***
	24	24	51	***59***	***63***	***65***	***67***	***68***	***68***	***69***
	26	26	55	***64***	***68***	***71***	***72***	***73***	***74***	***75***
	28	28	59	***69***	***74***	***76***	***78***	***79***	***80***	***81***
	30	30	64	***74***	***79***	***81***	***83***	***85***	***86***	***86***

Torching ***Continuous Crown Fire***

FLAME LEN-ft		BUILDUP INDEX (BUI)								
		10	**30**	**50**	**70**	**90**	**110**	**130**	**150**	**170**
INITIAL SPREAD INDEX (ISI)	**2**	1	3	4	4	5	5	5	5	5
	4	2	5	6	7	7	8	8	8	8
	6	3	6	8	9	9	10	10	11	11
	8	3	7	9	10	12	12	13	13	13
	10	4	8	11	12	13	14	15	15	16
	12	4	9	12	14	15	16	17	17	17
	14	5	10	14	16	17	18	18	19	19
	16	5	11	15	17	***18***	***19***	***20***	***20***	***21***
	18	5	12	16	***18***	***19***	***20***	***21***	***22***	***22***
	20	6	13	***17***	***19***	***21***	***22***	***22***	***23***	***23***
	22	6	14	***18***	***20***	***22***	***23***	***23***	***24***	***25***
	24	6	15	***19***	***21***	***23***	***24***	***25***	***25***	***26***
	26	6	16	***19***	***22***	***23***	***25***	***25***	***26***	***27***
	28	6	16	***20***	***23***	***24***	***25***	***26***	***27***	***28***
	30	7	17	***21***	***23***	***25***	***26***	***27***	***28***	***28***

9.3.11 M-1 and M-2 (75% Conifer) Fire Spread and Flame Length Outputs

M-1-Boreal Mixedwood-Leafless; 75% Conifer

ROS ch/hr		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	1	3	3	4	4	4	4	4	4
	4	4	8	9	10	10	10	10	11	11
	6	7	14	16	17	18	18	18	19	19
	8	10	20	24	25	26	27	27	27	28
	10	13	27	32	34	35	36	37	37	37
	12	17	35	40	***43***	***44***	***45***	***46***	***47***	***47***
	14	20	42	***49***	***52***	***54***	***55***	***56***	***57***	***57***
	16	24	***49***	***57***	***61***	***63***	***65***	***66***	***67***	***67***
	18	27	***57***	***66***	***70***	***73***	***74***	***76***	***76***	***77***
	20	30	***64***	***74***	***79***	***82***	***84***	***85***	***86***	***87***
	22	34	***71***	***83***	***88***	***91***	***93***	***95***	***96***	***97***
	24	37	***78***	***91***	***97***	***100***	***102***	***104***	***105***	***106***
	26	40	***85***	***99***	***105***	***109***	***111***	***113***	***114***	***115***
	28	44	***92***	***106***	***113***	***117***	***120***	***122***	***123***	***124***
	30	47	***98***	***114***	***121***	***125***	***128***	***130***	***132***	***133***

Torching ***Continuous Crown Fire***

FLAME LEN-ft		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	2	4	5	6	6	7	7	7	7
	4	3	6	8	9	10	10	11	11	11
	6	4	8	10	12	13	14	15	15	15
	8	4	9	13	15	16	17	18	18	19
	10	5	11	15	17	19	20	20	21	21
	12	5	13	17	***19***	***21***	***22***	***23***	***24***	***24***
	14	6	15	***19***	***21***	***23***	***24***	***25***	***26***	***26***
	16	6	***17***	***21***	***23***	***25***	***26***	***27***	***28***	***28***
	18	7	***18***	***22***	***25***	***26***	***28***	***29***	***30***	***30***
	20	7	***19***	***23***	***26***	***28***	***29***	***30***	***31***	***32***
	22	8	***20***	***24***	***27***	***29***	***31***	***32***	***33***	***34***
	24	8	***21***	***26***	***29***	***31***	***32***	***33***	***34***	***35***
	26	8	***22***	***27***	***30***	***32***	***33***	***35***	***36***	***36***
	28	9	***23***	***27***	***31***	***33***	***35***	***36***	***37***	***38***
	30	9	***23***	***28***	***32***	***34***	***36***	***37***	***38***	***39***

M-2-Boreal Mixedwood-Green; 75% Conifer

ROS ch/hr		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	1	3	3	3	4	4	4	4	4
	4	4	8	9	9	10	10	10	10	10
	6	6	13	15	16	17	17	18	18	18
	8	9	20	23	24	25	26	26	26	27
	10	12	26	30	32	34	34	35	35	36
	12	16	33	38	***41***	***42***	***43***	***44***	***45***	***45***
	14	19	40	***46***	***50***	***51***	***52***	***53***	***54***	***54***
	16	22	***47***	***55***	***58***	***60***	***62***	***63***	***63***	***64***
	18	26	***54***	***63***	***67***	***69***	***71***	***72***	***73***	***73***
	20	29	***61***	***71***	***75***	***78***	***80***	***81***	***82***	***83***
	22	32	***68***	***78***	***84***	***87***	***89***	***90***	***91***	***92***
	24	35	***74***	***86***	***92***	***95***	***97***	***99***	***100***	***101***
	26	38	***81***	***93***	***100***	***103***	***106***	***107***	***108***	***109***
	28	41	***87***	***101***	***107***	***111***	***114***	***116***	***117***	***118***
	30	44	***93***	***108***	***115***	***119***	***122***	***124***	***125***	***126***

Torching ***Continuous Crown Fire***

FLAME LEN-ft		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	2	4	5	6	6	6	7	7	7
	4	3	6	8	9	10	10	11	11	11
	6	4	8	10	12	13	14	14	15	15
	8	4	9	13	14	16	17	17	18	18
	10	5	11	15	17	18	19	20	21	21
	12	5	13	17	***19***	***21***	***22***	***22***	***23***	***23***
	14	6	15	***19***	***21***	***22***	***24***	***25***	***25***	***26***
	16	6	***16***	***20***	***23***	***24***	***25***	***26***	***27***	***28***
	18	7	***17***	***22***	***24***	***26***	***27***	***28***	***29***	***30***
	20	7	***19***	***23***	***25***	***27***	***29***	***30***	***31***	***31***
	22	7	***19***	***24***	***27***	***29***	***30***	***31***	***32***	***33***
	24	8	***20***	***25***	***28***	***30***	***31***	***33***	***34***	***34***
	26	8	***21***	***26***	***29***	***31***	***33***	***34***	***35***	***36***
	28	8	***22***	***27***	***30***	***32***	***34***	***35***	***36***	***37***
	30	9	***23***	***28***	***31***	***33***	***35***	***36***	***37***	***38***

9.3.12 M-3 and M-4 (30% Dead Balsam Fir) Fire Spread and Flame Length Outputs

M-3-30% Dead Balsam Fir Mixedwood-leafless

ROS ch/hr		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	1	1	1	1	1	1	1	1	1
	4	1	3	4	4	4	4	4	4	4
	6	3	6	7	7	7	7	8	8	8
	8	4	9	10	11	11	11	11	12	12
	10	6	12	14	15	15	16	16	16	16
	12	7	15	18	19	20	20	20	21	21
	14	9	19	22	23	24	25	25	25	26
	16	11	23	26	28	29	30	30	30	31
	18	13	26	30	32	34	34	35	35	***36***
	20	14	30	35	37	***38***	***39***	***40***	***40***	***41***
	22	16	34	***39***	***42***	***43***	***44***	***45***	***45***	***46***
	24	18	37	***43***	***46***	***48***	***49***	***50***	***50***	***51***
	26	20	***41***	***48***	***51***	***53***	***54***	***55***	***55***	***56***
	28	21	***45***	***52***	***55***	***57***	***58***	***59***	***60***	***61***
	30	23	***48***	***56***	***59***	***62***	***63***	***64***	***65***	***65***

Torching ***Continuous Crown Fire***

FLAME LEN-ft		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	1	3	3	4	4	4	5	5	5
	4	2	4	5	6	7	7	8	8	8
	6	3	6	7	8	9	10	10	10	11
	8	3	7	9	10	11	12	12	13	13
	10	4	8	10	12	13	14	15	15	16
	12	4	9	12	14	15	16	17	17	18
	14	4	10	14	16	17	18	19	19	20
	16	5	11	15	17	19	20	20	21	21
	18	5	12	16	19	20	21	22	23	***23***
	20	5	13	18	20	***21***	***23***	***23***	***24***	***25***
	22	6	15	***19***	***21***	***23***	***24***	***25***	***25***	***26***
	24	6	16	***20***	***22***	***24***	***25***	***26***	***27***	***27***
	26	6	***16***	***21***	***23***	***25***	***26***	***27***	***28***	***28***
	28	7	***17***	***21***	***24***	***26***	***27***	***28***	***29***	***30***
	30	7	***18***	***22***	***25***	***27***	***28***	***29***	***30***	***31***

M-4-30% Dead Balsam Fir Mixedwood-Green

ROS ch/hr		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	<1	<1	<1	<1	<1	<1	<1	<1	<1
	4	1	1	1	1	2	2	2	2	2
	6	1	3	3	3	4	4	4	4	4
	8	2	5	6	6	7	7	7	7	7
	10	4	8	9	10	10	11	11	11	11
	12	5	11	13	14	15	15	15	15	16
	14	7	15	18	19	20	20	20	21	21
	16	9	19	22	24	25	25	26	26	26
	18	11	24	27	29	30	31	31	32	32
	20	13	28	32	35	36	37	***37***	***38***	***38***
	22	15	32	38	***40***	***42***	***43***	***43***	***44***	***44***
	24	18	37	43	***46***	***47***	***48***	***49***	***50***	***50***
	26	20	41	***48***	***51***	***53***	***54***	***55***	***56***	***56***
	28	22	46	***53***	***56***	***58***	***60***	***61***	***61***	***62***
	30	24	50	***58***	***62***	***64***	***65***	***66***	***67***	***68***

Torching ***Continuous Crown Fire***

FLAME LEN-ft		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	1	1	2	2	2	2	2	2	2
	4	1	3	4	4	4	5	5	5	5
	6	2	4	5	6	7	7	7	8	8
	8	2	5	7	8	9	9	10	10	10
	10	3	7	9	10	11	11	12	12	13
	12	4	8	10	12	13	14	14	15	15
	14	4	9	12	14	15	16	17	17	18
	16	4	10	14	16	17	18	19	19	20
	18	5	11	15	18	19	20	21	21	22
	20	5	13	17	19	21	22	***23***	***23***	***24***
	22	6	14	18	***21***	***22***	***23***	***24***	***25***	***25***
	24	6	15	20	***22***	***24***	***25***	***26***	***27***	***27***
	26	6	17	***21***	***23***	***25***	***26***	***27***	***28***	***29***
	28	7	17	***22***	***24***	***26***	***27***	***29***	***29***	***30***
	30	7	18	***23***	***25***	***27***	***29***	***30***	***31***	***31***

9.3.13 M-3 and M-4 (60% Dead Balsam Fir) Fire Spread and Flame Length Outputs

M-3-60% Dead Balsam Fir Mixedwood-leafless

ROS ch/hr		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	3	6	7	7	8	8	8	8	8
	4	8	16	18	20	20	21	21	21	22
	6	13	27	32	34	35	36	***37***	***37***	***37***
	8	19	40	***46***	***49***	***51***	***52***	***53***	***54***	***54***
	10	25	***52***	***61***	***65***	***67***	***69***	***70***	***71***	***71***
	12	31	***65***	***75***	***80***	***83***	***85***	***86***	***87***	***88***
	14	37	***77***	***89***	***95***	***99***	***101***	***103***	***104***	***105***
	16	42	***89***	***103***	***110***	***114***	***116***	***118***	***119***	***121***
	18	48	***100***	***116***	***124***	***128***	***131***	***133***	***135***	***136***
	20	53	***111***	***128***	***137***	***142***	***145***	***147***	***149***	***150***
	22	57	***121***	***140***	***149***	***155***	***158***	***161***	***162***	***164***
	24	62	***130***	***151***	***161***	***167***	***170***	***173***	***175***	***177***
	26	***66***	***139***	***161***	***172***	***178***	***182***	***185***	***187***	***189***
	28	***70***	***147***	***171***	***182***	***188***	***193***	***196***	***198***	***200***
	30	***74***	***155***	***180***	***191***	***198***	***203***	***206***	***208***	***210***

Torching ***Continuous Crown Fire***

FLAME LEN-ft		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	3	6	7	9	9	10	10	11	11
	4	4	9	12	14	15	16	17	18	18
	6	5	13	17	19	20	22	***22***	***23***	***24***
	8	6	16	***20***	***23***	***24***	***26***	***27***	***27***	***28***
	10	7	***19***	***23***	***26***	***28***	***29***	***30***	***31***	***32***
	12	8	***21***	***26***	***29***	***31***	***32***	***34***	***34***	***35***
	14	8	***23***	***28***	***31***	***33***	***35***	***36***	***37***	***38***
	16	9	***24***	***30***	***33***	***36***	***37***	***39***	***40***	***41***
	18	10	***26***	***31***	***35***	***38***	***39***	***41***	***42***	***43***
	20	10	***27***	***33***	***37***	***39***	***41***	***43***	***44***	***45***
	22	10	***28***	***34***	***38***	***41***	***43***	***45***	***46***	***47***
	24	13	***29***	***35***	***39***	***42***	***45***	***46***	***47***	***48***
	26	***14***	***30***	***36***	***41***	***44***	***46***	***48***	***49***	***50***
	28	***15***	***31***	***37***	***42***	***45***	***47***	***49***	***50***	***51***
	30	***16***	***31***	***38***	***43***	***46***	***48***	***50***	***51***	***53***

M-4-60% Dead Balsam Fir Mixedwood-Green

ROS ch/hr		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	1	1	2	2	2	2	2	2	2
	4	2	5	6	6	6	6	7	7	7
	6	5	10	12	12	13	13	13	14	14
	8	8	16	19	20	21	22	22	22	22
	10	11	24	27	29	30	31	31	32	32
	12	15	31	36	***39***	***40***	***41***	***42***	***42***	***43***
	14	19	40	***46***	***49***	***51***	***52***	***53***	***53***	***54***
	16	23	48	***56***	***59***	***61***	***63***	***64***	***64***	***65***
	18	27	56	***65***	***70***	***72***	***74***	***75***	***76***	***76***
	20	31	65	***75***	***80***	***83***	***85***	***86***	***87***	***88***
	22	35	73	***84***	***90***	***93***	***95***	***97***	***98***	***99***
	24	38	81	***94***	***100***	***103***	***106***	***107***	***109***	***109***
	26	42	88	***102***	***109***	***113***	***116***	***118***	***119***	***120***
	28	46	96	***111***	***118***	***123***	***125***	***127***	***129***	***130***
	30	49	103	***119***	***127***	***132***	***135***	***137***	***138***	***140***

Torching ***Continuous Crown Fire***

FLAME LEN-ft		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	1	3	4	4	5	5	5	5	6
	4	2	5	7	8	8	9	9	10	10
	6	3	7	9	11	12	13	13	14	14
	8	4	9	12	14	16	17	17	18	18
	10	5	11	15	18	19	20	21	21	22
	12	6	14	18	***20***	***22***	***23***	***24***	***25***	***25***
	14	6	16	***20***	***23***	***24***	***26***	***27***	***27***	***28***
	16	7	***18***	***22***	***25***	***27***	***28***	***29***	***30***	***31***
	18	7	***20***	***24***	***27***	***29***	***30***	***31***	***32***	***33***
	20	8	***21***	***26***	***29***	***31***	***32***	***33***	***34***	***35***
	22	8	***22***	***27***	***30***	***32***	***34***	***35***	***36***	***37***
	24	9	***23***	***28***	***32***	***34***	***36***	***37***	***38***	***39***
	26	9	***24***	***30***	***33***	***35***	***37***	***39***	***40***	***41***
	28	9	***25***	***31***	***34***	***37***	***39***	***40***	***41***	***42***
	30	10	***26***	***32***	***35***	***38***	***40***	***41***	***43***	***44***

9.3.14 M-3 and M-4 (100% Dead Balsam Fir) Fire Spread and Flame Length Outputs

M-3-100% Dead Balsam Fir Mixedwood-leafless

ROS ch/hr		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	7	14	16	17	18	18	18	19	19
	4	16	34	39	***42***	***43***	***44***	***45***	***45***	***46***
	6	26	***55***	***64***	***68***	***70***	***72***	***73***	***74***	***75***
	8	36	***76***	***88***	***94***	***98***	***100***	***101***	***103***	***103***
	10	46	***97***	***112***	***120***	***124***	***127***	***129***	***130***	***131***
	12	55	***116***	***135***	***144***	***149***	***152***	***154***	***156***	***158***
	14	64	***134***	***156***	***166***	***172***	***176***	***179***	***181***	***182***
	16	***72***	***151***	***175***	***187***	***193***	***198***	***201***	***203***	***205***
	18	***79***	***166***	***193***	***206***	***213***	***218***	***221***	***224***	***226***
	20	***86***	***180***	***209***	***223***	***231***	***236***	***240***	***243***	***245***
	22	***92***	***193***	***224***	***239***	***248***	***253***	***257***	***260***	***262***
	24	***97***	***205***	***238***	***253***	***263***	***269***	***273***	***276***	***278***
	26	***102***	***215***	***250***	***266***	***276***	***282***	***287***	***290***	***293***
	28	***107***	***225***	***261***	***278***	***288***	***295***	***300***	***303***	***306***
	30	***111***	***234***	***271***	***289***	***299***	***306***	***311***	***315***	***317***
		Torching		***Continuous Crown Fire***						
FLAME LGTH-ft		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	4	8	11	13	14	15	16	16	17
	4	6	15	19	***21***	***23***	***24***	***25***	***25***	***26***
	6	7	***19***	***24***	***26***	***28***	***30***	***31***	***32***	***33***
	8	8	***23***	***28***	***31***	***33***	***35***	***36***	***37***	***38***
	10	9	***25***	***31***	***34***	***37***	***39***	***40***	***41***	***42***
	12	10	***28***	***33***	***37***	***40***	***42***	***44***	***45***	***46***
	14	13	***29***	***36***	***40***	***43***	***45***	***47***	***48***	***49***
	16	***16***	***31***	***38***	***42***	***45***	***48***	***49***	***51***	***52***
	18	***17***	***32***	***40***	***44***	***47***	***50***	***52***	***53***	***54***
	20	***18***	***34***	***41***	***46***	***49***	***52***	***54***	***55***	***56***
	22	***19***	***35***	***42***	***47***	***51***	***53***	***55***	***57***	***58***
	24	***20***	***36***	***43***	***49***	***52***	***55***	***57***	***59***	***60***
	26	***20***	***37***	***45***	***50***	***53***	***56***	***58***	***60***	***61***
	28	***21***	***37***	***45***	***51***	***54***	***57***	***59***	***61***	***62***
	30	***21***	***38***	***46***	***52***	***55***	***58***	***60***	***62***	***63***

M-4-100% Dead Balsam Fir Mixedwood-Green

ROS ch/hr		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	3	6	7	7	8	8	8	8	8
	4	7	15	18	19	20	20	21	21	21
	6	13	27	31	33	34	35	35	36	***36***
	8	18	38	***45***	***48***	***49***	***50***	***51***	***52***	***52***
	10	24	***51***	***59***	***62***	***65***	***66***	***67***	***68***	***69***
	12	30	***63***	***73***	***77***	***80***	***82***	***83***	***84***	***85***
	14	35	***74***	***86***	***92***	***95***	***98***	***99***	***100***	***101***
	16	41	***86***	***100***	***106***	***110***	***113***	***114***	***116***	***117***
	18	46	***97***	***113***	***120***	***124***	***127***	***129***	***131***	***132***
	20	51	***108***	***125***	***133***	***138***	***141***	***143***	***145***	***146***
	22	56	***118***	***137***	***146***	***151***	***154***	***157***	***158***	***160***
	24	60	***127***	***148***	***157***	***163***	***167***	***169***	***171***	***173***
	26	65	***136***	***158***	***168***	***175***	***179***	***181***	***183***	***185***
	28	69	***145***	***168***	***179***	***185***	***190***	***193***	***195***	***197***
	30	73	***153***	***177***	***189***	***196***	***200***	***203***	***206***	***207***
		Torching		***Continuous Crown Fire***						
FLAME LGTH-ft		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	3	6	7	8	9	10	10	11	11
	4	4	9	12	14	15	16	17	17	18
	6	5	12	16	19	20	21	22	23	***23***
	8	6	16	***20***	***22***	***24***	***25***	***26***	***27***	***28***
	10	7	***18***	***23***	***25***	***27***	***29***	***30***	***31***	***31***
	12	8	***21***	***25***	***28***	***30***	***32***	***33***	***34***	***35***
	14	8	***22***	***27***	***30***	***33***	***34***	***36***	***37***	***38***
	16	9	***24***	***29***	***33***	***35***	***37***	***38***	***39***	***40***
	18	9	***25***	***31***	***34***	***37***	***39***	***40***	***41***	***42***
	20	10	***27***	***32***	***36***	***39***	***41***	***42***	***44***	***44***
	22	10	***28***	***34***	***38***	***40***	***43***	***44***	***45***	***46***
	24	12	***29***	***35***	***39***	***42***	***44***	***46***	***47***	***48***
	26	14	***30***	***36***	***40***	***43***	***46***	***47***	***49***	***50***
	28	15	***30***	***37***	***41***	***44***	***47***	***49***	***50***	***51***
	30	16	***31***	***38***	***42***	***46***	***48***	***50***	***51***	***52***

9.3.15 S-1 and S-2 Fire Spread and Flame Length Outputs

S-1 Jack Pine Slash

ROS ch/hr		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	2	5	6	7	7	7	7	7	7
	4	5	12	14	15	16	17	17	17	17
	6	7	19	23	25	26	27	28	28	28
	8	10	27	33	35	37	38	39	39	40
	10	13	35	42	46	48	49	50	51	51
	12	16	42	51	56	58	60	61	62	63
	14	19	50	60	66	69	71	72	73	74
	16	22	57	69	75	79	81	83	84	85
	18	25	64	78	85	89	91	93	94	95
	20	27	71	86	94	98	101	103	105	106
	22	30	78	94	102	107	110	113	114	116
	24	32	84	102	111	116	119	122	124	125
	26	35	90	109	119	124	128	131	133	134
	28	37	96	117	127	132	136	139	141	143
	30	39	102	123	134	140	144	147	149	151

FLAME LEN-ft		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	4	9	11	12	13	13	14	14	14
	4	6	13	17	18	19	20	20	20	21
	6	7	17	21	23	24	25	25	25	26
	8	9	20	24	27	28	29	29	30	30
	10	10	22	27	30	31	32	33	33	34
	12	11	24	30	33	35	36	36	37	37
	14	11	26	32	35	37	38	39	39	40
	16	12	28	34	38	40	41	42	42	42
	18	13	29	36	40	42	43	44	44	45
	20	14	31	38	42	44	45	46	47	47
	22	14	32	40	43	46	47	48	49	49
	24	15	33	41	45	47	49	50	50	51
	26	15	34	42	47	49	50	51	52	52
	28	16	35	44	48	50	52	53	53	54
	30	16	36	45	49	52	53	54	55	55

S-2 White Spruce/Balsam Slash

ROS ch/hr		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	1	1	2	2	2	2	2	2	2
	4	2	4	5	6	6	6	6	6	6
	6	3	8	9	10	11	11	11	11	11
	8	5	12	14	15	16	17	17	17	17
	10	6	16	19	21	22	23	23	23	24
	12	8	20	25	27	28	29	29	30	30
	14	9	25	30	32	34	35	36	36	37
	16	11	29	35	38	40	41	42	43	43
	18	13	33	40	44	46	47	48	49	49
	20	14	37	45	49	51	53	54	55	55
	22	16	41	50	54	57	58	59	60	61
	24	17	45	54	59	62	63	65	66	66
	26	19	48	58	63	66	68	70	71	72
	28	20	51	62	68	71	73	74	76	76
	30	21	55	66	72	75	77	79	80	81

FLAME LEN-ft		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	3	7	8	9	9	10	10	10	10
	4	5	11	13	14	15	16	16	17	17
	6	7	14	17	19	20	21	22	22	23
	8	8	17	21	23	25	26	26	27	27
	10	9	20	24	27	28	30	30	31	32
	12	10	22	27	30	32	33	34	35	35
	14	11	24	30	33	35	36	37	38	39
	16	12	26	32	35	37	39	40	41	41
	18	13	28	34	38	40	41	43	43	44
	20	14	30	36	40	42	44	45	46	47
	22	14	31	38	41	44	46	47	48	49
	24	15	32	39	43	46	48	49	50	51
	26	15	33	41	45	47	49	51	52	52
	28	16	34	42	46	49	51	52	53	54
	30	16	35	43	47	50	52	54	55	55

9.3.16 S-3 Fire Spread and Flame Length Outputs

S-3 Coastal Cedar / Hemlock - Douglas-fir Slash

ROS ch/hr		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	<1	<1	1	1	1	1	1	1	1
	4	1	3	3	4	4	4	4	4	4
	6	3	8	10	11	11	11	12	12	12
	8	6	16	19	21	22	23	23	23	24
	10	10	26	31	34	36	37	37	38	38
	12	14	37	45	49	51	52	53	54	55
	14	19	49	59	64	67	69	70	71	72
	16	23	60	73	79	83	85	87	88	89
	18	27	72	87	94	98	101	103	105	106
	20	32	82	100	108	113	116	119	121	122
	22	35	92	111	121	127	130	133	135	137
	24	39	101	122	133	139	143	146	148	150
	26	42	109	132	143	150	154	158	160	162
	28	45	116	141	153	160	165	168	170	172
	30	47	122	148	161	168	173	177	180	182

FLAME LEN-ft		BUILDUP INDEX (BUI)								
		10	30	50	70	90	110	130	150	170
INITIAL SPREAD INDEX (ISI)	2	2	5	6	7	7	8	8	8	8
	4	5	11	15	17	18	19	19	20	20
	6	8	19	24	27	29	30	31	32	32
	8	11	25	32	37	39	41	42	43	44
	10	13	32	40	46	49	51	53	54	55
	12	16	37	48	54	58	61	62	64	65
	14	18	42	54	61	66	69	71	72	73
	16	20	47	60	68	72	76	78	80	81
	18	21	51	65	73	78	82	85	86	88
	20	23	54	69	78	84	87	90	92	93
	22	24	57	73	82	88	92	95	97	98
	24	25	59	76	86	92	96	99	101	103
	26	26	61	78	89	95	100	103	105	106
	28	27	63	81	91	98	103	106	108	109
	30	27	65	83	94	100	105	108	110	112

9.3.17 O-1a and O-1b Fire Spread and Flame Length Outputs

O-1a-Matted Grass

ROS ch/hr		**Degree of Curing**					
		50%	**60%**	**70%**	**80%**	**90%**	**100%**
INITIAL SPREAD INDEX	**2**	1	2	4	7	9	11
	4	3	6	11	16	22	27
	6	5	9	19	28	37	47
	8	7	13	27	40	54	67
	10	9	18	35	53	70	88
	12	11	22	44	65	87	109
	14	13	26	52	78	104	130
	16	15	30	60	91	121	151
	18	18	34	68	103	137	171
	20	20	38	76	115	153	191

O-1b-Standing Grass

ROS ch/hr		**Degree of Curing**					
		50%	**60%**	**70%**	**80%**	**90%**	**100%**
INITIAL SPREAD INDEX	**2**	1	2	3	5	6	8
	4	2	5	9	14	19	23
	6	4	9	18	26	35	44
	8	7	14	27	41	54	68
	10	10	19	38	56	75	94
	12	12	24	48	73	97	121
	14	15	30	60	89	119	149
	16	18	35	71	106	141	177
	18	21	41	82	123	164	205
	20	24	46	93	139	186	232

1 TON/AC FUEL LOAD

Flame Length-ft		**Degree of Curing**					
		50%	**60%**	**70%**	**80%**	**90%**	**100%**
INITIAL SPREAD INDEX	**2**	1	2	2	3	3	3
	4	2	2	3	4	4	5
	6	2	3	4	5	6	6
	8	3	4	5	6	7	7
	10	3	4	6	7	8	8
	12	3	4	6	7	8	9
	14	3	5	7	8	9	10
	16	4	5	7	9	10	11
	18	4	5	7	9	10	11
	20	4	6	8	9	11	12

Flame Length-ft		**Degree of Curing**					
		50%	**60%**	**70%**	**80%**	**90%**	**100%**
INITIAL SPREAD INDEX	**2**	1	1	2	2	3	3
	4	2	2	3	4	4	5
	6	2	3	4	5	6	6
	8	3	4	5	6	7	7
	10	3	4	6	7	8	9
	12	3	5	6	8	9	10
	14	4	5	7	8	10	11
	16	4	6	8	9	10	12
	18	4	6	8	10	11	12
	20	5	6	9	10	12	13

2 TON/AC FUEL LOAD

Flame Length-ft		**Degree of Curing**					
		50%	**60%**	**70%**	**80%**	**90%**	**100%**
INITIAL SPREAD INDEX	**2**	2	2	3	4	4	4
	4	2	3	4	5	6	7
	6	3	4	6	7	8	9
	8	4	5	7	8	9	10
	10	4	6	8	9	10	12
	12	4	6	8	10	12	13
	14	5	7	9	11	12	14
	16	5	7	10	12	13	15
	18	5	7	10	12	14	16
	20	6	8	11	13	15	16

Flame Length-ft		**Degree of Curing**					
		50%	**60%**	**70%**	**80%**	**90%**	**100%**
INITIAL SPREAD INDEX	**2**	1	2	3	3	3	4
	4	2	3	4	5	6	6
	6	3	4	6	7	8	8
	8	4	5	7	8	9	10
	10	4	6	8	9	11	12
	12	5	6	9	11	12	13
	14	5	7	10	12	13	15
	16	6	8	10	13	14	16
	18	6	8	11	13	15	17
	20	6	9	12	14	16	18

3 TON/AC FUEL LOAD

Flame Length-ft		**Degree of Curing**					
		50%	**60%**	**70%**	**80%**	**90%**	**100%**
INITIAL SPREAD INDEX	**2**	2	3	4	4	5	5
	4	3	4	5	6	7	8
	6	4	5	7	8	9	10
	8	4	6	8	10	11	12
	10	5	7	9	11	13	14
	12	5	7	10	12	14	15
	14	6	8	11	13	15	17
	16	6	9	12	14	16	18
	18	7	9	12	15	17	19
	20	7	9	13	16	18	20

Flame Length-ft		**Degree of Curing**					
		50%	**60%**	**70%**	**80%**	**90%**	**100%**
INITIAL SPREAD INDEX	**2**	2	2	3	4	4	5
	4	3	4	5	6	7	8
	6	4	5	7	8	9	10
	8	4	6	8	10	11	12
	10	5	7	9	11	13	14
	12	6	8	11	13	15	16
	14	6	8	12	14	16	18
	16	7	9	13	15	17	19
	18	7	10	13	16	18	20
	20	8	10	14	17	20	22

9.3.18 Fire Area and Perimeter for Sheltered Fuels (C, M, D, S)

		Effective Windspeed (in Miles per Hour); Eye Level (EL)														
10 Meter		1	3	5	6	8	9	11	12	14	15	18	21	24	27	30
EL Open		1	2	3	4	5	6	7	8	9	10	11	13	15	17	19
		Burned Area (in Acres)														
Total Spread Distance (in chains)	5	2	2	1	1	1	1	1	1	1	1	1	0	0	0	0
	10	8	7	6	5	5	4	3	3	3	3	2	2	2	1	1
	15	17	16	13	12	10	9	8	7	6	6	5	4	4	3	3
	20	31	28	24	22	18	16	14	13	11	10	9	7	6	6	5
	25	49	44	37	34	28	26	22	20	17	16	13	11	10	9	8
	30	70	63	54	49	41	37	31	29	25	23	19	17	15	13	12
	35	95	86	73	67	55	50	42	39	34	31	26	22	20	18	16
	40	124	113	96	87	72	66	55	51	44	41	34	29	26	23	21
	45	157	143	121	110	91	83	70	64	55	52	43	37	33	30	27
	50	194	176	150	136	113	103	86	79	68	64	53	46	40	36	33
	55	235	213	181	165	136	124	104	96	83	77	64	55	49	44	40
	60	279	254	215	196	162	148	124	114	98	92	77	66	58	53	48
	65	328	298	253	230	190	173	146	134	116	108	90	78	68	62	56
	70	380	345	293	267	221	201	169	156	134	125	104	90	79	71	66
	75	437	396	337	307	253	231	194	179	154	144	120	103	91	82	75
	80	497	451	383	349	288	263	221	203	175	164	136	117	104	93	86
	85	561	509	432	394	325	297	249	230	198	185	154	133	117	105	97
	90	629	571	485	441	365	333	279	257	222	207	173	149	131	118	108
	95	700	636	540	492	407	370	311	287	247	231	192	166	146	132	121
	100	776	704	598	545	450	411	345	318	274	256	213	183	162	146	134
	150	1746	1585	1346	1226	1014	924	775	715	616	575	480	413	364	328	301
	200	3105	2818	2393	2180	1802	1642	1378	1271	1094	1022	853	734	648	584	535
	250	4851	4402	3739	3407	2816	2566	2154	1985	1710	1597	1332	1147	1012	912	836
	300	6985	6340	5384	4905	4054	3695	3101	2859	2462	2300	1919	1651	1457	1313	1203
		Fireline Perimeter (in Chains)														
Total Spread Distance (in chains)	5	16	15	14	13	13	12	12	12	11	11	11	11	10	10	10
	10	31	30	28	27	25	25	23	23	22	22	22	21	21	21	21
	15	47	45	42	40	38	37	35	35	34	33	32	32	31	31	31
	20	62	60	56	54	50	49	47	46	45	44	43	42	42	42	41
	25	78	75	69	67	63	61	59	58	56	55	54	53	52	52	52
	30	94	89	83	80	76	74	70	69	67	67	65	64	63	62	62
	35	109	104	97	94	88	86	82	81	78	78	76	74	73	73	72
	40	125	119	111	107	101	98	94	92	90	89	86	85	84	83	83
	45	141	134	125	121	113	110	106	104	101	100	97	96	94	94	93
	50	156	149	139	134	126	123	117	115	112	111	108	106	105	104	103
	55	172	164	153	148	138	135	129	127	123	122	119	117	115	115	114
	60	187	179	167	161	151	147	141	138	134	133	130	127	126	125	124
	65	203	194	181	174	164	159	152	150	146	144	140	138	136	135	135
	70	219	209	195	188	176	172	164	161	157	155	151	149	147	146	145
	75	234	224	208	201	189	184	176	173	168	166	162	159	157	156	155
	80	250	239	222	215	201	196	188	184	179	177	173	170	168	167	166
	85	265	253	236	228	214	208	199	196	191	188	184	181	178	177	176
	90	281	268	250	241	227	221	211	207	202	200	195	191	189	187	186
	95	297	283	264	255	239	233	223	219	213	211	205	202	199	198	197
	100	312	298	278	268	252	245	235	231	224	222	216	212	210	208	207
	150	468	447	417	402	378	368	352	346	336	333	324	319	315	312	310
	200	625	596	556	537	503	490	469	461	448	443	432	425	420	416	414
	250	781	745	695	671	629	613	586	576	560	554	540	531	525	521	517
	300	937	895	834	805	755	735	704	692	672	665	648	637	630	625	621

9.3.19 Fire Area and Perimeter for Open Fuels (O-1a, O-1b)

		Effective Windspeed (in Miles per Hour), Eye Level (EL)														
10 Meter		**1**	**3**	**5**	**6**	**8**	**9**	**11**	**12**	**14**	**15**	**18**	**21**	**24**	**27**	**30**
EL Open		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**12**	**14**	**16**	**18**	**20**
		Burned Area (in Acres)														
Total Spread Distance (in chains)	**5**	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
	10	6	3	3	2	2	2	2	2	2	2	2	1	1	1	1
	15	13	8	6	6	5	5	4	4	4	4	3	3	3	3	3
	20	22	14	11	10	9	8	7	7	7	7	6	6	5	5	5
	25	35	22	17	15	14	13	12	11	11	10	9	9	8	8	7
	30	50	31	25	22	20	19	17	16	15	15	14	13	12	11	11
	35	69	42	34	30	27	25	23	22	21	20	19	17	16	15	15
	40	90	55	44	39	35	33	30	29	27	26	24	23	21	20	19
	45	114	70	56	50	45	42	38	36	35	33	31	29	27	25	24
	50	140	86	70	61	55	52	47	45	43	41	38	36	33	31	30
	55	170	104	84	74	67	63	57	54	52	49	46	43	40	38	36
	60	202	124	100	88	79	74	67	64	62	59	54	51	47	45	43
	65	237	146	117	104	93	87	79	75	72	69	64	60	55	53	50
	70	275	169	136	120	108	101	92	87	84	80	74	70	64	61	58
	75	316	194	156	138	124	116	105	100	96	92	85	80	74	70	67
	80	359	221	178	157	141	132	120	114	110	105	97	91	84	80	76
	85	405	249	201	177	160	149	135	129	124	118	109	103	95	90	86
	90	454	279	225	199	179	167	151	145	139	133	122	116	106	101	96
	95	506	311	251	222	199	187	169	161	155	148	136	129	118	113	107
	100	561	345	278	245	221	207	187	178	172	164	151	143	131	125	119
	150	1262	776	626	552	497	465	421	402	386	368	340	321	295	280	268
	200	2244	1379	1112	982	883	827	748	714	686	654	604	571	524	499	476
	250	3506	2154	1738	1534	1380	1292	1169	1116	1072	1023	944	892	818	779	744
	300	5049	3102	2503	2209	1987	1860	1683	1606	1544	1473	1359	1285	1178	1122	1071
		Fireline Perimeter (in Chains)														
Total Spread Distance (in chains)	**5**	14	12	11	11	11	11	11	11	11	11	10	10	10	10	10
	10	27	23	22	22	22	22	21	21	21	21	21	21	21	21	21
	15	41	35	34	33	33	32	32	32	32	32	31	31	31	31	31
	20	54	47	45	44	43	43	43	42	42	42	42	42	41	41	41
	25	68	59	56	55	54	54	53	53	53	53	52	52	52	51	51
	30	81	70	67	66	65	65	64	64	63	63	63	62	62	62	62
	35	95	82	79	77	76	75	75	74	74	74	73	73	72	72	72
	40	108	94	90	88	87	86	85	85	84	84	84	83	83	82	82
	45	122	106	101	99	98	97	96	95	95	95	94	94	93	93	92
	50	136	117	112	110	109	108	106	106	106	105	104	104	103	103	103
	55	149	129	124	121	119	118	117	117	116	116	115	114	114	113	113
	60	163	141	135	132	130	129	128	127	127	126	125	125	124	124	123
	65	176	152	146	143	141	140	138	138	137	137	136	135	134	134	134
	70	190	164	157	154	152	151	149	148	148	147	146	146	145	144	144
	75	203	176	169	165	163	161	160	159	158	158	157	156	155	154	154
	80	217	188	180	176	174	172	170	170	169	168	167	166	165	165	164
	85	230	199	191	187	185	183	181	180	179	179	177	177	176	175	175
	90	244	211	202	198	195	194	192	191	190	189	188	187	186	185	185
	95	258	223	214	209	206	205	202	201	201	200	198	197	196	196	195
	100	271	235	225	220	217	215	213	212	211	210	209	208	207	206	205
	150	407	352	337	330	326	323	319	318	317	315	313	312	310	309	308
	200	542	469	450	441	434	431	426	424	422	420	418	416	413	412	411
	250	678	587	562	551	543	538	532	530	528	525	522	520	517	515	514
	300	937	895	834	805	755	735	704	692	672	665	648	637	630	625	621

9.4 FWI & FBP Calculations Worksheet

Forecasted Weather:

	Yesterday's ( ) Values			Today's ( ) Daily Values							
STATION	FFMC	DMC	DC	RnCd/FFMC		RnCd/DMC		RnCd/DC		BUI	ISI
Site Estimate											

Slope Equivalent Windspeed		
Fuel Type	Slope, %	Slope Wind

FFMC Slope-Aspect Adjustments			
FFMC-fl	Slope, %	Aspect	FFMC-Sl

Hourly FFMC/ISI Adjustments							
Time	Temp	RH	Eff WSpd 10m	EL	FFMC	ISI	BISI
0800							
0900							
1000							
1100							
1200							
1300							
1400							
1500							
1600							
1700							
1800							
1900							
2000							

Fuel Type & Modifier	Spread Dir	ISI		Spread		Flame		Torching or Crowning?
		Min	Max	Min	Max	Min	Max	

Spot Distance	
No of Trees	
Tree Spp	
Tree DBH	
Cover Ht.	
Windspeed	
Spot Dist.	

ALLOWABLE SCORCH HT.	SOURCE	
Total Tree Height (feet)	Est. from Stand Inventory	
Ht. to Live Crown (feet)	Est. from Stand Inventory	
Crown Ratio (dec. e.g. .7)	Est. from Stand Inventory	
Crown Height (feet)	Calculated; 1 - 2 or 1 X 3	
Allow. Crown Scorch (dec.)	Sensitivity to Mortality	
Allow. Crown Scorch (feet)	Calculated; 4 X 5	
Allow. Scorch Height (feet)	Calculated 2 + 6	

FIRE SIZE AND SHAPE	
OPEN FUELS	
Duration	
Spread Distance	
Effective Windspeed	
Area	
Perimeter	
Length:Width	

SMOKE & EFFECTS	Daily/Max	Hour:	Hour:
13. Surface Fuel Consump.			
14. Scorch Height			
Surface Wind Direction			
Transport Wind			
Transport Wind Direction			
Mixing Height			

SHELTERED FUELS	
Duration	
Spread Distance	
Effective Windspeed	
Area	
Perimeter	
Length:Width	

10 Contacts, Forms, Job Aids

Contents

10.1 Contacts

10.1.1 National Weather Service WFO Fire Weather Contacts

10.1.2 Geographic Area Predictive Services Contacts

10.1.3 FBAN/LTAN

10.2 Forms

10.3 Job Aids