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Supplementary Material

A framework for defining fire danger to support fire management operations in Australia

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BUTTONGRASS

QUICK GUIDE

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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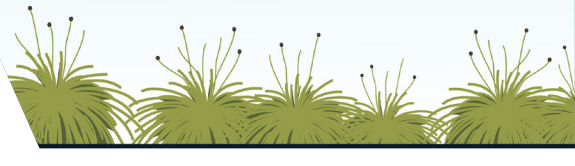
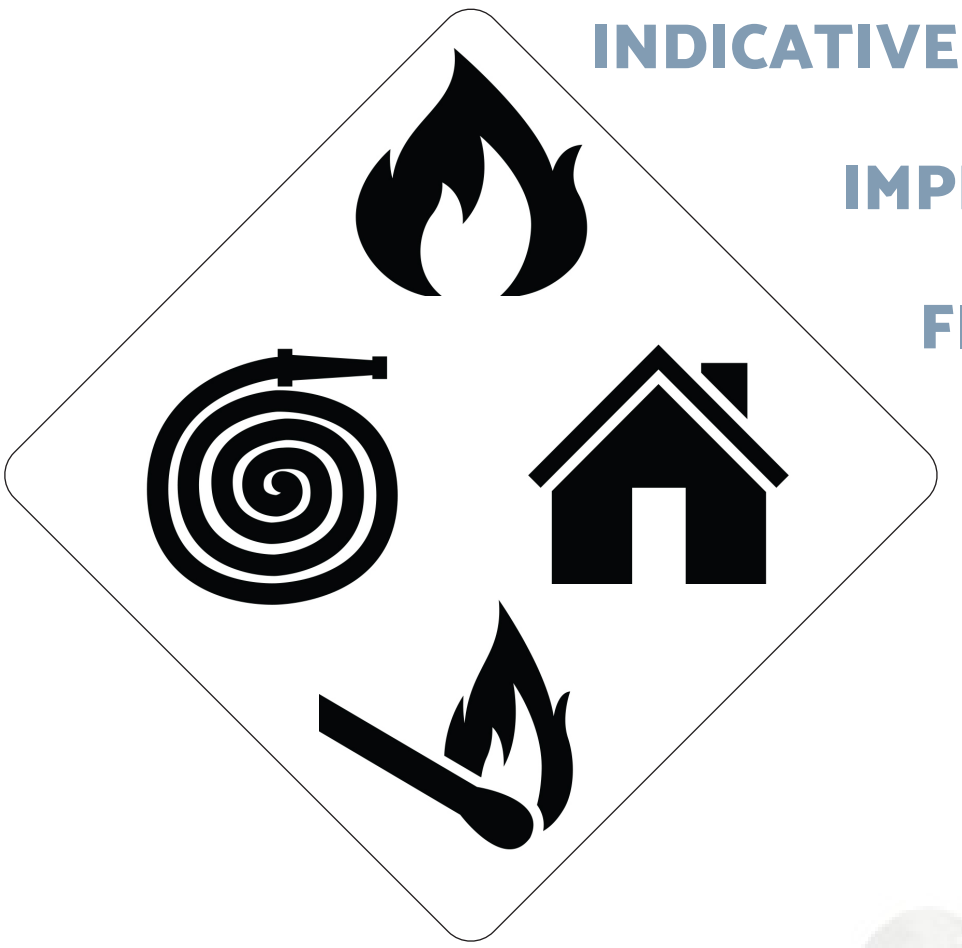


Australian
Fire Danger
Rating System



INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

IMPLICATIONS FOR PRESCRIBED BURNING

FIRE SUPPRESSION AND CONTAINMENT

POTENTIAL FOR IMPACT

BUTTONGRASS FUELS IN THE AUSTRALIAN FIRE DANGER RATING SYSTEM

In the Australian Fire Danger Rating System (AFDRS), fuel types have been grouped by application of the most relevant fire spread model. The Buttongrass moorlands fuel type is defined as treeless, or near treeless, communities dominated by sedges and low heaths with a significant proportion of buttongrass. This fuel type is largely restricted to Tasmania, although similar heathlands and moors can be found in select areas in other states.

BUTTONGRASS FUEL STRUCTURE

As a vegetation type buttongrass moorlands include a number of structural and floristic communities. The presence of buttongrass (*Gymnoschoenus sphaerocephalus*), a tussock sedge, defines this vegetation type. Other graminoid and shrubs are often present in this fuel type. Structurally, this vegetation type can vary from low, closed sedgeland with heath, to a medium height shrubland. With increasing time since fire disturbance, buttongrass moorland fuel complexes change to support and increasing presence of shrubs. For long unburned communities, where a layer of taller shrubs has developed, buttongrass moorlands are characterised as medium-height shrublands with a sedgy understorey.

Fire in buttongrass moorlands is typically sustained by the near-surface and elevated fuels. As the time since fire increases, so too does the proportion of dead fuels suspended in a well aerated elevated fuel layer that burns with high efficiency. This suspended dead fuel layer enables fire to spread even when fuel moisture content levels are high or fire spread is not sustained in adjacent different fuel types, such as forests. The litter fuel layer is incipient or completely absent. With increasing time since fire, the fuel complex also increases in flammability due to the accumulation of dead fuels in the elevated fuel layer. As fuels age above 15-20 years (after fire), it's possible that more than half the fine fuel in the elevated layer is dead fuel.

CONTENTS

FOR MORE INFORMATION ON FUELS REFER TO:
***A GUIDE TO RATE OF FIRE SPREAD MODELS FOR AUSTRALIAN VEGETATION* (2015 EDITION)**

FIRE SPREAD
IN BUTTONGRASS FUELS

Rate of fire spread is the foundation variable for all calculations in the Australian Fire Danger Rating System. The buttongrass fire spread model is applied to areas mapped as buttongrass moorlands.

BACKGROUND

The buttongrass fire spread model system was developed within the scope of a comprehensive study aimed at characterising fire danger in Tasmanian buttongrass moorlands carried out by the Tasmania Parks and Wildlife Service in the 1990s. The model is based on data from experimental fires, operational prescribed burns and wildfires, covering a wide range of burning conditions. The experimental and prescribed fire data came from twelve different locations throughout Tasmania, covering a broad range of fuel characteristics.

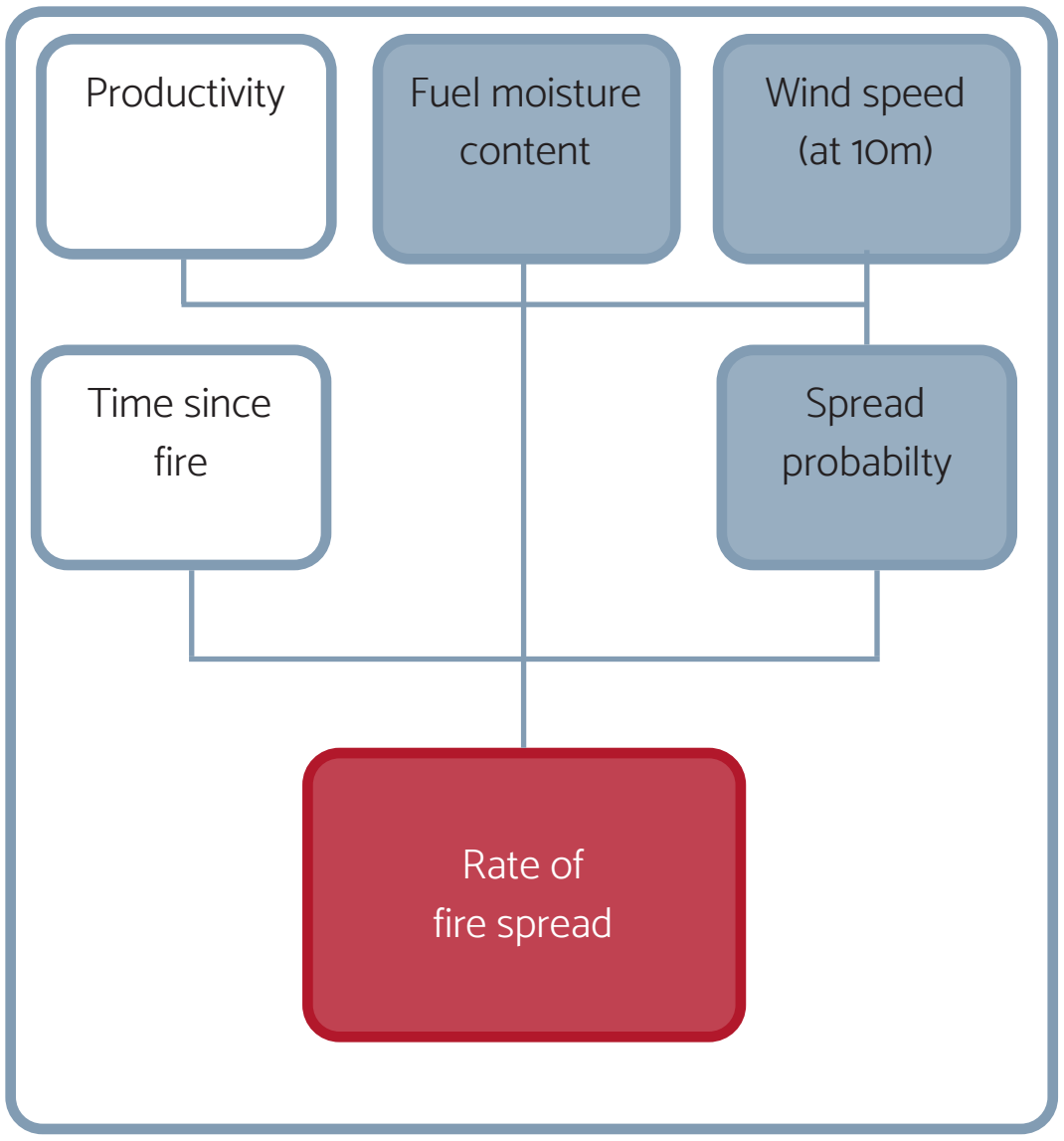
WHERE IS THE MODEL APPLIED?

The Buttongrass model is applied to Tasmanian buttongrass moorlands as well as similar sedgelands and moors found in certain areas in other states.

HOW IS THE MODEL APPLIED?

The absence of a litter layer in buttongrass fuels, together with fire spread occurring under high fuel moisture content, makes it necessary to calculate fire spread rate through a two-step process. The first calculation involves determining the probability of sustained propagation; if the probability is higher than 50%, the system then assumes sustained propagation will occur and a rate of fire spread is calculated. If the probability is lower than 50%, the system infers that fire will not spread and fire danger is not rateable.

WHAT ARE THE MAIN INPUTS?



Rate of fire spread in Buttongrass is calculated as a function of productivity time since fire, 10 m open wind speed and fine fuel moisture content.

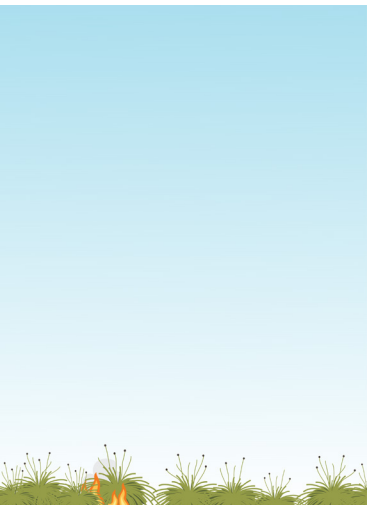
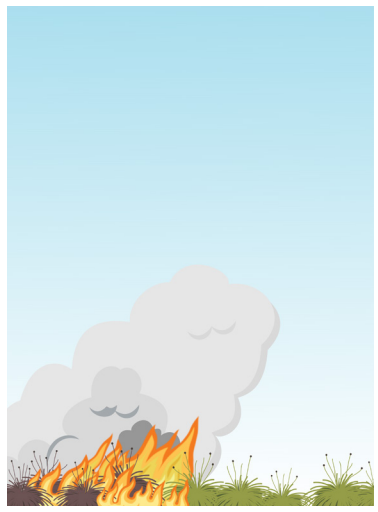
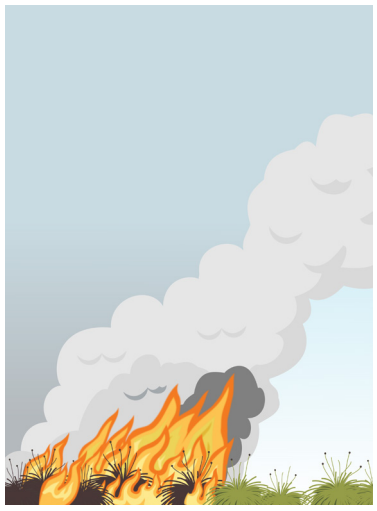
This probability calculation requires as inputs the 10-m open wind speed, moisture content of dead fuels and an estimate of site productivity. Dead fuel moisture content is estimated from relative humidity, dew point temperature, the time since last rainfall, and the amount of this rainfall. The second calculation determines the rate of fire spread, requiring as a further input the time since fire. Time since fire and site productivity are used in the model as easy to access surrogates of other fuel variables, such as quantity and proportion of dead fuel.

WHAT IS THE MODEL SENSITIVE TO?

The open nature of this fuel complex makes wind the variable with the strongest effect on rate of fire spread. The moisture content of suspended dead fuels has also a significant effect on model behaviour although its effect is lower than wind. Recent rainfall also has an effect by increasing fuel moisture and decreasing the likelihood of sustained fire spread. Notably, fire spread is often possible with high dead fuel moisture contents values that typically would not enable fire spread in other fuel types. This is linked to exposure of elevated dead fuels to wind, and the effect of this variable in increasing energy transfer into unburned fuels as the fire spread. Fuel age has a strong effect on fire propagation while fuels are young (typically less than 20 years old), while in older fuels, the effect of fuel age on the rate of fire spread is less pronounced.

MORE DETAIL ON THE MODEL CAN BE FOUND IN:
A GUIDE TO RATE OF FIRE SPREAD MODELS FOR AUSTRALIAN VEGETATION

UNDERSTANDING THE
FIRE BEHAVIOUR INDEX
IN BUTTONGRASS FUELS

Fire Behaviour Index 0-5	6-11	12-23	24-49	50-99	100+
					
No rating		Moderate	High	Extreme	Catastrophic
fire behaviour		fire behaviour	suppression	impact	impact
Fires are likely to self-extinguish	Typical prescribed burning conditions. Fires generally easy to suppress.	Fires more difficult to control.	Increasing focus on defensive suppression strategies. Initial attack success critical to prevent large fire development.	High levels of threat to life and property. Elevated risk to firefighter safety. Conditions limit strategic suppression options.	High probability of loss of life and property when in close proximity to assets.

A SCALE OF POTENTIAL FIRE DANGER

The Fire Behaviour Index (FBI) was developed to assist operational decision making, while the Fire Danger Ratings provide the broad categories needed to communicate fire danger to the community.

The FBI provides a scale of potential fire danger (should a fire start) based on the predicted rate of fire spread. In buttongrass fuels, the rate of fire spread is used to categorise fire danger on the FBI scale.

TRANSITIONS AND CATEGORIES

The FBI is made up of step-ups or transitions, where an increase in category is triggered by a change in:

1. fire behaviour,
2. suppression response, or
3. potential impacts.

Each category is defined in terms of:

1. indicative fire behaviour and fire weather,
2. implications for prescribed burning,
3. fire suppression and containment, and
4. potential impacts.

BUTTONGRASS

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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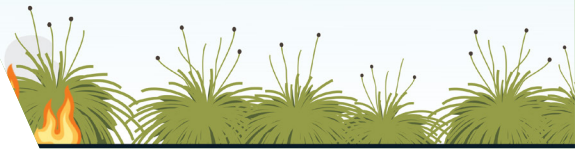
Fire Behaviour Index
0-5

- Mostly self-extinguishing, trouble-free fires.
- Moorland Fire Danger Rating: 0



INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

Fires unlikely to be sustained and may be difficult to ignite.

- Rate of Spread: 0.30 m/hr
- Max. Flame Height: Small flame heights typically <1 m
- Spotting Potential: Potential for any spotting is minimal

IMPLICATIONS FOR PRESCRIBED BURNING

Marginal prescribed burn conditions, even at peak of the day.

Fire may fail to sustain over fuel discontinuities.

FIRE SUPPRESSION AND CONTAINMENT

Fire control relatively simple.

Mostly contained within simple, natural boundaries, road networks and fuel breaks >2 m.

Delayed containment possible with suitable conditions.

Head-fire readily suppressed with offensive, direct attack techniques.

Initial attack success is typically very high.

CREDIBLE WORST CASE
MAX. POTENTIAL
in 4 hr

AREA
<1 ha

PERIMETER
<0.5 km

POTENTIAL FOR IMPACT

Community losses are unlikely.

CONDITIONS TO CONSIDER

BUTTONGRASS

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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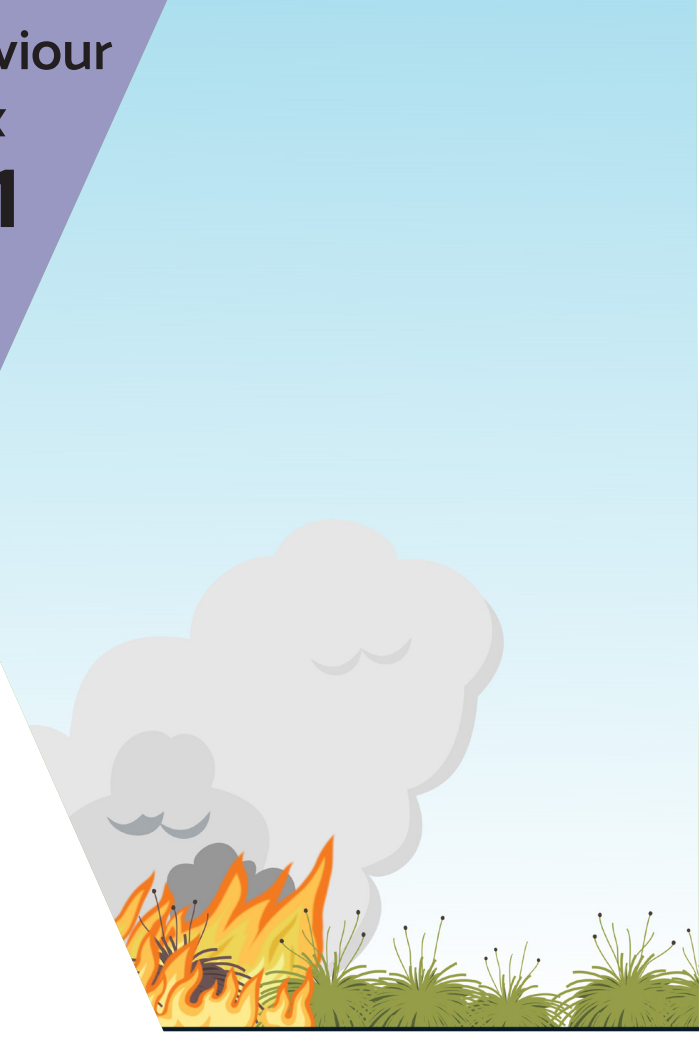
Fire Behaviour Index
6-11



- Typical prescribed burning conditions.
- Fires generally easy to suppress.
- Moorland Fire Danger Rating: LOW (1-5)

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

Mostly slow spreading fires.

- Rate of Spread: 30 -450 m/hr
- Max. Flame Height: <6 m
- Spotting Potential: Possible short distance spotting up to 5 m can be expected

IMPLICATIONS FOR PRESCRIBED BURNING

Suitable fire behaviour for hazard reductions and ecosystem management burns.

FIRE SUPPRESSION AND CONTAINMENT

Fire control mostly simple with sufficient resources and becoming more complex at higher intensities.

Fires typically contained within natural boundaries, road networks and fuel breaks >5 m.

Offensive, direct attack techniques on head-fire or flanks largely successful in fire control.

Delayed containment sometimes possible with suitable conditions.

CREDIBLE WORST CASE
MAX. POTENTIAL
in 4 hr

AREA
<150 ha

PERIMETER
<5 km

POTENTIAL FOR IMPACT

Community losses are unlikely, however unattended or poorly prepared houses and infrastructure may be at risk.

CONDITIONS TO CONSIDER

BUTTONGRASS

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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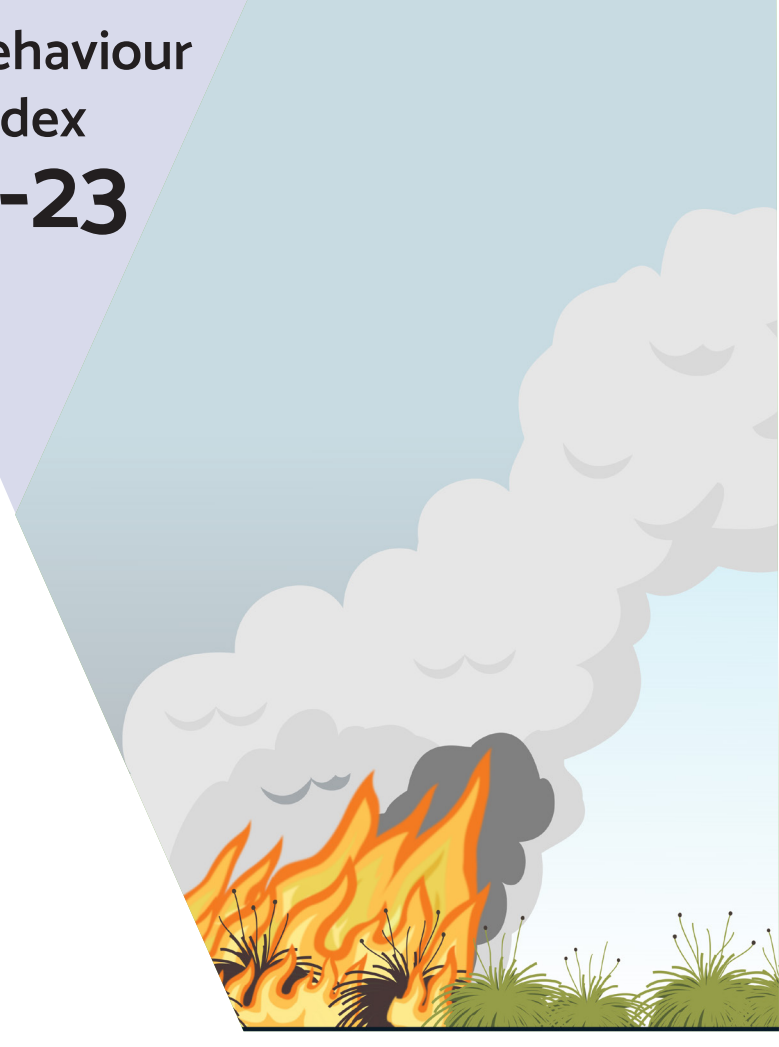
Fire Behaviour Index
12-23



- Fires difficult to control.
- Moorland Fire Danger Rating: MODERATE (6-11) HIGH (13-24)

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

Typically wind driven and quickly spreading fires.

- Rate of Spread: 450 -2,000 m/hr
- Max. Flame Height: 2-9 m
- Spotting Potential: Possible short distance spotting up to 30 m can be expected

IMPLICATIONS FOR PRESCRIBED BURNING

Conditions may be suitable for prescribed burning provided sufficient, secure, non-flammable boundaries are present.

Fire behaviour too intense to suppress fire without relying on non-flammable boundaries.

FIRE SUPPRESSION AND CONTAINMENT

Fires generally becoming more complex and require more resources to control.

Combinations of direct, indirect or parallel attack may be necessary for fire control.

Requires increased effort and resources to contain fire within existing road networks and fuel break boundaries.

Fires typically requiring fuel breaks 10-25 m wide and supported by pumps to achieve containment (control lines >5 m for flanks and back-fires).

CREDIBLE WORST CASE
MAX. POTENTIAL
in 4 hr

AREA
<850 ha

PERIMETER
<10 km

POTENTIAL FOR IMPACT

Community losses are unlikely, however unattended or poorly prepared houses and infrastructure may be at risk.

CONDITIONS TO CONSIDER

- C-Haines >95th percentile (approx. 5-7)
- Wind change forecast during the peak of the afternoon, potential conditions for 'dead man zone'

BUTTONGRASS

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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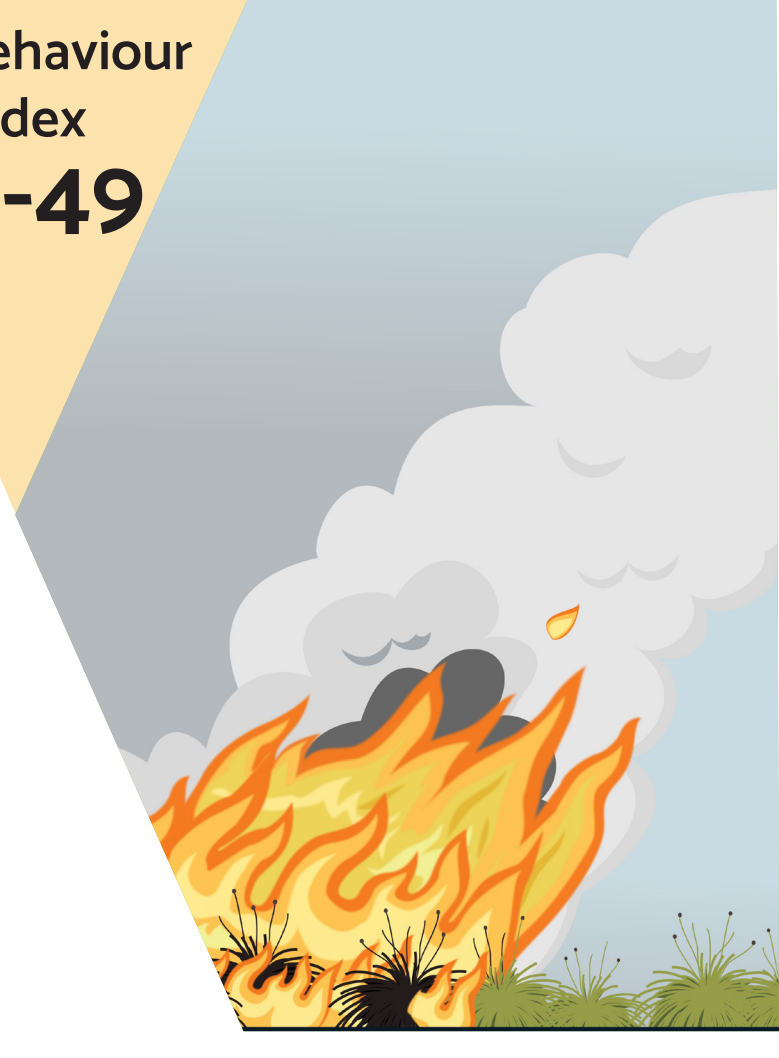
Fire Behaviour Index
24-49



- Increasing focus on defensive suppression strategies.
- Initial attack success critical to prevent large fire development.
- Moorland Fire Danger Rating: VERY HIGH (25-50)

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

Wind driven, rapidly spreading fires with potential for development into large fire area/size and with the potential for short distance spotting and long flame lengths.

- Rate of Spread: 2-4 km/hr
- Max. Flame Height: 3-12 m
- Spotting Potential: High risk of spotting across fire breaks. Spotting up to 500 m is common

IMPLICATIONS FOR PRESCRIBED BURNING

Conditions will be unsuitable for prescribed burning.

Potential fireline intensity and spotting activity pose a serious risk to firefighter safety and the community.

FIRE SUPPRESSION AND CONTAINMENT

Offensive strategies likely to be challenged during the peak of the day with focus largely centred on the rear and flanks.

Suppression increasingly focused on defensive strategies.

Fire control is likely to be difficult and require increased resourcing.

Fuel breaks 25-50 m wide supported by tankers required for containment (control lines >10 m for flanks and back-fires).

Personnel positioned down-wind and to the flanks of the fire should be made aware of the high risk of the fire jumping fire-breaks.

Increased risk to firefighter safety.

CREDIBLE WORST CASE
MAX. POTENTIAL
in 4 hr

AREA
<3,500 ha

PERIMETER
<20 km

POTENTIAL FOR IMPACT

High likelihood of pasture/crop/stock loss together with loss of rural assets such as fencing, machinery and buildings.

CONDITIONS TO CONSIDER

- C-Haines >95th percentile (approx. 5-7)
- Wind change forecast during the peak of the afternoon, potential conditions for 'dead man zone'

BUTTONGRASS

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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Fire Behaviour Index 50-99

- High probability of loss of life and property when in close proximity to assets.
- Elevated risk to firefighter safety.
- Initial attack success critical to prevent large fire development.
- Conditions limit strategic suppression options.
- Moorland Fire Danger Rating: EXTREME (51-100)

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

Extremely rapid fire growth and high likelihood of large final fire area/size. Possibility for fire behaviour to become erratic and plume driven. Strong convective column formation. Wind speed and direction likely to be erratic at times.

- Rate of Spread: 4-8 km/hr
- Max. Flame Height: 4-16 m
- Spotting Potential: High risk of spotting across fire breaks. Spotting over 2 km is common

IMPLICATIONS FOR PRESCRIBED BURNING

Conditions will be unsuitable for prescribed burning. Potential fireline intensity and spotting activity pose a serious risk to firefighter safety and the community.

FIRE SUPPRESSION AND CONTAINMENT

Control of developed fires is extremely difficult and unlikely until conditions ease.

Suppression will be largely based on defensive strategies, ensuring firefighter and community preparedness and safety.

Fuel breaks >100 m wide and supported by tankers are required for containment (control lines >10 m and supported by pumps for flanks and back-fires).

Offensive strategies could position crews in danger, however safe opportunities may exist for direct, indirect or parallel attack on the rear and flanks.

Essential no personnel be positioned down-wind or to the flank of the fire unless they have safe fuel-free zones to retreat into.

Conditions on the fireground are likely to be extremely windy and smoky limiting visibility and restricting aviation and access. Increased risk to firefighter safety.

CREDIBLE WORST CASE
MAX. POTENTIAL in 4 hr

AREA
<15,000 ha

PERIMETER
<45 km

POTENTIAL FOR IMPACT

Increasingly high likelihood of pasture/crop/stock loss together with loss of rural assets such as fencing, machinery and buildings.
Limited visibility due to smoke and dust.
Strong winds are likely to impact infrastructure (e.g. power lines) and fall trees increasing the likelihood of obstructed roads and power outages.

CONDITIONS TO CONSIDER

- C-Haines >95th percentile (approx. 5-7)
- Wind change forecast during the peak of the afternoon, potential conditions for 'dead man zone'

BUTTONGRASS

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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Fire Behaviour Index **100+**

- High probability of loss of life and property when in close proximity to assets.
- Elevated risk to firefighter safety.
- Initial attack success critical to prevent large fire development.
- Conditions limit strategic suppression options.
- Moorland Fire Danger Rating: EXTREME (over 100)

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

Extremely rapid fire growth and high likelihood of large final fire area/size. Possibility for fire behaviour to become erratic and plume driven. Strong convective column formation. Wind speed and direction likely to be erratic at times.

- Rate of Spread: >8 km/hr
- Max. Flame Height: > 8 m
- Spotting Potential: High risk of spotting across fire breaks. Spotting over 2 km is common

IMPLICATIONS FOR PRESCRIBED BURNING

Conditions will be unsuitable for prescribed burning. Potential fireline intensity and spotting activity pose a serious risk to firefighter safety and the community.

FIRE SUPPRESSION AND CONTAINMENT

Fire control is extremely difficult and unlikely until conditions ease. Suppression will be largely based on defensive strategies, ensuring firefighter and community preparedness and safety. Offensive strategies could position crews in danger, however safe opportunities may exist for direct, indirect or parallel attack on the rear and flanks. Important initial attack opportunities may exist for new ignitions. Conditions on the fireground are likely to be extremely windy and smoky limiting visibility and restricting aviation and access. Conditions are likely to impact performance and effectiveness of aerial resources with a high probability that some aircraft will be unable to operate due to high winds and limited visibility. Systems such as communications, will be heavily challenged with a likelihood of difficulties and outages. Essential no personnel be positioned down-wind or to the flank of the fire unless they have safe fuel-free zones to retreat into. Increased risk to firefighter safety.

CREDIBLE WORST CASE

MAX. POTENTIAL in 4 hr

AREA

>15,000 ha

PERIMETER

>45 km

POTENTIAL FOR IMPACT

Extremely high likelihood of pasture/crop/stock loss together with loss of rural assets such as fencing, machinery and buildings. Very limited visibility due to smoke and dust. Very high risk to the community related to inappropriate pre-considered plans, inadequate sheltering.
Strong winds are very likely to impact infrastructure (e.g. power lines) and fall trees resulting in a high likelihood of obstructed roads and power outages.

CONDITIONS TO CONSIDER

- C-Haines >95th percentile (approx. 5-7)
- Wind change forecast during the peak of the afternoon, potential conditions for 'dead man zone'

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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BUTTONGRASS

FIRE BEHAVIOUR INDEX			
0-5	MAX FLAME HEIGHT <1 m	RATE OF SPREAD 0-30 m/hr	Fires unlikely to be sustained and may be difficult to ignite.
6-11	<6 m	30-450 m/hr	Mostly slow spreading fires.
12-23	2-9 m	450-2040 m/hr	Typically wind driven and quickly spreading fires.
24-49	3-12 m	2040-4200 m/hr	Wind driven, rapidly spreading fires with potential for development into large fire area/size and with the potential for short distance spotting and long flame lengths.
50-99	4-16m	4200-8400 m/hr	Extremely rapid fire growth and increasing likelihood of large final fire area/size. Possibility for fire behaviour to become erratic and plume driven. Strong convective column formation. Wind speed and direction likely to be erratic at times.
100+	>8m	>8400 m/hr	Extremely rapid fire growth and high likelihood of large final fire area/size. Possibility for fire behaviour to become erratic and plume driven. Strong convective column formation. Wind speed and direction likely to be erratic at times.

SPOTTING POTENTIAL
Potential for any spotting is minimal.
Possible short distance spotting up to 5 m can be expected
Possible short distance spotting up to 30 m can be expected
High risk of spotting across fire breaks. Spotting up to 500 m is common
High risk of spotting across fire breaks. Spotting up to 2 km is common
High risk of spotting across fire breaks. Spotting over 2 km is common

IMPLICATIONS FOR PRESCRIBED BURNING

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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FIRE BEHAVIOUR INDEX

MARGINAL	0-5	Marginal prescribed burn conditions, even at peak of the day. Fire may fail to sustain over fuel discontinuities.
GENERALLY SUITABLE	6-11	Suitable fire behaviour for hazard reductions and ecosystem management burns.
MARGINAL	12-23	Conditions may be suitable for prescribed burning provided sufficient, secure, non-flammable boundaries are present. Fire behaviour too intense to suppress fire without relying on non-flammable boundaries.
GENERALLY UNSUITABLE	24-49	Conditions are unlikely to be suitable for prescribed burning. Potential rates of spread, long flame lengths and short distance spotting pose a serious risk of burn escapes and fire intensity may be inconsistent with land management objectives.
UNSUITABLE	50-99	Conditions will be unsuitable for prescribed burning. Potential fireline intensity and rates of spread pose a serious risk to firefighter safety and the community.
UNSUITABLE	100+	Conditions will be unsuitable for prescribed burning. Potential fireline intensity and spotting activity pose a serious risk to firefighter safety and the community.

FIRE SUPPRESSION AND CONTAINMENT

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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FIRE BEHAVIOUR INDEX		CREDIBLE WORST CASE
0-5	Fire control relatively simple. Mostly contained within simple, natural boundaries, road networks and fuel breaks >2 m. Delayed containment possible with suitable conditions. Head-fire readily suppressed with offensive, direct attack techniques. Initial attack success is typically very high.	MAX. POTENTIAL in 4 hr AREA <1 ha PERIMETER <0.5 km
6-11	Fire control mostly simple with sufficient resources and becoming more complex at higher intensities. Fires typically contained within natural boundaries, road networks and fuel breaks >5 m. Offensive, direct attack techniques on head-fire or flanks largely successful in fire control. Delayed containment sometimes possible with suitable conditions.	AREA <150 ha PERIMETER <5 km
12-23	Fires generally becoming more complex and require more resources to control. Combinations of direct, indirect or parallel attack may be necessary for fire control. Requires increased effort and resources to contain fire within existing road networks and fuel break boundaries. Fires typically requiring fuel breaks 10-25 m wide and supported by pumps to achieve containment (control lines >5 m for flanks and back-fires).	AREA <850 ha PERIMETER <10 km
24-49	Offensive strategies likely to be challenged during the peak of the day with focus largely centred on the rear and flanks. Suppression increasingly focused on defensive strategies. Fire control is likely to be difficult and require increased resourcing. Fuel breaks 25-50 m wide supported by tankers required for containment (control lines >10 m for flanks and back-fires). Personnel positioned down-wind and to the flanks of the fire should be made aware of the high risk of the fire jumping fire-breaks.	AREA <3500 ha PERIMETER <20 km
50-99	Control of developed fires is extremely difficult and unlikely until conditions ease. Suppression will be largely based on defensive strategies, ensuring firefighter and community preparedness and safety. Fuel breaks >100 m wide and supported by tankers are required for containment (control lines >10 m and supported by pumps for flanks and back-fires). Offensive strategies could position crews in danger, however safe opportunities may exist for direct, indirect or parallel attack on the rear and flanks. Essential no personnel be positioned down-wind or to the flank of the fire unless they have safe fuel-free zones to retreat into. Conditions on the fireground are likely to be extremely windy and smoky limiting visibility and restricting aviation and access.	AREA <15,000 ha PERIMETER <45 km
100+	Fire control is extremely difficult and unlikely until conditions ease. Suppression will be largely based on defensive strategies, ensuring firefighter and community preparedness and safety. Offensive strategies could position crews in danger, however safe opportunities may exist for direct, indirect or parallel attack on the rear and flanks. Important initial attack opportunities may exist for new ignitions. Conditions on the fireground are likely to be extremely windy and smoky limiting visibility and restricting aviation and access. Conditions are likely to impact performance and effectiveness of aerial resources with a high probability that some aircraft will be unable to operate due to high winds and limited visibility. Systems such as communications, will be heavily challenged with a likelihood of difficulties and outages. Essential no personnel be positioned down-wind or to the flank of the fire unless they have safe fuel-free zones to retreat into.	AREA >15,000 ha PERIMETER >45 km

POTENTIAL FOR IMPACT

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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FIRE BEHAVIOUR INDEX

UNLIKELY	0-5	Community losses are unlikely.
UNLIKELY	6-11	Community losses are unlikely however unattended or poorly prepared houses and infrastructure may be at risk.
MINIMAL	12-23	Community losses are unlikely, however unattended or poorly prepared houses and infrastructure may be at risk.
INCREASING	24-49	High likelihood of pasture/crop/stock loss together with loss of rural assets such as fencing, machinery and buildings.
HIGH	50-99	Increasingly high likelihood of pasture/crop/stock loss together with loss of rural assets such as fencing, machinery and buildings. Limited visibility due to smoke and dust.
VERY HIGH	100+	Extremely high likelihood of pasture/crop/stock loss together with loss of rural assets such as fencing, machinery and buildings. Very limited visibility due to smoke and dust. Very high risk to the community related to inappropriate pre-considered plans, inadequate sheltering.

SUPPLEMENTARY INFORMATION
FOR BUTTONGRASS FUELS

To define each category against modelled outputs within the Fire Behaviour Index scale, various methodologies and assumptions are applied. These are outlined below.

FLAME HEIGHT

Flame heights are based on the Marsden-Smedley et al (1999) equation for flame height

RATE OF SPREAD

Rates of spread are based on those categorised in Table 9 of Marsden-Smedley et al. (1999)

SPOTTING DISTANCE

Spotting distances are based on descriptions within Table 9 of Marsden-Smedley et al. (1999)

FIRE AREA AND PERIMETER

Potential fire area and perimeter are based on a 4-hour fire run under maximum fire danger with a range of length-breadth ratio as determined by wind speeds ranging from 10-40 km/hr (as per Cruz et al (2015)) and a fuel load varying from 10-20 t/ha.
The values assume no suppression.

IMPACT RELATED THRESHOLDS AND DESCRIPTIONS

Impact related thresholds and descriptions have been based largely on the work of Kilinc et al (2013), Harris et al (2011) and Blanchi et al (2010).

PROJECT DOCUMENTATION

A comprehensive list of project documentation for the Australian Fire Danger Rating System is available via the AFAC website at: https://www.afac.com.au/initiative/afdrs/afdrs-publications.

SUPPORTING REFERENCES AND FURTHER READING

Blanchi, R., et al. (2010). Meteorological conditions and wildfire-related house loss in Australia. International Journal of Wildland Fire 19(7): 914-926.

Byram, G. M. (1959). Combustion of forest fuels. Forest Fire: Control and Use. K. P. Davis. New York, McGraw-Hill: 61-89.

Cruz, M. G., et al. (2015). A Guide to Rate of Fire Spread Models for Australian Vegetation. Melbourne, Victoria, CSIRO Land and Water Flagship, Canberra, ACT, and AFAC.

Harris, S., et al. (2011). Establishing a link between the power of fire and community loss: The first steps towards developing a bushfire severity scale. Melbourne, Victoria, Victorian Government Department of Sustainability and Environment.

Marsden-Smedley, J.B., Catchpole, W.R. (1995a). Fire modelling in Tasmanian buttongrass moorlands I. Fuel characteristics. International Journal of Wildland Fire 5, 203-214.

Marsden-Smedley, J.B., Catchpole, W.R. (1995b). Fire modelling in Tasmanian buttongrass moorlands II. Fire behaviour. International Journal of Wildland Fire 5, 215-228.

Marsden-Smedley, J.B., Catchpole, W.R., Pyrke, A. (2001). Fire modelling in Tasmanian buttongrass moorlands. IV Sustaining versus non-sustaining fires. International Journal of Wildland Fire 10, 255-262.

Marsden-Smedley, J.B., Rudman, T., Catchpole, W.R., Pyrke, A. (1999). Buttongrass moorland fire behaviour prediction and management. Tasforests 11, 87-107.

VERSION

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Administrator: NSW Rural Fire Service

CONTACT

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THE AFDRS PROJECT IS BEING LED BY:

NSW RURAL FIRE SERVICE

Australian Government
Bureau of Meteorology

afac

PRIMARILY FUNDED BY:

Australian Government
National Recovery and Resilience Agency

PARTNER AGENCIES:

A.C.T. RURAL FIRE SERVICE

CFS

EMV EMERGENCY MANAGEMENT VICTORIA

BUSHFIRES NT

NORTHERN TERRITORY GOVERNMENT

QUEENSLAND FIRE AND EMERGENCY SERVICES

GOVERNMENT OF WESTERN AUSTRALIA
Department of Biodiversity, Conservation and Attractions

GOVERNMENT OF WESTERN AUSTRALIA
DFES
Department of Fire & Emergency Services

Tasmanian Government

Tasmania Fire Service

SUPPORTING BODIES:

AUSTRALIAN CAPITAL TERRITORY EMERGENCY SERVICES AGENCY

ACT FIRE & RESCUE

ACT Government
Environment, Planning and Sustainable Development

CFA

RURAL FIRE SERVICE QUEENSLAND

Government of South Australia
South Australian Fire and Emergency Services Commission

Government of South Australia
Department for Environment and Water

VICTORIA State Government
Environment, Land, Water and Planning

WALGA

FOREST

QUICK GUIDE

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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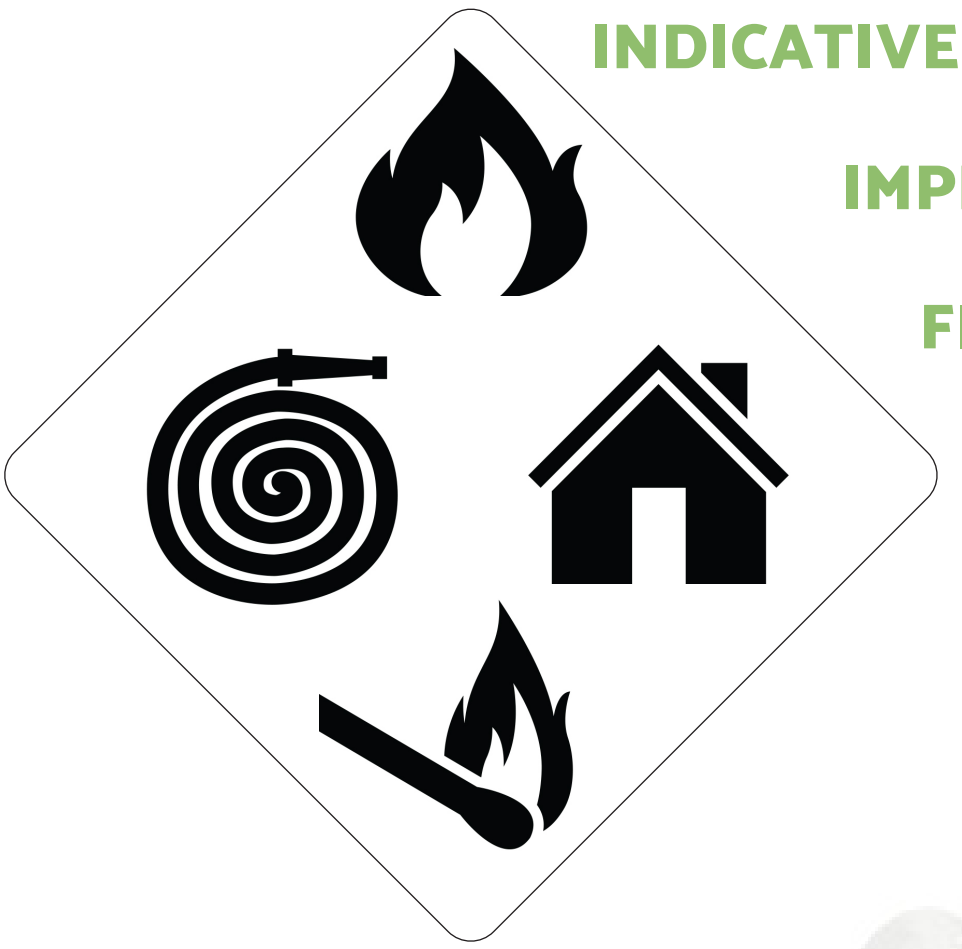
Australian
Fire Danger
Rating System



INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

IMPLICATIONS FOR PRESCRIBED BURNING

FIRE SUPPRESSION AND CONTAINMENT

POTENTIAL FOR IMPACT

FOREST FUELS
IN THE AUSTRALIAN FIRE DANGER RATING SYSTEM

In the Australian Fire Danger Rating System (AFDRS), fuel types have been grouped by application of the most relevant fire spread model. Forest fuels within the system include the wide variety of dry and wet eucalypt forests that are found in Australia including temperate woodlands where litter and/or shrub fuels dominate the understorey as well as hardwood plantations.

DRY EUCALYPT FOREST FUEL STRUCTURE

These forests comprise of a broad mix of genera but are typically dominated by eucalypts. The open canopy nature of dry eucalypt forests often allows for the development of an understorey layer of dominated trees, shrubs and/or herbaceous vegetation that provide vertical fuel continuity.

Understorey fuels responsible for fire propagation are typically leaf litter, twigs and bark, and the finer components of the understorey herbaceous and shrub layer, which can vary from dense to almost absent depending on site conditions and time since last fire. Coarse woody debris represents the bulk of the available biomass but are mostly consumed after the passage of the flame front. In eucalypt fuel complexes the presence of tree species with fibrous bark is a key factor driving fire propagation, namely through prolific spotting that occurs under very dry and windy conditions. Candlebark and ribbon gums species contribute with aerodynamically optimum firebrands that can cause long distance spotting up to tens of kilometers, although it is virtually impossible to accurately quantify these distances. The relatively open nature of these forests means that understorey dead fuels dry rapidly, often within a few days of rain, and are available to sustain fire propagation over a number of months each fire season.

WET EUCALYPT FOREST FUEL STRUCTURE

At maturity wet eucalypt forests are 30 to 50 m tall and present a multi-storey structure, with the dominant overstorey layer cover varying between 30 and 70%. A well-developed understorey stratum might include a layer of sub-dominant and suppressed trees and tall shrubs. The lower section of this layer might have a well-developed shrub layer. Surface fuel quantities are characteristically higher in these forests than observed in dry eucalypt forests, and a well-developed duff layer is often present.

CONTENTS

The rate at which dead surface fuels dry is restricted by the dense understorey, and so fuels tend to be wetter in these forests than in adjacent dry eucalypt forests. Surface fuels may not dry out until mid-summer, and in the most sheltered locations may only become available to burn following extended drought. However, under these conditions very large quantities of organic material will be available for combustion. The tall and dense stand structure will also limit wind penetration into the lower understorey space.

Common wet eucalypt forests are karri forests in southern Western Australia, mountain ash forests in Victoria and Tasmania, and blackbutt in New South Wales.

FOR MORE INFORMATION ON FUELS REFER TO:
***A GUIDE TO RATE OF FIRE SPREAD MODELS FOR AUSTRALIAN VEGETATION* (2015 EDITION)**

FIRE SPREAD
IN FOREST FUELS

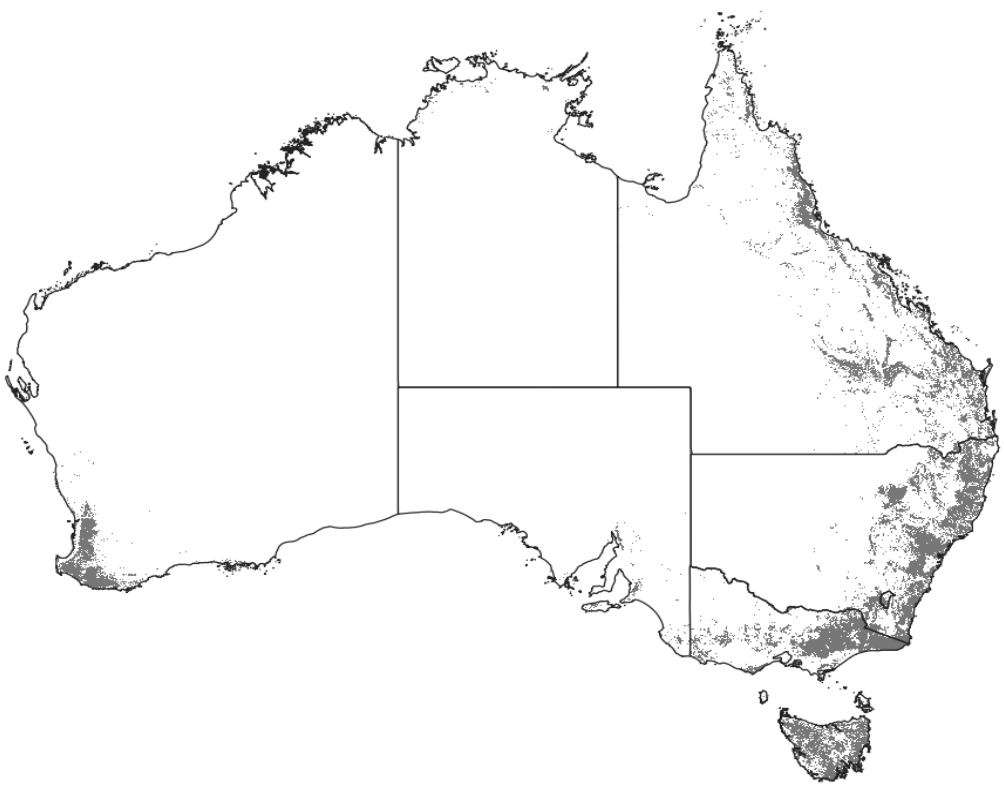
Rate of fire spread is the foundation variable for all calculations in the Australian Fire Danger Rating System. In Forest fuels the *Dry Eucalypt Forest Fire Model* (DEFFM or 'Vesta') is applied to determine the rate of fire spread.

BACKGROUND

The *Dry Eucalypt Forest Fire Model* was a result of research from Project Vesta which aimed to investigate the behaviour of moderate to high-intensity fires in dry eucalypt forest under conditions of moderate to high forest fire danger associated with dry summer conditions.

The Project was conducted in south-western Western Australia during the summers of 1998, 1999 and 2001 at two sites in eucalypt forest comprised of jarrah and marri. The sites were selected to be representative of most dry eucalypt forests found around the country.

WHERE IS THE MODEL APPLIED?

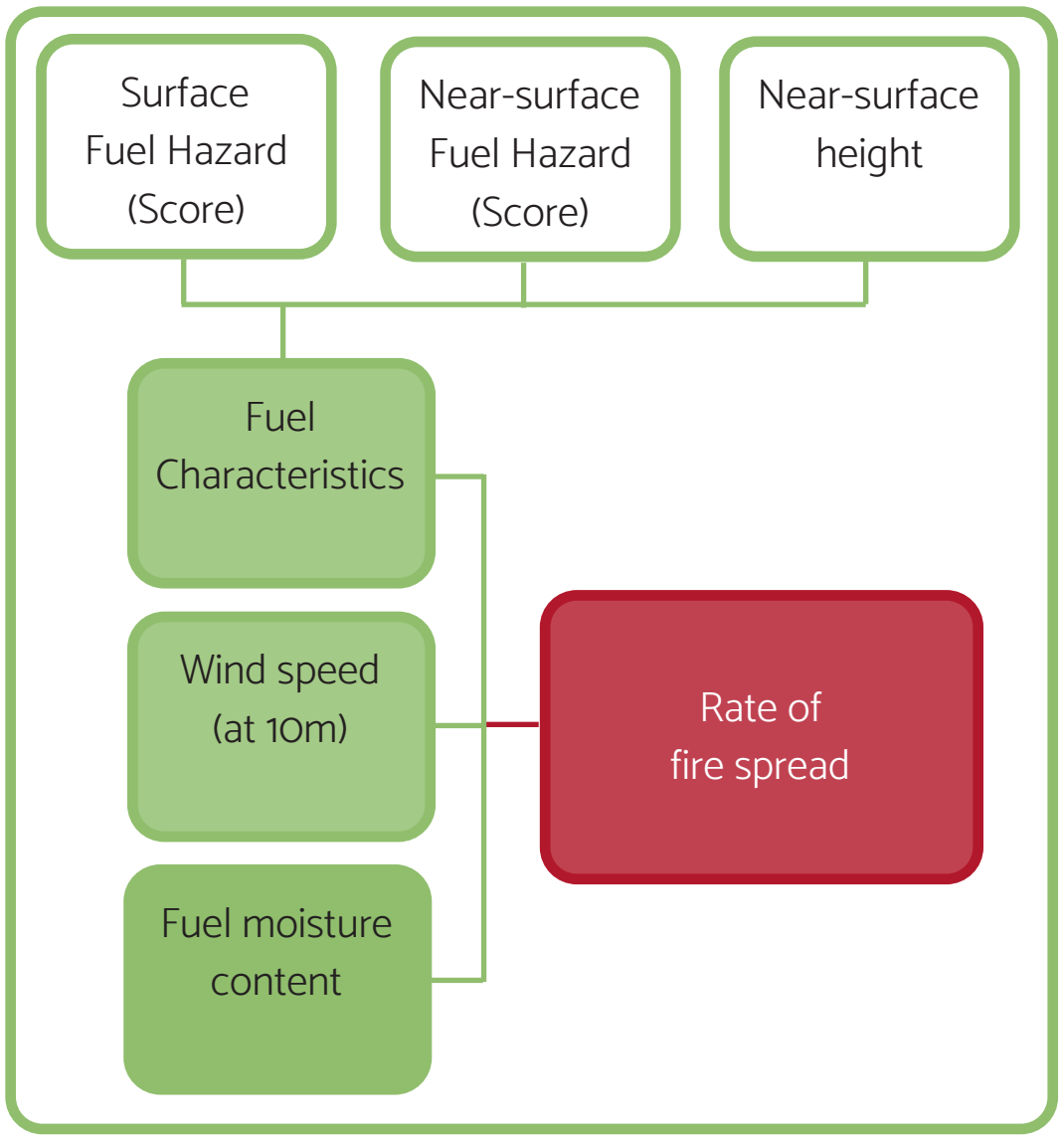


The DEFFM is applied to all dry and wet forest fuel types in Australia with the largest aggregations generally occurring in areas where average rainfall typically exceeds 500 mm annually, mostly on the east coast but also in the southwest of Western Australia.

HOW IS THE MODEL APPLIED?

The DEFFM was developed for dry summer conditions when dangerous wildfires occur. To apply the model more broadly across the full range of conditions and limitations in potential fuel availability, the AFDRS modifies the amount of fuel available based on a function of the drought factor (DF). In dry forests this is a steady linear relationship (where the amount of fuel available to burn increasing consistently as the DF increases from 0 to 10), while in wet forests, the AFDRS assumes no fuel is available to burn while

WHAT ARE THE MAIN INPUTS?



Rate of fire spread in Forests is calculated as a function of the surface and near-surface fuel characteristics, 10 m open wind speed and fine fuel moisture content.

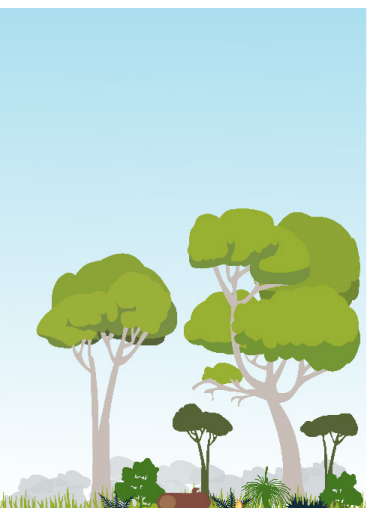
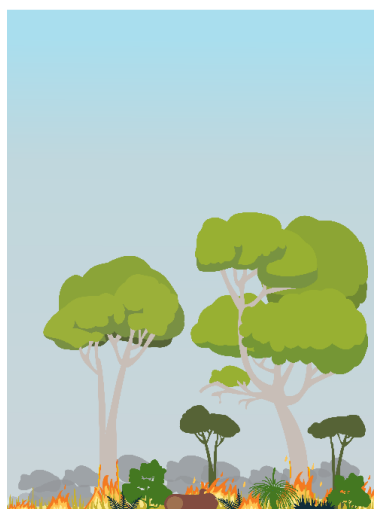
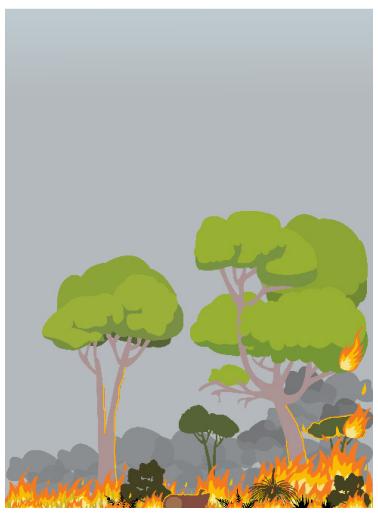
The fuel hazard scores are a numeric value from 0.0 to 4.0 based on visual assessment of per cent cover and fuel hazard of different fuel strata. The scores represent a subjective assessment of the flammability of each strata based on the morphological development of vegetation, bulk density, continuity, accumulation of litter fuel and type of bark.

WHAT IS THE MODEL SENSITIVE TO?

Fuel structure is incorporated into the model through descriptors of the surface (fuel hazard score, FHS) and near-surface (FHS and height) fuel layers. The surface FHS has a slightly higher effect on rate of fire spread than the near surface FHS. Variation of surface FHS from 1 to 4 will result in an approximate three-fold increase in the rate of fire spread. The same change in the near-surface FHS will result in a 2.3-fold increase in rate of spread. The model is also sensitive to the height of the near surface fuel layer. A doubling of the near surface height will result in a 65% increase in the rate of fire spread. Model sensitivity to the near-surface fuel height warrants special care in its estimation. Measurement errors in the definition of this layer can result in significant bias in the model output.

MORE DETAIL ON THE MODEL CAN BE FOUND IN: A GUIDE TO RATE OF FIRE SPREAD MODELS FOR AUSTRALIAN VEGETATION (2015 EDITION)

UNDERSTANDING THE
FIRE BEHAVIOUR INDEX
IN FOREST FUELS

Fire Behaviour Index 0-5	6-11	12-23	24-49	50-99	100+
					
No rating	**Moderate**	**High**	**Extreme**	**Catastrophic**	
fire behaviour Fires are likely to self-extinguish	fire behaviour Typical prescribed burning conditions Fires are likely to be mostly self-sustaining	suppression Fires typically suppressed with offensive fire management strategies (i.e. direct, parallel or indirect attack)	impact Increasing focus on defensive suppression strategies Transition to medium distance spotting Aerial suppression less likely to be effective at controlling fire	impact Increased likelihood of community loss and significant consequences Transition to long distance spotting	impact High probability of loss of life and property

A SCALE OF POTENTIAL FIRE DANGER

The Fire Behaviour Index (FBI) was developed to assist operational decision making, while the Fire Danger Ratings provide the broad categories needed to communicate fire danger to the community.

The FBI provides a scale of potential fire danger (should a fire start) based on the predicted rate of fire spread. In forest fuels, the rate of fire spread together with fuel load, are used to determine the fireline intensity and this value is used to categorise fire danger on the FBI scale.

TRANSITIONS AND CATEGORIES

The FBI is made up of step-ups or transitions, where an increase in category is triggered by a change in:

1. fire behaviour,
2. suppression response, or
3. potential impacts.

Each category is defined in terms of:

1. indicative fire behaviour and fire weather,
2. implications for prescribed burning,
3. fire suppression and containment, and
4. potential impacts.

FOREST

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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Fire Behaviour Index
0-5

- Mostly self-extinguishing, trouble-free fires.

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

Fire difficult to ignite and sustain.

Fires generally unlikely to spread and likely to self-extinguish.

- Rate of Spread: 0-40 m/hr
- Max. Flame Height: <1 m
- Spotting Potential: Potential for any spotting is very limited and likely <150 m

IMPLICATIONS FOR PRESCRIBED BURNING

Marginal prescribed burning conditions, even at peak of the day.

Opportunities may arise where burn objectives target very low intensity, particularly heavy or dry fuels.

FIRE SUPPRESSION AND CONTAINMENT

Fire control relatively simple.

Delayed containment possible with suitable conditions.

Head-fire readily suppressed with offensive, direct attack techniques.

Initial attack success is typically very high.

TIME TO 5 ha

11 hrs

Small fires that may be allowed to spread within an extended (time and area) containment objective.

CREDIBLE WORST CASE
MAX. POTENTIAL
in 4 hr (30 min)

AREA
<1.5 ha (<0.2 ha)

PERIMETER
<0.5 km (<0.1 km)

POTENTIAL FOR IMPACT

Community losses are unlikely.

CONDITIONS TO CONSIDER

FOREST

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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Fire Behaviour Index
6-11

- Typical prescribed burning conditions.
- Fires generally easy to suppress and contain.

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

Slow spreading fires, typically involving surface and near-surface fuels and sometimes bark and elevated fuels. Spotting is sporadic and limited to short-distances.

- Rate of Spread: 20-110 m/hr
- Max. Flame Height: <4 m
- Spotting Potential: Potential for spotting is limited with short distance spotting possible up to 400 m

IMPLICATIONS FOR PRESCRIBED BURNING

Typical prescribed burning conditions.

Simple burns with adequate resourcing.

Upper limit for private landholder burning provided adequate resourcing, training, necessary approvals and permits.

FIRE SUPPRESSION AND CONTAINMENT

Fire control mostly simple with sufficient resources and becoming more complex at higher intensities.

Offensive, direct attack techniques on head-fire or flanks largely successful in fire control.

Delayed containment sometimes possible with suitable conditions.

Fires may be allowed to spread within an extended (time and area) containment objective.

TIME TO 5 ha

4 hrs

CREDIBLE WORST CASE

MAX. POTENTIAL in 4 hr (30 min)

AREA

<10 ha (<1.3 ha)

PERIMETER

<1 km (<0.1 km)

POTENTIAL FOR IMPACT

Community losses are unlikely however unattended or poorly prepared houses and infrastructure may be at risk.

CONDITIONS TO CONSIDER

- Strong wind gusts

FOREST

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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Fire Behaviour Index
12-23

- Most bushfires occur in this category.
- Fires typically suppressed with direct, parallel or indirect attack.

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

Actively spreading fires typically involving surface, near-surface, elevated and bark fuel layers and occasionally canopy fuels. Low-moderate spotting frequency; isolated medium range spotting can occur.

- Rate of Spread: 60-600 m/hr
- Max. Flame Height: 2-8 m
- Spotting Potential: Short distance spotting occurring with increasing frequency with possible medium distance spotting up to 2 km

IMPLICATIONS FOR PRESCRIBED BURNING

Conditions may be suitable for more complex prescribed burning subject to adequate resourcing and well established boundaries/edges.

Prescribed burning may be conducted away from the peak of the day when conditions are optimal and lighting techniques are suitable to achieve prescribed burning objectives.

FIRE SUPPRESSION AND CONTAINMENT

TIME TO 5 ha

45 mins

Fires generally becoming more complex and require more resources to control.

Combinations of direct, indirect or parallel attack may be necessary for fire control.

CREDIBLE WORST CASE
MAX. POTENTIAL in 4 hr (30 min)

AREA

<300 ha (<40 ha)

PERIMETER

<6.5 km (1 km)

POTENTIAL FOR IMPACT

Unattended or poorly prepared houses and infrastructure may be at risk.

CONDITIONS TO CONSIDER

- C-Haines >95th percentile (approx. >10)
- Wind change forecast during the peak of the afternoon, potential conditions for 'dead man zone'
- Strong wind gusts

FOREST

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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Fire Behaviour Index
24-49

- Increasing focus on defensive suppression strategies.
- Initial attack success critical to prevent large fire development.

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

Rapidly spreading fires with potential for development into large burn areas within burning period. Fires typically involving most fuel layers. Short-range spotting is prevalent, with possibility of medium range and occasional long-range distance spotting.

- Rate of Spread: 0.3-1 km/hr
- Max. Flame Height: 7-14 m
- Spotting Potential: Short and medium distance spotting occurring with increasing frequency with possible long distance spotting up to 4 km

IMPLICATIONS FOR PRESCRIBED BURNING

Conditions are unlikely to be suitable for prescribed burning.

Potential fireline intensity and spotting activity pose a serious risk for burn escapes.

Fire intensity may be inconsistent with land management objectives.

FIRE SUPPRESSION AND CONTAINMENT

TIME TO 5 ha

25 mins

Both ground and aerial resources using offensive strategies likely to be unsuccessful during the peak of the day, with focus largely centred on the rear and flanks.

Suppression increasingly focused on defensive strategies.

Fire control is likely to be difficult and require increased resourcing.

Increased risk to firefighter safety.

CREDIBLE WORST CASE
MAX. POTENTIAL
in 4 hr (30 min)

AREA

<1,000 ha (<120 ha)

PERIMETER

<11 km (1.5 km)

POTENTIAL FOR IMPACT

6 % of house loss has occurred under these conditions.

Increased potential for pasture/crop/stock losses as well as rural assets such as fencing, machinery and buildings.

CONDITIONS TO CONSIDER

- C-Haines >95th percentile (approx. >10)
- Wind change forecast during the peak of the afternoon, potential conditions for 'dead man zone'
- Strong wind gusts

FOREST

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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Fire Behaviour Index **50-100**

- High levels of threat to life/property.
- Conditions limit strategic suppression options.
- Elevated risk to firefigter safety.
- Initial attack success critical to prevent large fire development.

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

Fires likely to quickly transition to crowning. Possibility for fire behaviour to become erratic and plume driven. Strong convective column formation. Wind speed and direction likely to be erratic at times.

- Rate of Spread: 0.7-3 km/hr
- Max. Flame Height: 11 m - approx. double forest height
- Spotting Potential: High ember density in short and medium range with possible long distance spotting up to 12 km

IMPLICATIONS FOR PRESCRIBED BURNING

Conditions will be unsuitable for prescribed burning.

Potential fireline intensity and spotting activity pose a serious risk to firefighter safety and the community.

FIRE SUPPRESSION AND CONTAINMENT

TIME TO 5 ha

10 mins

Control of developed fires is extremely difficult and unlikely until conditions ease.

Suppression will be largely based on defensive strategies, ensuring firefighter and community preparedness and safety.

Offensive strategies could position crews in danger, however safe opportunities may exist for direct, indirect or parallel attack on the rear and flanks. Important initial attack opportunities may exist for new ignitions.

Conditions on the fireground are likely to be extremely windy and smoky limiting visibility and restricting aviation and access. Aerial resources are likely to be ineffective at holding fire. Increased risk to firefighter safety.

CREDIBLE WORST CASE

MAX. POTENTIAL in 4 hr (30 min)

AREA

<9,000 ha (<1,100 ha)

PERIMETER

<35 km (4.5 km)

POTENTIAL FOR IMPACT

24% of house loss has occurred under these conditions. Limited visibility due to smoke and dust. High risk to the community related to inappropriate pre-considered plans, inadequate sheltering. High likelihood of pasture/crop/stock loss together with loss of rural assets such as fencing, machinery and buildings.

Increased risk of long term economic and environmental impacts.

Strong winds are likely to impact infrastructure (e.g. power lines) with falling trees increasing the likelihood of new ignitions as well as causing road obstructions and power outages.

CONDITIONS TO CONSIDER

- C-Haines >95th percentile (approx. >10)
- Wind change forecast during the peak of the afternoon, potential conditions for 'dead man zone'

FOREST

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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Fire Behaviour Index **100+**

- High probability of loss of life and property.
- Elevated risk to firefighter safety.
- Initial attack success critical to prevent large fire development.
- Conditions limit strategic suppression options.
- Wind speed and limited visibility may ground some aviation resources.

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

Fires likely to quickly transition to crowning. Possibility for fire behaviour to become erratic and plume driven. Strong convective column formation. Wind speed and direction likely to be erratic at times.

- Rate of Spread: >2 km/hr can be expected and possibly >3 km/hr
- Max. Flame Height: >30 m (approx. double forest height)
- Spotting Potential: High ember density in short and medium range with possible long distance spotting occurring 20-30 km ahead of the main fire front

IMPLICATIONS FOR PRESCRIBED BURNING

Conditions will be unsuitable for prescribed burning.

Potential fireline intensity and spotting activity pose a serious risk to firefighter safety and the community.

FIRE SUPPRESSION AND CONTAINMENT

TIME TO 5 ha

<10 mins

Fire control of developed fires is extremely difficult and unlikely until conditions ease. Focus will be largely based on defensive strategies, ensuring firefighter and community preparedness and safety. Offensive strategies could position crews in danger, however safe opportunities may exist for direct, indirect or parallel attack on the rear and flanks. Important initial attack opportunities may exist for new ignitions. Conditions on the fireground are likely to be extremely windy and smoky, limiting visibility and restricting aviation operations. Conditions are likely to impact performance and effectiveness of aerial resources with a high probability that some aircraft will be unable to operate due to high winds and limited visibility. Systems such as communications, will be heavily challenged with a likelihood of difficulties and outages.

CREDIBLE WORST CASE

MAX. POTENTIAL in 4 hr (30 min)

AREA

>9,000 ha

(>1,100 ha)

PERIMETER

>35 km (>4.5 km)

POTENTIAL FOR IMPACT

70% of house loss has occurred under these conditions. Limited visibility due to smoke and dust. Very high risk to the community related to inappropriate pre-considered plans, inadequate sheltering. Extremely high likelihood of pasture/crop/stock loss together with loss of rural assets such as fencing, machinery and buildings. Very high risk of long term economic and environmental impacts.
Extremely strong winds are likely to impact infrastructure (e.g. power lines) and fall trees increasing the likelihood of new ignitions as well as obstructed roads and power outages.

CONDITIONS TO CONSIDER

- C-Haines >95th percentile (approx. >10)
- Wind change forecast during the peak of the afternoon, potential conditions for 'dead man zone'

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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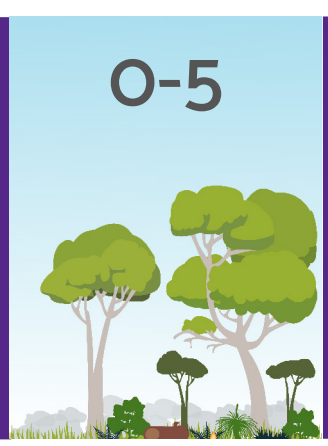
FIRE BEHAVIOUR INDEX

MAX FLAME HEIGHT <1 m	0-5 	**RATE OF SPREAD** 0-40 m/hr	Fire difficult to ignite and sustain. Fires generally unlikely to spread and likely to self-extinguish.	**SPOTTING POTENTIAL** Potential for any spotting is very limited and likely **<150 m**
<4 m	6-11 	20-110 m/hr	Slow spreading fires, typically involving surface and near-surface fuels and sometimes bark and elevated fuels. Spotting is sporadic and limited to short-distances.	Potential for spotting is limited with short distance spotting possible up to **400 m**
2-8 m	12-23 	60-600 m/hr	Actively spreading fires typically involving surface, near-surface, elevated and bark fuel layers and occasionally canopy fuels. Low-moderate spotting frequency; isolated medium range spotting can occur.	Short distance spotting occurring with increasing frequency with possible medium distance spotting up to **2 km**
7-14 m	24-49 	0.3-1 km/hr	Rapidly spreading fires with potential for development into large burn areas within burning period. Fires typically involving most fuel layers. Short-range spotting is prevalent, with possibility of medium range and occasional long-range distance spotting.	Short and medium distance spotting occurring with increasing frequency with possible long distance spotting up to **4 km**
11 m - approx. double forest	50-99 	0.7-3 km/hr	Fires likely to quickly transition to crowning. Possibility for fire behaviour to become erratic and plume driven. Strong convective column formation. Wind speed and direction likely to be erratic at times.	High ember density in short and medium range with possible long distance spotting up to **12 km**
>30 m (approx. double forest height)	100+ 	>2 km/hr can be expected, possibly >3 km/hr	Fires likely to quickly transition to crowning. Possibility for fire behaviour to become erratic and plume driven. Strong convective column formation. Wind speed and direction likely to be erratic at times.	High ember density in short and medium range with possible long distance spotting occurring **20-30 km** ahead of the main fire front

IMPLICATIONS FOR PRESCRIBED BURNING

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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FIRE BEHAVIOUR INDEX

MARGINAL

0-5

Marginal prescribed burning conditions, even at peak of the day.

Opportunities may arise where burn objectives target very low intensity, particularly heavy or dry fuels.

GENERALLY SUITABLE

6-11

Typical prescribed burning conditions.

Simple burns with adequate resourcing.

Upper limit for private landholder burning provided adequate resourcing, training, necessary approvals and permits.

MARGINAL

12-23

Conditions may be suitable for more complex prescribed burning subject to adequate resourcing and well established boundaries/edges.

Prescribed burning may be conducted away from the peak of the day when conditions are optimal and lighting techniques are suitable to achieve prescribed burning objectives.

GENERALLY UNSUITABLE

24-49

Conditions are unlikely to be suitable for prescribed burning.

Potential fireline intensity and spotting activity pose a serious risk for burn escapes.

Fire intensity may be inconsistent with land management objectives.

UNSUITABLE

50-99

Conditions will be unsuitable for prescribed burning.

Potential fireline intensity and spotting activity pose a serious risk to firefighter safety and the community.

UNSUITABLE

100+

Conditions will be unsuitable for prescribed burning.

Potential fireline intensity and spotting activity pose a serious risk to firefighter safety and the community.

FIRE SUPPRESSION AND CONTAINMENT

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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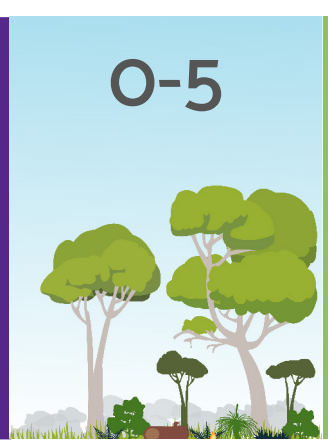
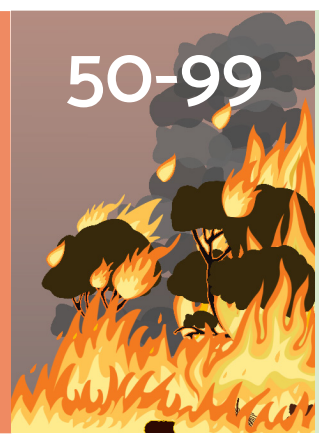
FIRE BEHAVIOUR INDEX			CREDIBLE WORST CASE
TIME TO 5 HA 11 hrs	0-5 	Fire control relatively simple. Delayed containment possible with suitable conditions. Head-fire readily suppressed with offensive, direct attack techniques. Initial attack success is typically very high. Small fires that may be allowed to spread within an extended (time and area) containment objective.	MAX. POTENTIAL in 4 hr (30 min) **AREA** <1.5 ha (<0.2 ha) **PERIMETER** <0.5 km (<0.1 km)
4 hrs	6-11 	Fire control mostly simple with sufficient resources and becoming more complex at higher intensities. Offensive, direct attack techniques on head-fire or flanks largely successful in fire control. Delayed containment sometimes possible with suitable conditions. Fires may be allowed to spread within an extended (time and area) containment objective.	**AREA** <10 ha (<1.3 ha) **PERIMETER** <1 km (<0.1 km)
45 mins	12-23 	Fires generally becoming more complex and require more resources to control. Combinations of direct, indirect or parallel attack may be necessary for fire control.	**AREA** <300 ha (<40 ha) **PERIMETER** <6.5 km (1 km)
25 mins	24-49 	Both ground and aerial resources using offensive strategies are likely to be unsuccessful during the peak of the day, with focus largely centred on the rear and flanks. Suppression increasingly focused on defensive strategies. Fire control is likely to be difficult and requires increased resourcing. Increased risk to firefighter safety.	**AREA** <1,000 ha (<120 ha) **PERIMETER** <11 km (1.5 km)
10 mins	50-99 	Control of developed fires is extremely difficult and unlikely until conditions ease. Suppression will be largely based on defensive strategies, ensuring firefighter and community preparedness and safety. Offensive strategies could position crews in danger, however safe opportunities may exist for direct, indirect or parallel attack on the rear and flanks. Important initial attack opportunities may exist for new ignitions. Conditions on the fireground are likely to be extremely windy and smoky limiting visibility and restricting aviation and access. Aerial resources are likely to be ineffective at holding fire. Increased risk to firefighter safety.	**AREA** <9,000 ha (<1,100 ha) **PERIMETER** <35 km (4.5 km)
<10 mins	100+ 	Fire control of developed fires is extremely difficult and unlikely until conditions ease. Focus will be largely based on defensive strategies, ensuring firefighter and community preparedness and safety. Offensive strategies could position crews in danger, however safe opportunities may exist for direct, indirect or parallel attack on the rear and flanks. Important initial attack opportunities may exist for new ignitions. Conditions on the fireground are likely to be extremely windy and smoky limiting visibility and restricting aviation and access. Conditions are likely to impact performance and effectiveness of aerial resources with a high probability that some aircraft will be unable to operate due to high winds and limited visibility. Systems such as communications, will be heavily challenged with a likelihood of difficulties and outages.	**AREA** >9,000 ha (>1,100 ha) **PERIMETER** >35 km (>4.5 km)

POTENTIAL FOR IMPACT

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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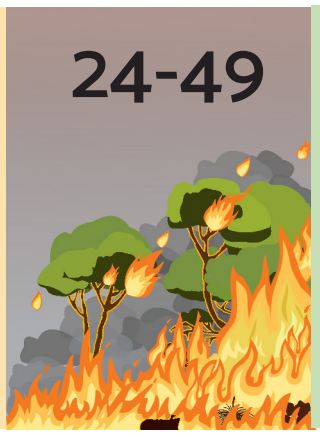
FOREST

FIRE BEHAVIOUR INDEX

UNLIKELY	0-5 	Community losses are unlikely.
UNLIKELY	6-11 	Community losses are unlikely however unattended or poorly prepared houses and infrastructure may be at risk.
MINIMAL	12-23 	Unattended or poorly prepared houses and infrastructure may be at risk.
INCREASING	24-49 	6 % of house loss has occurred under these conditions. Increased potential for pasture/crop/stock losses as well as rural assets such as fencing, machinery and buildings.
HIGH	50-99 	24% of house loss has occurred under these conditions. Limited visibility due to smoke and dust. High risk to the community related to inappropriate pre-considered plans, inadequate sheltering. High likelihood of pasture/crop/stock loss together with loss of rural assets such as fencing, machinery and buildings. Increased risk of long term economic and environmental impacts. Strong winds are likely to impact infrastructure (e.g. power lines) and fall trees increasing the likelihood of new ignitions as well as obstructed roads and power outages.
VERY HIGH	100+ 	70% of house loss has occurred under these conditions. Limited visibility due to smoke and dust. Very high risk to the community related to inappropriate pre-considered plans, inadequate sheltering. Extremely high likelihood of pasture/crop/stock loss together with loss of rural assets such as fencing, machinery and buildings. Very high risk of long term economic and environmental impacts. Extremely strong winds are likely to impact infrastructure (e.g. power lines) with falling trees increasing the likelihood of new ignitions as well as road obstructions and power outages.

SUPPLEMENTARY INFORMATION FOR FOREST FUELS

To define each category against modelled outputs within the Fire Behaviour Index (FBI) scale, various methodologies and assumptions are applied. These are outlined below.

FLAME HEIGHT

Flame heights are based on McArthur's equation for flame height in Noble (1980).

RATE OF SPREAD

Rates of spread are back-calculated from FBI model outputs based on Byram's fireline intensity and a range of fuel load varying from 10-20 t/ha.

SPOTTING DISTANCE

Spotting distances are based on McArthur's equation for spotting distance in Noble (1980).

FIRE AREA AND PERIMETER

Potential fire area and perimeter are based on a 4-hour fire run under maximum fire danger with a range of length-breadth ratio as determined by wind speeds ranging from 10-40 km/hr (as per Cruz et al (2015)) and a fuel load varying from 10-20 t/ha.
The values assume no suppression.

FUEL LOAD

The lowest FBI category assumes that only 50% of the fuel load is available for burning, and this is represented in flame heights, rates of spread and potential fire size.

Forest FBI 6-23 assume an additional 3 t/ha is available (contributed by bark & elevated layers), and FBI above 50 assumes an additional 8 t/ha is available (contributed by bark, elevated and canopy fuel layers).

REFERENCE TIME TO 5 HA

Reference time to 5 ha is based on the shortest time for the category under following conditions: wind speed 25 km/hr, L:B ratio of 3:3 and a fuel load of 10 t/ha.

IMPACT RELATED THRESHOLDS AND DESCRIPTIONS

Impact related thresholds and descriptions have been based largely on the work of Kilinc et al (2013), Harris et al (2011) and Blanchi et al (2010).

PROJECT DOCUMENTATION

A comprehensive list of project documentation for the Australian Fire Danger Rating System is available via the AFAC website at: https://www.afac.com.au/initiative/afdrs/afdrs-publications.

SUPPORTING REFERENCES AND FURTHER READING

Blanchi, R., et al. (2010). Meteorological conditions and wildfire-related house loss in Australia. International Journal of Wildland Fire 19(7): 914-926.

Byram, G. M. (1959). Combustion of forest fuels. Forest Fire: Control and Use. K. P. Davis. New York, McGraw-Hill: 61-89.

Cruz, M. G., et al. (2015). A Guide to Rate of Fire Spread Models for Australian Vegetation. Melbourne, Victoria, CSIRO Land and Water Flagship, Canberra, ACT, and AFAC.

Harris, S., et al. (2011). Establishing a link between the power of fire and community loss: The first steps towards developing a bushfire severity scale. Melbourne, Victoria, Victorian Government Department of Sustainability and Environment.

Kilinc, M., et al. (2013). Project title: A scale for determining the destructive potential of bushfires. Milestone report for the period 2013. Technical Report 1. Monash University, Geography and Environmental Science and University of New South Wales, Canberra.

Noble, I. R., et al. (1980). McArthur's fire-danger meters expressed as equations. Australian Journal of Ecology 5: 201-203.

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THE AFDRS PROJECT IS BEING LED BY:

NSW RURAL FIRE SERVICE

Australian Government
Bureau of Meteorology

afac

PRIMARILY FUNDED BY:

Australian Government
National Recovery and Resilience Agency

PARTNER AGENCIES:

A.C.T. RURAL FIRE SERVICE

CFS

EMV EMERGENCY MANAGEMENT VICTORIA

BUSHFIRES NT

NORTHERN TERRITORY GOVERNMENT

QUEENSLAND FIRE AND EMERGENCY SERVICES

GOVERNMENT OF WESTERN AUSTRALIA
Department of Biodiversity, Conservation and Attractions

GOVERNMENT OF WESTERN AUSTRALIA
DFES
Department of Fire & Emergency Services

Tasmanian Government

Tasmania Fire Service

SUPPORTING BODIES:

AUSTRALIAN CAPITAL TERRITORY EMERGENCY SERVICES AGENCY

ACT FIRE & RESCUE

ACT Government
Environment, Planning and Sustainable Development

CFA

RURAL FIRE SERVICE QUEENSLAND

Government of South Australia
South Australian Fire and Emergency Services Commission

Government of South Australia
Department for Environment and Water

VICTORIA State Government
Environment, Land, Water and Planning

WALGA

GRASSLAND

QUICK GUIDE

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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Australian Fire Danger Rating System

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

IMPLICATIONS FOR PRESCRIBED BURNING

FIRE SUPPRESSION AND CONTAINMENT

POTENTIAL FOR IMPACT

GRASS FUELS
IN THE AUSTRALIAN FIRE DANGER RATING SYSTEM

In the Australian Fire Danger Rating System (AFDRS) fuel types have been grouped by application of the most relevant fire spread model. The grass fuel type is associated with tree-less and shrub-less areas dominated by herbaceous grass-like plants and excludes the special case of semi-arid and arid tussock grasslands (see spinifex) and savannas or open woodlands (see Savanna).

GRASS FUEL STRUCTURE

The grass fuel type incorporates a broad range of perennial and annual native grasslands, namely, tropical, arid, temperate and subalpine grasslands. Also in this group are introduced pastures and winter crops (e.g. wheat, barley, canola). These grasslands extend over a large rainfall spectrum from 100 mm to 4000 mm, resulting in a broad range of vegetation cover and fuel structural characteristics, with fuel loads ranging from less than 0.5 t/ha in arid areas or eaten-out paddocks and up to 20 t/ha in undisturbed exotic grasses.

Typically a grassland landscape will be represented by a mosaic of varied fuel-bed conditions, composed of native grasslands and improved pastures under different grazing pressures, and winter crops (e.g. wheat, barley, canola) that could be in an unharvested (early in the fire season) or harvested state.

Fuel characteristics that influence fire behaviour in grasslands are fuel arrangement and quantity. The speed a grassfire propagates have been found to be strongly influenced by the arrangement of the grass fuel layer, namely the height and continuity of the grass. Standing grass, as found in ungrazed pastures and unharvested crops, sustain higher rates of spread than matted or compacted grass characteristic of a grazed area. Grass fuel load is not as influential in the rate of spread of a wildfire as arrangement, unless fuel quantity is at such a low level that it limits the combustion process. But grass fuel load has a strong influence on flame size, flaming duration, radiation output and suppression difficulty. Grass fuel types are divided into three main fuel conditions in the AFDRS system: (1) undisturbed or natural (i.e. uncut and/or ungrazed), (2) grazed or cut, and (3) eaten-out or very heavily grazed grasslands.

Undisturbed condition: this condition comprise ungrazed and uncut grasslands and pastures and unharvested winter crops such as wheat and barley. The fuel is generally continuous and with a height above 0.5 m. Variations to this typical structure can be found in both arid regions, where cover will be lower, and tropical climates, where grass height can be in excess of 2-3 m, namely in areas covered by exotic grasses, such as gamba grass. Unharvested cereal crops are classified in this condition.

CONTENTS

Grazed or cut condition: this fuel condition is typical of agricultural areas of southern Australia. Grass fuel structure has been impacted by animal consumption and tramping, with average fuel height averaging 0.1-0.5 m tall. Most of the available fuel is likely to be in a matted condition, although clumps of standing grass are still present. Post-harvest stubble from winter crops are classified in this condition.

Eaten-out and heavily grazed condition: Grass fuels have been reduced and compacted due to the grazing pressure. Fuel height is typically less than 10 cm, with occasional small-scale patches of bare ground present. This condition is normally not widespread but restricted to some paddocks, although it can become widespread during severe drought or at the end of a particularly long fire season.

FOR MORE INFORMATION ON FUELS REFER TO: *A GUIDE TO RATE OF FIRE SPREAD MODELS FOR AUSTRALIAN VEGETATION* (2015 EDITION)

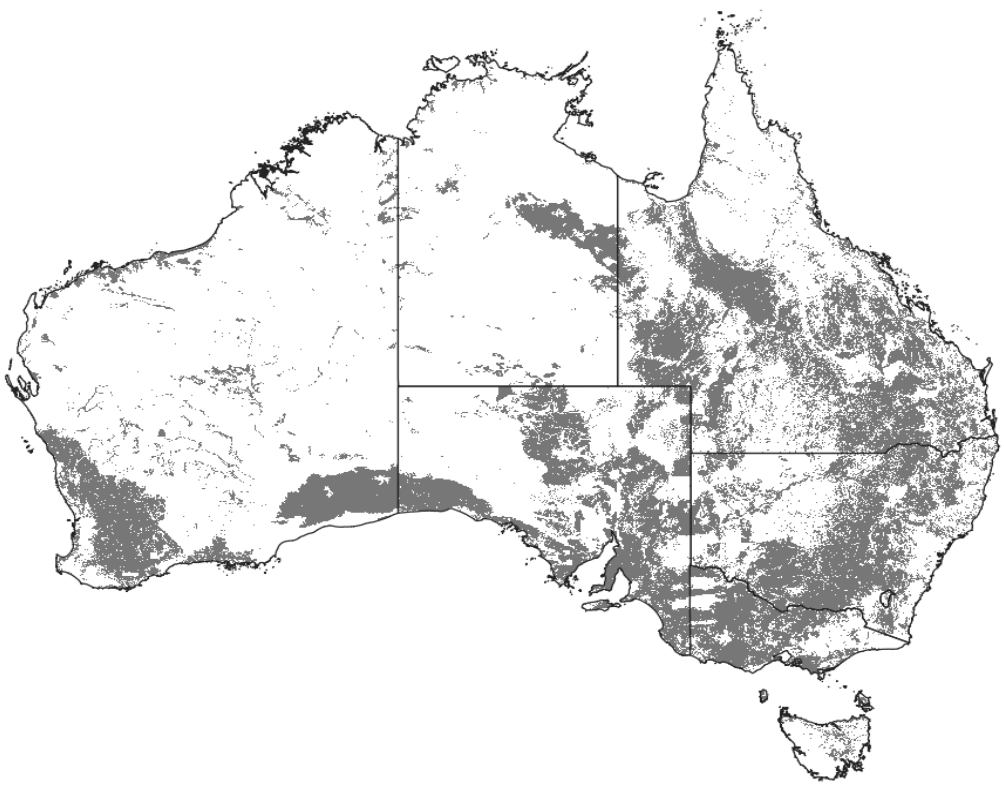
FIRE SPREAD
IN GRASS FUELS

Rate of fire spread is the foundation variable for all calculations in the Australian Fire Danger Rating System. In grass fuels the CSIRO grassland fire spread prediction system is applied to determine the rate of fire spread.

BACKGROUND

The CSIRO grassland fire spread prediction system superseded the previous Grassland Fire Danger Meters by incorporating new understanding of fire behaviour dynamics in grasslands. The system was developed from the analysis of moderate to high-intensity experimental fires conducted in open grasslands in the Northern Territory and data from wildfires spreading in southern Australia landscapes in the upper end of the fire intensity spectrum. This approach allowed to combine the high detail of the experimental data with the higher intensity of the wildfire data.

WHERE IS THE MODEL APPLIED?

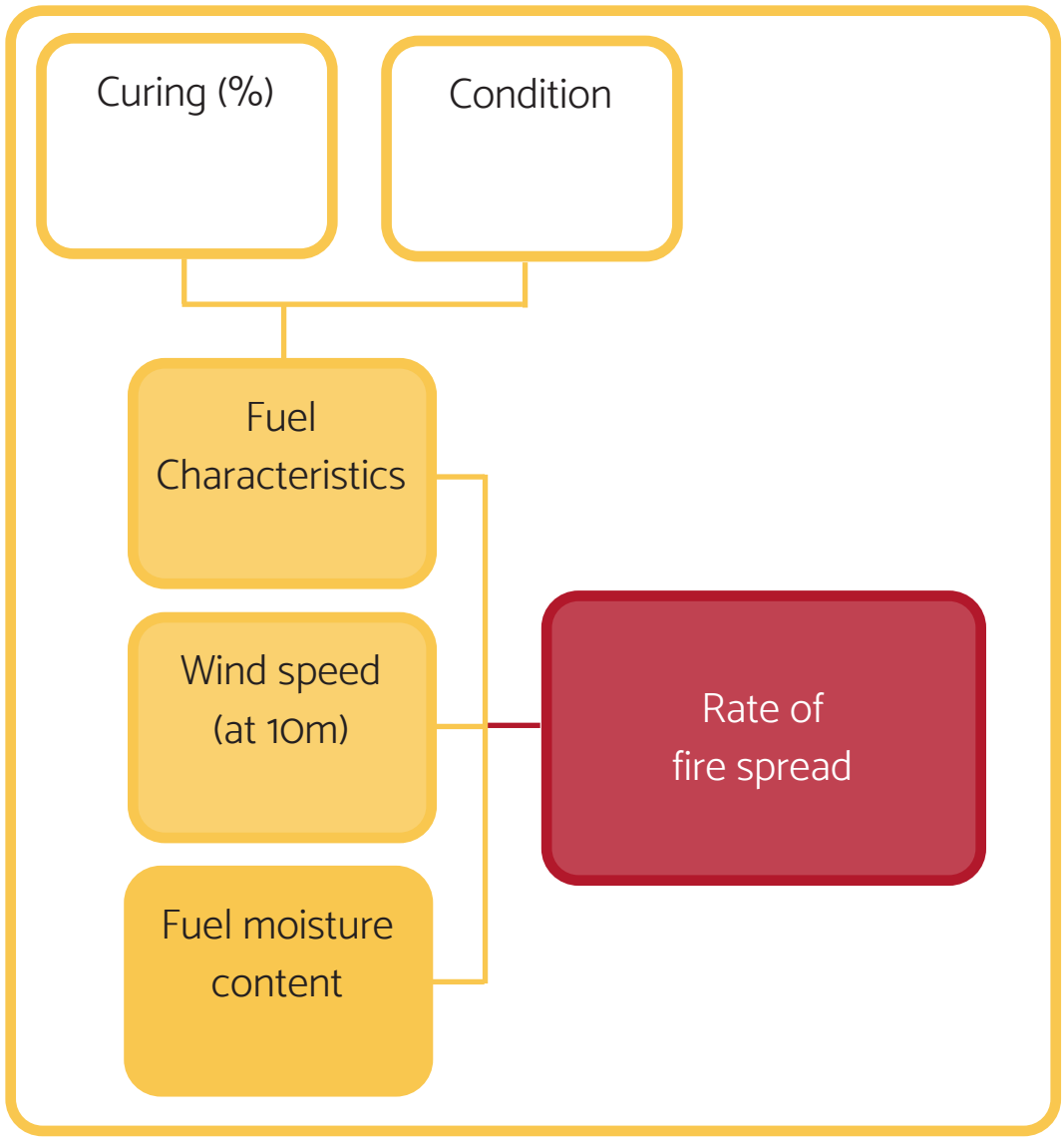


CSIRO grassland models are applied in open grassland systems that span from the northern tropical and subtropical regions to the more temperate southern regions of Australia, including native grasslands, pasture and crops. Certain regions of Australia with low precipitation (less than 200 mm annual precipitation) might not have enough plant cover to allow fire spread in a typical year, but extended wet periods might allow the development of an ephemeral grassland that will support fire propagation.

HOW IS THE MODEL APPLIED?

The model can be applied over the full range of fire danger conditions from knowledge of 10-m open wind speed, dead fuel moisture content, the degree of curing and an assessment of the fuel condition (undisturbed, grazed or eaten-out). The moisture content of dead grass swards can be estimated from air temperature and relative humidity. The degree of curing, the proportion of dead fuel in the grass sward, is estimated from remote sensing and field

WHAT ARE THE MAIN INPUTS?



Rate of fire spread in grass is calculated as a function of the curing and condition fuel characteristics, 10-m open wind speed and fine fuel moisture content.

Fires are assumed to not spread if the degree of curing is below 20%.

WHAT IS THE MODEL SENSITIVE TO?

In the CSIRO grassland fire spread prediction system variation, or uncertainty, in model inputs causes a comparable response in the model rate of fire spread output over most of the fire danger spectrum, with the exception of marginal to low severity burning conditions. For these burning conditions, namely for wind speeds below 10 km/h, dead fuel moisture contents higher than 15% and grass curing below 60%, the model shows higher sensitivity to changes in curing level and dead fuel moisture. A change in fuel condition from grazed to undisturbed or eaten-out causes a change in rate of fire spread of +18% and -50%, respectively.

MORE DETAIL ON THE MODEL CAN BE FOUND IN: *A GUIDE TO RATE OF FIRE SPREAD MODELS FOR AUSTRALIAN VEGETATION* (2015 EDITION)

UNDERSTANDING THE
FIRE BEHAVIOUR INDEX
IN GRASS FUELS

No rating	Moderate	High	Extreme	Catastrophic
Fires are likely to self-extinguish	Typical prescribed burning conditions. Fires usually contained within road networks and fuel breaks.	Fires typically controlled within established road networks and fuel breaks together with using direct, indirect or parallel attack suppression strategies.	Increasing focus on defensive suppression strategies. Fires may escalate very quickly.	High levels of threat to life and property. Conditions limit strategic suppression options. Extremely rapid fire growth. Elevated risk to firefighter safety.	High probability of loss of life and property
	fire behaviour	fire behaviour	suppression	impact	impact

A SCALE OF POTENTIAL FIRE DANGER

The Fire Behaviour Index (FBI) was developed to assist operational decision making, while the Fire Danger Ratings provide the broad categories needed to communicate fire danger to the community.

The FBI provides a scale of potential fire danger (should a fire start) based on the predicted rate of fire spread. In Grass fuels, the rate of fire spread together with fuel load, are used to determine the fireline intensity and this value is used to categorise fire danger on the FBI scale.

TRANSITIONS AND CATEGORIES

The FBI is made up of step-ups or transitions, where an increase in category is triggered by a change in:

1. fire behaviour,
2. suppression response, or
3. potential impacts.

Each category is defined in terms of:

1. indicative fire behaviour and fire weather,
2. implications for prescribed burning,
3. fire suppression and containment, and
4. potential impacts.

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UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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Fire Behaviour Index
0-5

- Mostly self-extinguishing, trouble-free fires.

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

- Fire difficult to ignite and sustain. Fires generally unlikely to spread and likely to self-extinguish.
- Rate of Spread: 0-30 m/hr
- Max. Flame Height: <0.5 m
- Spotting Potential: Potential for any spotting is extremely limited

IMPLICATIONS FOR PRESCRIBED BURNING

Marginal prescribed burning conditions, even at peak of the day.

FIRE SUPPRESSION AND CONTAINMENT

Fire control relatively simple.

Delayed containment possible with suitable conditions.

Head-fire readily suppressed with offensive, direct attack techniques.

Initial attack success is typically very high.

CREDIBLE WORST CASE
MAX. POTENTIAL
in 4 hr (30 min)

AREA
<0.5 ha (<0.1 ha)

PERIMETER
<0.5 km (<0.1 km)

POTENTIAL FOR IMPACT

Community losses are unlikely.

CONDITIONS TO CONSIDER

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UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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Fire Behaviour Index
6-11

- Typical prescribed burning conditions.
- Fires generally easily contained within simple road networks and fuel breaks.

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

Fire easily sustained. Typically wind driven fires that can spread quickly.

- Rate of Spread: <1.3 km/hr
- Max. Flame Height: <1.5 m
- Spotting Potential: Potential for short distance spotting is limited

IMPLICATIONS FOR PRESCRIBED BURNING

Typical prescribed burning conditions.

Simple burns with adequate resourcing.

Upper limit for private landholder burning provided adequate resourcing, training, necessary approvals and permits.

FIRE SUPPRESSION AND CONTAINMENT

Fire control mostly simple with sufficient resources and becoming more complex at higher intensities.

Offensive, direct attack techniques on head-fire or flanks largely successful in fire control.

3 m wide fuel breaks are largely successful at holding fire where trees are absent.

Delayed containment sometimes possible with suitable conditions.

CREDIBLE WORST CASE
MAX. POTENTIAL
in 4 hr (30 min)

AREA
<650 ha (<100 ha)

PERIMETER
<11.5 km (<1.5 km)

POTENTIAL FOR IMPACT

Community losses are unlikely however unattended or poorly prepared houses and infrastructure may be at risk.

CONDITIONS TO CONSIDER

- Strong wind gusts

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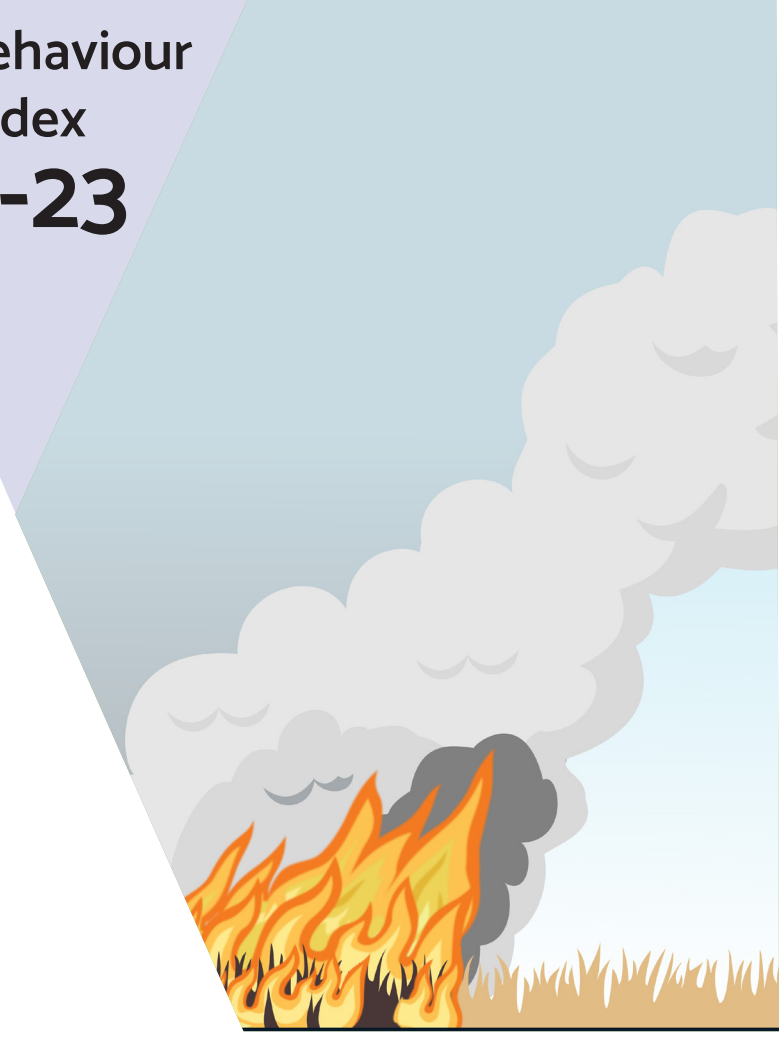
Fire Behaviour Index
12-23



- Fires typically controlled within established road networks and fuel breaks together with using direct, indirect or parallel attack suppression strategies.
- Most bushfires occur in this category.

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

Typically wind driven and rapidly spreading fires with the potential to gain size quickly.

- Rate of Spread: 0.6-5 km/hr
- Max. Flame Height: 1.5-2.5 m
- Spotting Potential: Possible short distance spotting occurring

IMPLICATIONS FOR PRESCRIBED BURNING

Conditions may be suitable for more complex prescribed burning subject to adequate resourcing and well established boundaries/edges.

Prescribed burning may be conducted away from the peak of the day when conditions are optimal and lighting techniques are suitable to achieve prescribed burning objectives.

FIRE SUPPRESSION AND CONTAINMENT

Fires generally becoming more complex and require more resources to control.

Combinations of direct, indirect or parallel attack may be necessary for fire control.

Requires increased effort and resources to contain fire within existing road networks and fuel break boundaries.

Increased likelihood that a 3 m break will be ineffective.

CREDIBLE WORST CASE
MAX. POTENTIAL in 4 hr (30 min)

AREA
<10,500 ha
(<1,500 ha)

PERIMETER
<45 km (<6 km)

POTENTIAL FOR IMPACT

Possible agricultural/pasture/crop/stock losses together with loss of rural assets such as fencing, machinery and buildings.

Unattended or poorly prepared houses and infrastructure may be at risk.

CONDITIONS TO CONSIDER

- C-Haines >95th percentile (approx. >10)
- Wind change forecast during the peak of the afternoon, potential conditions for ‘dead man zone’
- Strong wind gusts

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UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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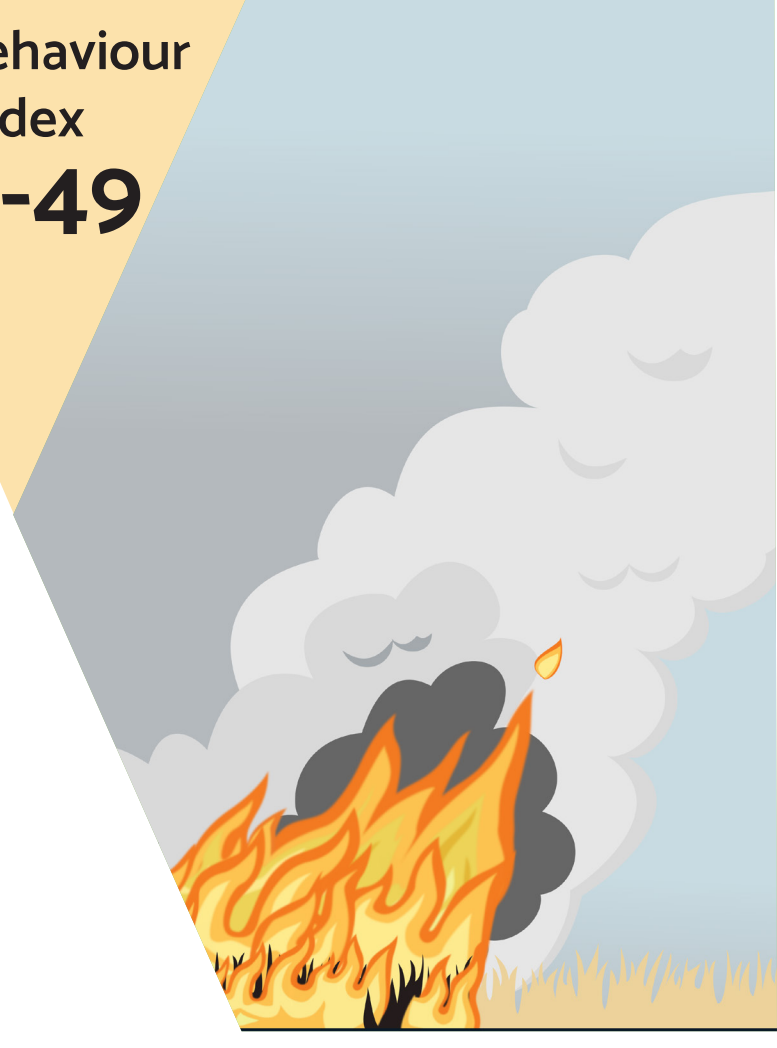
Fire Behaviour Index
24-49



- Increasing focus on defensive suppression strategies.
- Fires may escalate very quickly.

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

Wind driven, rapidly spreading fires with potential for development into large fire area/size and with the potential for short distance spotting and long flame lengths.

- Rate of Spread: 2.5-10 km/hr
- Max. Flame Height: 2-3 m
- Spotting Potential: Possible short distance spotting occurring with increasing frequency

IMPLICATIONS FOR PRESCRIBED BURNING

Conditions are unlikely to be suitable for prescribed burning.

Potential rates of spread, long flame lengths and short distance spotting pose a serious risk of burn escapes.

Fire intensity may be inconsistent with land management objectives.

FIRE SUPPRESSION AND CONTAINMENT

Offensive strategies likely to be challenged during the peak of the day with focus largely centred on the rear and flanks.

Suppression increasingly focused on defensive strategies.

Fire control may be difficult and typically requires larger fuel breaks >10 m wide, together with increased resourcing and effort to contain.

Increased risk to firefighter safety.

CREDIBLE WORST CASE
MAX. POTENTIAL
in 4 hr (30 min)

AREA
<37,000 ha
(<5,000 ha)

PERIMETER
<85 km (<11 km)

POTENTIAL FOR IMPACT

High likelihood of agricultural/pasture/crop/stock losses together with loss of rural assets such as homesteads, fencing, machinery and buildings.

CONDITIONS TO CONSIDER

- C-Haines >95th percentile (approx. >10)
- Wind change forecast during the peak of the afternoon, potential conditions for 'dead man zone'
- Strong wind gusts

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Fire Behaviour Index **50-99**

- High levels of threat to life/property.
- Conditions limit strategic suppression options.
- Extremely rapid fire growth.
- Elevated risk to firefighter safety.

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

Extremely rapid fire growth and increasing likelihood of large final fire area/size. Possibility for fire behaviour to become erratic and plume driven. Strong convective column formation. Wind speed and direction likely to be erratic at times.

- Rate of Spread: 5-16 km/hr
- Max. Flame Height: 2.5-3.5 m
- Spotting Potential: Likely short distance spotting occurring with increasing frequency

IMPLICATIONS FOR PRESCRIBED BURNING

Conditions will be unsuitable for prescribed burning.

Potential fireline intensity and spotting activity pose a serious risk to firefighter safety and the community.

FIRE SUPPRESSION AND CONTAINMENT

Fire control is extremely difficult and unlikely until conditions ease.

Suppression will be largely based on defensive strategies, ensuring firefighter and community preparedness and safety.

Offensive strategies could position crews in danger, however safe opportunities may exist for direct, indirect or parallel attack on the rear and flanks.

Important initial attack opportunities may exist for new ignitions.

Conditions on the fireground are likely to be extremely windy and smoky limiting visibility and restricting aviation and access.

Increased risk to firefighter safety.

CREDIBLE WORST CASE
MAX. POTENTIAL
in 4 hr (30 min)

AREA
<100,000 ha
(<13,000 ha)

PERIMETER
<140 km (<18 km)

POTENTIAL FOR IMPACT

Increasingly high likelihood of agricultural/pasture/crop/stock losses together with loss of rural assets such as homesteads, fencing, machinery and buildings. Limited visibility due to smoke and dust. High risk to the community related to inappropriate pre-considered plans, inadequate sheltering.

Strong winds are likely to impact infrastructure (e.g. power lines) and fall trees increasing the likelihood of obstructed roads and power outages.

CONDITIONS TO CONSIDER

- C-Haines >95th percentile (approx. >10)
- Wind change forecast during the peak of the afternoon, potential conditions for 'dead man zone'

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UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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Fire Behaviour Index **100+**

- High probability of loss of life and property.
- Extremely rapid fire growth.
- Elevated risk to firefighter safety.
- Initial attack success critical to prevent large fire development.
- Conditions limit strategic suppression options.

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

Extremely rapid fire growth and high likelihood of large final fire area/size. Possibility for fire behaviour to become erratic and plume driven. Strong convective column formation. Wind speed and direction likely to be erratic at times.

- Rate of Spread: >8 km/hr can be expected and possibly >16 km/hr
- Max. Flame Height: >3 m (possibly >3.5 m)
- Spotting Potential: Likely short distance spotting occurring with increasing frequency

IMPLICATIONS FOR PRESCRIBED BURNING

Conditions will be unsuitable for prescribed burning.

Potential fireline intensity and spotting activity pose a serious risk to firefighter safety and the community.

FIRE SUPPRESSION AND CONTAINMENT

Fire control is extremely difficult and unlikely until conditions ease. Suppression will be largely based on defensive strategies, ensuring firefighter and community preparedness and safety. Offensive strategies could position crews in danger, however safe opportunities may exist for direct, indirect or parallel attack on the rear and flanks. Important initial attack opportunities may exist for new ignitions. Conditions on the fireground are likely to be extremely windy and smoky limiting visibility and restricting aviation and access.

Conditions are likely to impact performance and effectiveness of aerial resources with a high probability that some aircraft will be unable to operate due to high winds and limited visibility. Systems such as communications, will be heavily challenged with a likelihood of difficulties and outages. Fuel breaks <100 m are likely to be ineffective at holding head-fires.

Extreme risk to firefighter safety.

CREDIBLE WORST CASE

MAX. POTENTIAL in 4 hr (30 min)

AREA

>100,000 ha

(>13,000 ha)

PERIMETER

>140 km (>80 km)

POTENTIAL FOR IMPACT

Extremely high likelihood of agricultural/pasture/crop/stock loss together with losses of rural assets such as homesteads, fencing, machinery and buildings. Very limited visibility due to smoke and dust. Very high risk to the community related to inappropriate pre-considered plans, inadequate sheltering.

Extremely strong winds are very likely to impact infrastructure (e.g. power lines) and fall trees resulting in a high likelihood of obstructed roads and power outages.

CONDITIONS TO CONSIDER

- C-Haines >95th percentile (approx. >10)
- Wind change forecast during the peak of the afternoon, potential conditions for 'dead man zone'

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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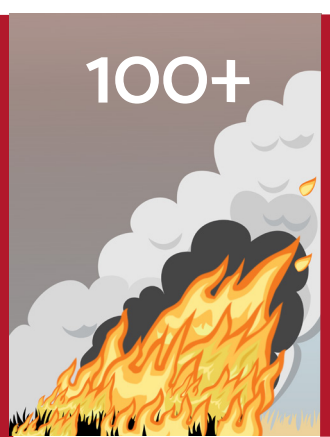
GRASS

FIRE BEHAVIOUR INDEX

0-5	MAX FLAME HEIGHT <1 m		RATE OF SPREAD 0-30 m/hr	Fire difficult to ignite and sustain. Fires generally unlikely to spread and likely to self-extinguish.	**SPOTTING POTENTIAL** Potential for any spotting is very limited.
6-11	<1.5 m		<1.3 km/hr	Fire easily sustained. Typically wind driven fires that can spread quickly.	Potential for spotting Potential for short distance spotting is limited.
12-23	1.5-2.5 m		0.5-6 km/hr	Typically wind driven and rapidly spreading fires with the potential to gain size quickly.	Possible short distance spotting occurring.
24-49	2-3 m		2.5-10 km/hr	Wind driven, rapidly spreading fires with potential for development into large fire area/size and with the potential for short distance spotting and long flame lengths.	Short distance spotting occurring with increasing frequency.
50-99	2.5-3.5m		5-16 km/hr	Extremely rapid fire growth and increasing likelihood of large final fire area/size. Possibility for fire behaviour to become erratic and plume driven. Strong convective column formation. Wind speed and direction likely to be erratic at times.	Likely short distance spotting occurring with increasing frequency.
100+	>3m		>8 km/hr can be expected, possibly >16 km/hr	Extremely rapid fire growth and high likelihood of large final fire area/size. Possibility for fire behaviour to become erratic and plume driven. Strong convective column formation. Wind speed and direction likely to be erratic at times.	Likely short distance spotting occurring with increasing frequency.

IMPLICATIONS FOR PRESCRIBED BURNING

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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GRASS

FIRE BEHAVIOUR INDEX

MARGINAL | **0-5**

Marginal prescribed burning conditions, even at peak of the day.

GENERALLY SUITABLE | **6-11**

Typical prescribed burning conditions. Simple burns with adequate resourcing.

Upper limit for private landholder burning provided adequate resourcing, training, necessary approvals and permits.

MARGINAL | **12-23**

Conditions may be suitable for more complex prescribed burning subject to adequate resourcing and well established boundaries/edges.

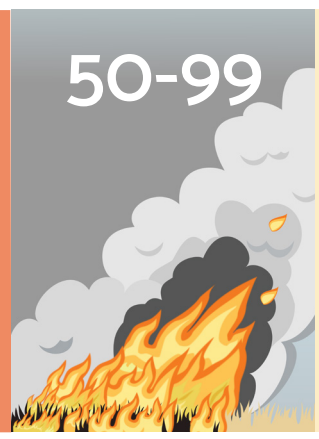
Prescribed burning may be conducted away from the peak of the day when conditions are optimal and lighting techniques are suitable to achieve prescribed burning objectives.

GENERALLY UNSUITABLE | **24-49**

Conditions are unlikely to be suitable for prescribed burning.

Potential rates of spread, long flame lengths and short distance spotting pose a serious risk of burn escapes. Fire intensity may be inconsistent with land management objectives.

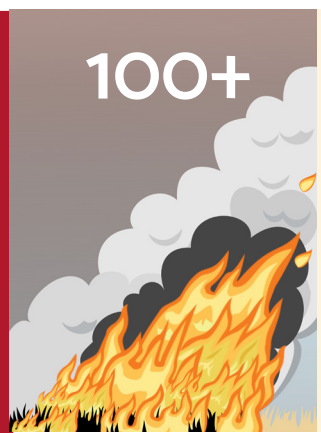
UNSUITABLE | **50-99**



Conditions will be unsuitable for prescribed burning.

Potential fireline intensity and rates of spread pose a serious risk to firefighter safety and the community.

UNSUITABLE | **100+**



Conditions will be unsuitable for prescribed burning.

Potential fireline intensity and spotting activity pose a serious risk to firefighter safety and the community.

FIRE SUPPRESSION AND CONTAINMENT

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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GRASS

FIRE BEHAVIOUR INDEX		CREDIBLE WORST CASE
0-5	Fire control relatively simple. Delayed containment possible with suitable conditions. Head-fire readily suppressed with offensive, direct attack techniques. Initial attack success is typically very high. Small fires that may be allowed to spread within an extended (time and area) containment objective.	MAX. POTENTIAL in 4 hr (30 min) AREA <0.5 ha (<0.1 ha) PERIMETER <0.5 km (<0.1 km)
6-11	Fire control mostly simple with sufficient resources and becoming more complex at higher intensities. Offensive, direct attack techniques on head-fire or flanks largely successful in fire control. 3 m wide fuel breaks are largely successful at holding fire where trees are absent3. Delayed containment sometimes possible with suitable conditions. Fires may be allowed to spread within an extended (time and area) containment objective.	AREA <650 ha (<100 ha) PERIMETER <11.5 km (<1.5 km)
12-23	Fires generally becoming more complex and require more resources to control. Combinations of direct, indirect or parallel attack may be necessary for fire control. Requires increased effort and resources to contain fire within existing road networks and fuel break boundaries. Increased likelihood that a 3 m break will be ineffective3.	AREA <10,500 ha (<1,550 ha) PERIMETER <45 km (<6 km)
24-49	Offensive strategies likely to be challenged during the peak of the day with focus largely centred on the rear and flanks. Suppression increasingly focused on defensive strategies. Fire control may be difficult and typically requires larger fuel breaks >10 m wide3, together with increased resourcing and effort to contain.	AREA <37,000 ha (<5,000 ha) PERIMETER <85 km (<11 km)
50-99	Fire control is extremely difficult and unlikely until conditions ease. Suppression will be largely based on defensive strategies, ensuring firefighter and community preparedness and safety. Offensive strategies could position crews in danger, however safe opportunities may exist for direct, indirect or parallel attack on the rear and flanks. Important initial attack opportunities may exist for new ignitions. Conditions on the fireground are likely to be extremely windy and smoky limiting visibility and restricting aviation and access.	AREA <100,000 ha (<13,000 ha) PERIMETER <140 km (<80 km)
100+	Fire control is extremely difficult and unlikely until conditions ease. Suppression will be largely based on defensive strategies, ensuring firefighter and community preparedness and safety. Offensive strategies could position crews in danger, however safe opportunities may exist for direct, indirect or parallel attack on the rear and flanks. Important initial attack opportunities may exist for new ignitions. Conditions on the fireground are likely to be extremely windy and smoky limiting visibility and restricting aviation and access. Conditions are likely to impact performance and effectiveness of aerial resources with a high probability that some aircraft will be unable to operate due to high winds and limited visibility. Systems such as communications, will be heavily challenged with a likelihood of difficulties and outages. Fuel breaks <100 m are likely to be ineffective at holding head-fires.	AREA >100,000 ha (>13,000 ha) PERIMETER >140 km (>80 km)

POTENTIAL FOR IMPACT

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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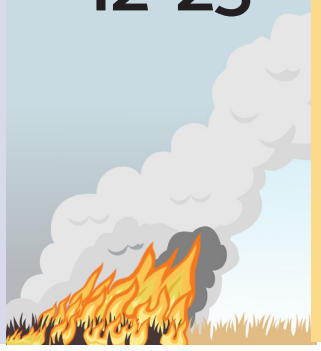
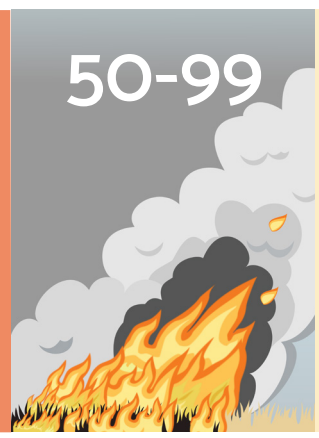
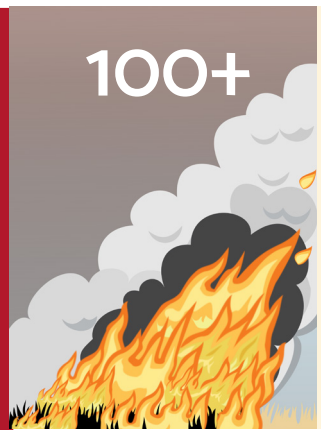
GRASS

FIRE BEHAVIOUR INDEX

UNLIKELY	0-5 	Community losses are unlikely.
UNLIKELY	6-11 	Community losses are unlikely however unattended or poorly prepared houses and infrastructure may be at risk.
MINIMAL	12-23 	Possible agricultural/pasture/crop/stock losses together with loss of rural assets such as fencing, machinery and buildings. Unattended or poorly prepared houses and infrastructure may be at risk.
INCREASING	24-49 	High likelihood of agricultural/pasture/crop/stock losses together with loss of rural assets such as homesteads, fencing, machinery and buildings.
HIGH	50-99 	Increasingly high likelihood of agricultural/pasture/crop/stock losses together with loss of rural assets such as homesteads, fencing, machinery and buildings. Limited visibility due to smoke and dust. High risk to the community related to inappropriate pre-considered plans, inadequate sheltering2. Strong winds are likely to impact infrastructure (e.g. power lines) and fall trees increasing the likelihood of obstructed roads and power outages.
VERY HIGH	100+ 	Extremely high likelihood of agricultural/pasture/crop/stock loss together with losses of rural assets such as homesteads, fencing, machinery and buildings. Very limited visibility due to smoke and dust. Very high risk to the community related to inappropriate pre-considered plans, inadequate sheltering. Extremely strong winds are very likely to impact infrastructure (e.g. power lines) and fall trees resulting in a high likelihood of obstructed roads and power outages.

SUPPLEMENTARY INFORMATION
FOR GRASS FUELS

To define each category against modelled outputs within the Fire Behaviour Index (FBI) scale, various methodologies and assumptions are applied. These are outlined below.

FLAME HEIGHT

Flame heights are based on figure for 'grazed' grassland in Cruz et al. (2015a)

RATE OF SPREAD

Rates of spread are back-calculated from FBI model outputs based on Byram's fireline intensity and a range of fuel load varying from 3-6 t/ha.

FIRE AREA AND PERIMETER

Potential fire area and perimeter are based on a 4-hour fire run under maximum fire danger with a range of length-breadth ratio as determined by wind speeds ranging from 10-40 km/hr (as per Cruz et al (2015a)) and a fuel load varying from 3-6 t/ha.
The values assume no suppression.

IMPACT RELATED THRESHOLDS AND DESCRIPTIONS

Impact related thresholds and descriptions have been based largely on the work of Kilinc et al (2013), Harris et al (2011) and Blanchi et al (2010).

PROJECT DOCUMENTATION

A comprehensive list of project documentation for the Australian Fire Danger Rating System is available via the AFAC website at: https://www.afac.com.au/initiative/afdrs/afdrs-publications.

SUPPORTING REFERENCES AND FURTHER READING

Blanchi, R., et al. (2010). Meteorological conditions and wildfire-related house loss in Australia. International Journal of Wildland Fire 19(7): 914-926.

Byram, G. M. (1959). Combustion of forest fuels. Forest Fire: Control and Use. K. P. Davis. New York, McGraw-Hill: 61-89.

Cheney, N.P., Gould, J.S., Catchpole, W.R. (1998). Prediction of Fire Spread in Grasslands. International Journal of Wildland Fire 8, 1-13.

Cruz, M. G., et al. (2015a). A Guide to Rate of Fire Spread Models for Australian Vegetation. Melbourne, Victoria, CSIRO Land and Water Flagship, Canberra, ACT, and AFAC.

Cruz, M.G., Gould, J.S., Kidnie, S., Bessell, R., Nichols, D., Slijepcevic, A. (2015b). Effects of curing on grassfires: II. Effect of grass senescence on the rate of fire spread. International Journal of Wildland Fire 24, 838-848.

Harris, S., et al. (2011). Establishing a link between the power of fire and community loss: The first steps towards developing a bushfire severity scale. Melbourne, Victoria, Victorian Government Department of Sustainability and Environment.

Kilinc, M., et al. (2013). Project title: A scale for determining the destructive potential of bushfires. Milestone report for the period 2013. Technical Report 1. Monash University, Geography and Environmental Science and University of New South Wales, Canberra.

Noble, I. R., et al. (1980). McArthur's fire-danger meters expressed as equations. Australian Journal of Ecology 5: 201-203.

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CONTACT

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THE AFDRS PROJECT IS BEING LED BY:

NSW RURAL FIRE SERVICE

Australian Government
Bureau of Meteorology

afac

PRIMARILY FUNDED BY:

Australian Government
National Recovery and Resilience Agency

PARTNER AGENCIES:

A.C.T. RURAL FIRE SERVICE

CFS

EMV EMERGENCY MANAGEMENT VICTORIA

BUSHFIRES NT

NORTHERN TERRITORY GOVERNMENT

QUEENSLAND FIRE AND EMERGENCY SERVICES

GOVERNMENT OF WESTERN AUSTRALIA
Department of Biodiversity, Conservation and Attractions

GOVERNMENT OF WESTERN AUSTRALIA
DFES
Department of Fire & Emergency Services

Tasmanian Government

Tasmania Fire Service

SUPPORTING BODIES:

AUSTRALIAN CAPITAL TERRITORY EMERGENCY SERVICES AGENCY

ACT FIRE & RESCUE

ACT Government
Environment, Planning and Sustainable Development

CFA

RURAL FIRE SERVICE QUEENSLAND

Government of South Australia
South Australian Fire and Emergency Services Commission

Government of South Australia
Department for Environment and Water

VICTORIA State Government
Environment, Land, Water and Planning

WALGA

MALLEE-HEATH

QUICK GUIDE

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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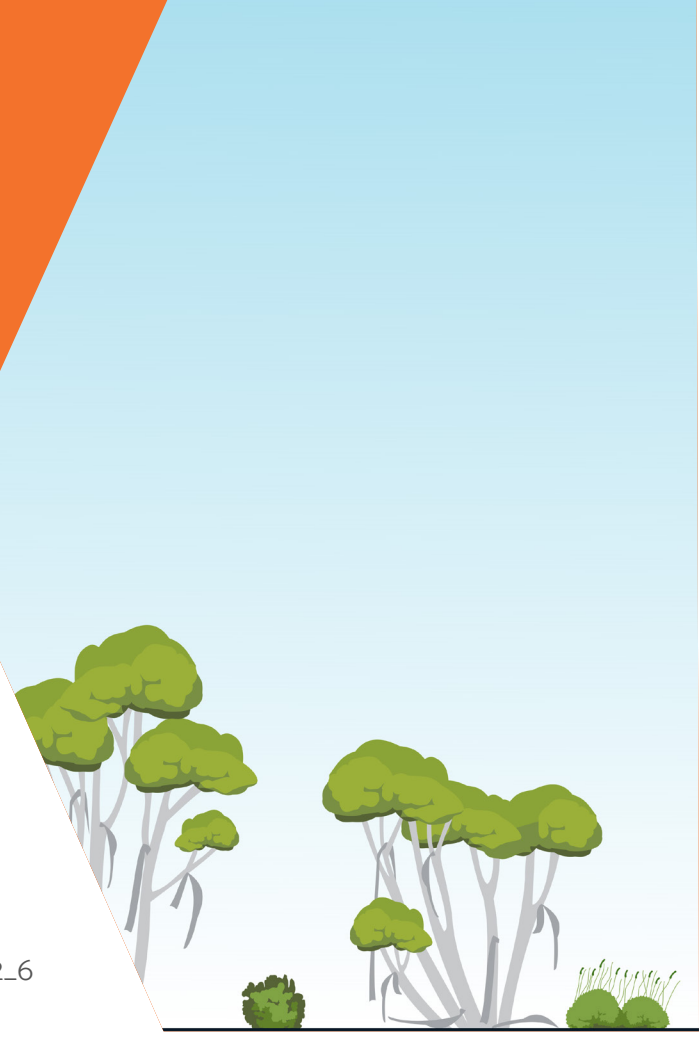
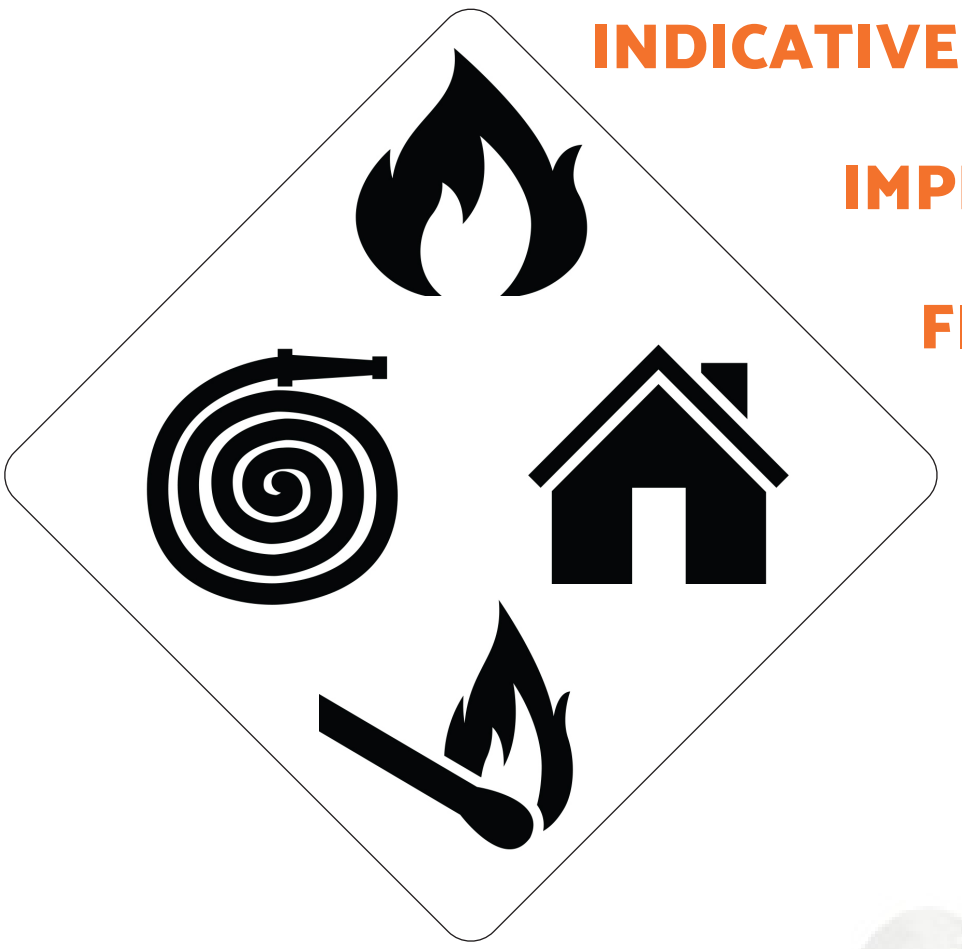


Australian Fire Danger Rating System



INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

IMPLICATIONS FOR PRESCRIBED BURNING

FIRE SUPPRESSION AND CONTAINMENT

POTENTIAL FOR IMPACT

MALLEE-HEATH FUELS

IN THE AUSTRALIAN FIRE DANGER RATING SYSTEM

In the Australian Fire Danger Rating System, fuel types have been grouped by application of the most relevant fire spread model. The mallee-heath fuel type is associated with eucalypt dominated shrublands in semi-arid (200 to 550 mm mean annual rainfall) sandy areas throughout southern Australia.

MALLEE-HEATH FUEL STRUCTURE

Mallee-heath vegetation is characterised by a multi-stemmed (mallee form) eucalyptus overstorey with an understorey of elevated and near-surface fuels. Fuels tend to be quite discontinuous, both vertically (no contact between different strata) and horizontally, with areas devoid of fuel limiting fire propagation under mild conditions.

The overstorey component typically has a cover of less than 20-25%, with the cover increasing with time since fire and mean precipitation of an area A shrub understorey (0.5 to 2 m tall) comprising a wide variety of species constitutes the elevated layer. This layer is the most important fuel layer for fire propagation due to its fine, well-aerated fuels within the canopy (a large proportion of which is dead) and the presence of volatile chemicals within the foliage such as terpenes and waxes. The near-surface layer (0.1–0.3 m tall) is comprised of tussock and hummock grasses, ephemeral herbs, low sedges, low shrubs and dead suspended material. Although it may not alone sustain fire spread, the high dead/live ratios of this layer make it important in sustaining fire propagation in the elevated layer. Ephemeral grasses can appear following periods of above average rainfall, increasing near-surface fuel cover to a level where it becomes the main stratum carrying the fire. The litter (surface) layer varies between well-developed under the mallee clumps to very sparse under shrubs where fine dead leaves mix with sand. Fuel accumulation beneath mallee clumps can cause a substantial increase in fire intensity, leading to the combustion of suspended bark strips, crowning and generation of firebrands; fire behaviour characteristics observed under severe fire weather conditions.

In general, the higher the aridity, the higher the horizontal fuel discontinuity, including increased gaps between elevated and near surface fuels. In dune systems, fuels will be sparser in the dune, and more continuous in the swales.

Fire behaviour in mallee-heath vegetation in coastal areas, where higher moisture availability leads to more continuous fuel beds, is likely better described with the Shrubland fuel type model.

CONTENTS

FOR MORE INFORMATION ON FUELS REFER TO:
***A GUIDE TO RATE OF FIRE SPREAD MODELS FOR AUSTRALIAN VEGETATION* (2015 EDITION)**

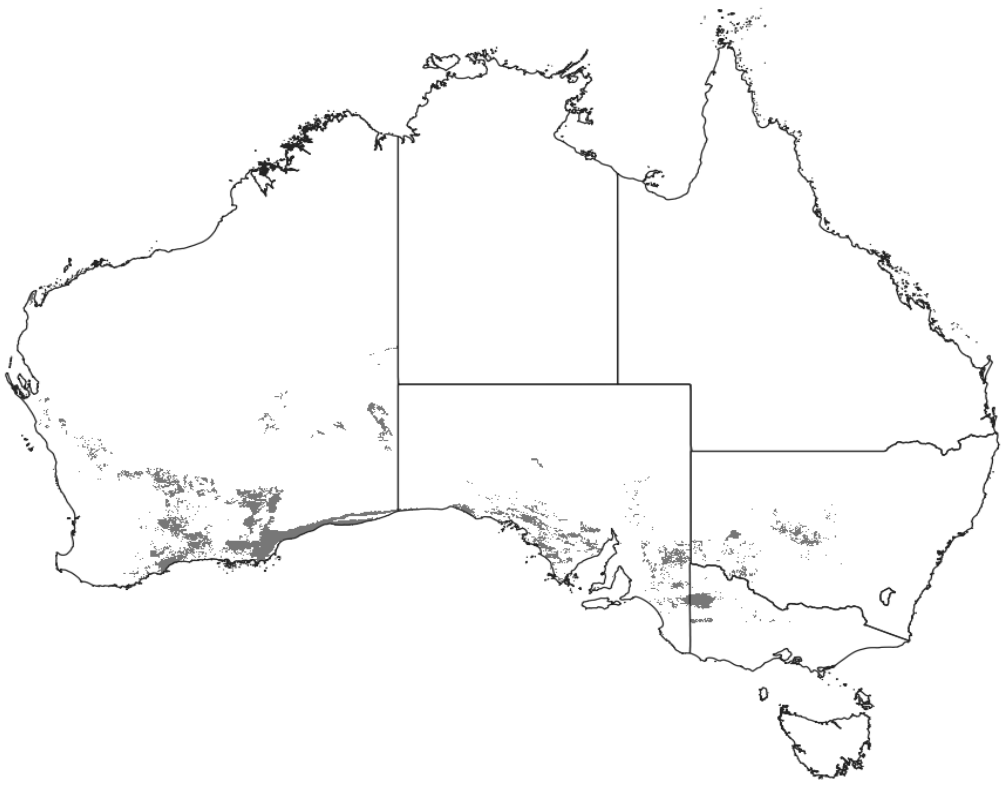
FIRE SPREAD
IN MALLEE-HEATH FUELS

Rate of fire spread is the foundation variable for all calculations in the Australian Fire Danger Rating System. The semi-arid mallee heath model is applied to the estimation of the potential rate of fire spread in this fuel type.

BACKGROUND

The semi-arid mallee heath model was developed from the analysis of fire behaviour data from Western Australia and South Australia. The data came from both prescribed burns and high-intensity experimental fires exhibiting wildfire like-intensities. The model estimates the likelihood of fire propagation (i.e. "go/no-go"), type of fire (i.e. surface or crown) and the rate of forward fire spread.

WHERE IS THE MODEL APPLIED?



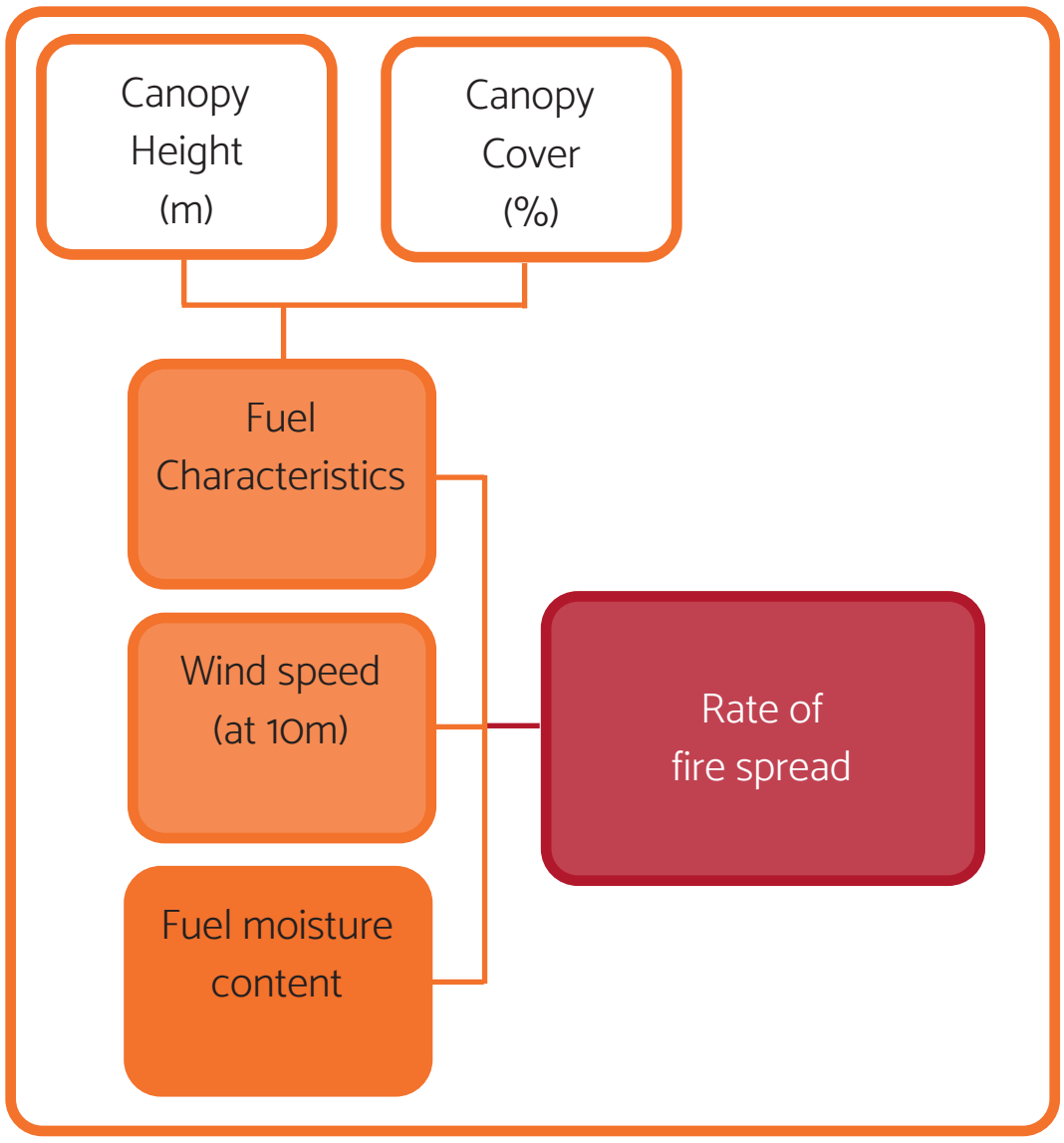
The semi-arid mallee-heath model is applied in several areas with this vegetation type in southern Australia, namely in WA, SA, Victoria and NSW. The model is also applied to semi-arid vegetation with similar structural form.

HOW IS THE MODEL APPLIED?

The semi-arid mallee-heath model can be applied over the full range of fire danger conditions from knowledge of 10-m open wind speed, moisture content of fine dead elevated fuels, and the height and cover of the mallee overstorey. The moisture content of fine dead fuels is estimated from air temperature and relative humidity.

The model first calculates if a fire is likely to spread sustainably under a set of environmental conditions. If fire is likely to spread, the model then estimate what type of fire is present, surface fire or crown fire, and the associated rate of fire spread.

WHAT ARE THE MAIN INPUTS?



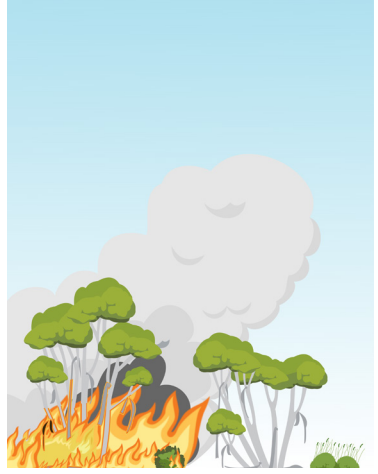
Rate of fire spread in Mallee-heath is calculated as a function of the canopy fuel characteristics, 10-m open wind speed and fine fuel moisture content.

WHAT IS THE MODEL SENSITIVE TO?

The semi-arid mallee-heath model is most sensitive to changes in wind speed, followed by dead fuel moisture content and then the mallee overstorey characteristics. The stepwise changes that occur when the onset of fire propagation and crowning occur makes the model quite sensitive to wind and fuel moisture when the simulations are close to the threshold points, namely when fuel moistures are low and wind speeds are high. The effect of fuels is complex, with an increase in mallee height causing a reduction in rate of fire spread of the surface fire, whereas an increase in cover will increase the rate of crown fire spread.

MORE DETAIL ON THE MODEL CAN BE FOUND IN: *A GUIDE TO RATE OF FIRE SPREAD MODELS FOR AUSTRALIAN VEGETATION* (2015 EDITION)

UNDERSTANDING THE
FIRE BEHAVIOUR INDEX
IN MALLEE-HEATH FUELS

Fire Behaviour Index	0-5	6-11	12-23	24-49	50+
					
	No rating	Moderate	High	Extreme	Catastrophic
fire behaviour	Fires are likely to self-extinguish	Typical prescribed burning conditions Generally spread as surface fires	Vigorous surface fires with intermittent crowning possible	Active crown fires that may escalate very quickly May require active suppression around assets with insufficient break widths	
impact				Elevated risk to the safety of visitors and local communities Damaging crown fires with extremely rapid fire growth	Increased likelihood of community loss and significant consequences

A SCALE OF POTENTIAL FIRE DANGER

The Fire Behaviour Index (FBI) was developed to assist operational decision making, while the Fire Danger Ratings provide the broad categories needed to communicate fire danger to the community.

The FBI provides a scale of potential fire danger (should a fire start) based on the probability and predicted rate of fire spread. In mallee-heath fuels, rate of fire spread together with fuel load, are used to determine the fireline intensity and this value is used to categorise fire danger on the FBI scale.

TRANSITIONS AND CATEGORIES

The FBI is made up of step-ups or transitions, where an increase in category is triggered by a change in:

1. fire behaviour,
2. suppression response, or
3. potential impacts.

Each category is defined in terms of:

1. indicative fire behaviour and fire weather,
2. implications for prescribed burning,
3. fire suppression and containment, and
4. potential impacts.

MALLEE-HEATH

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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Fire Behaviour Index
0-5

- Mostly self-extinguishing fires.

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

Probability of self-sustained, surface fire is low.

Probability of self-sustained surface fire lower than 50%.

- Rate of Spread: <40 m/hr
- Max. Flame Height: <1 m
- Spotting Potential: Potential for any spotting is extremely limited

IMPLICATIONS FOR PRESCRIBED BURNING

Marginal prescribed burning conditions, even at peak of the day.

FIRE SUPPRESSION AND CONTAINMENT

Fire containment relatively simple and typically contained within simple road networks, fuel breaks and buffers without the need for active fire suppression.

CREDIBLE WORST CASE
MAX. POTENTIAL in 4 hr

AREA
<1 ha

PERIMETER
<0.5 km

POTENTIAL FOR IMPACT

Community losses are unlikely.

CONDITIONS TO CONSIDER

5

MALLEE-HEATH

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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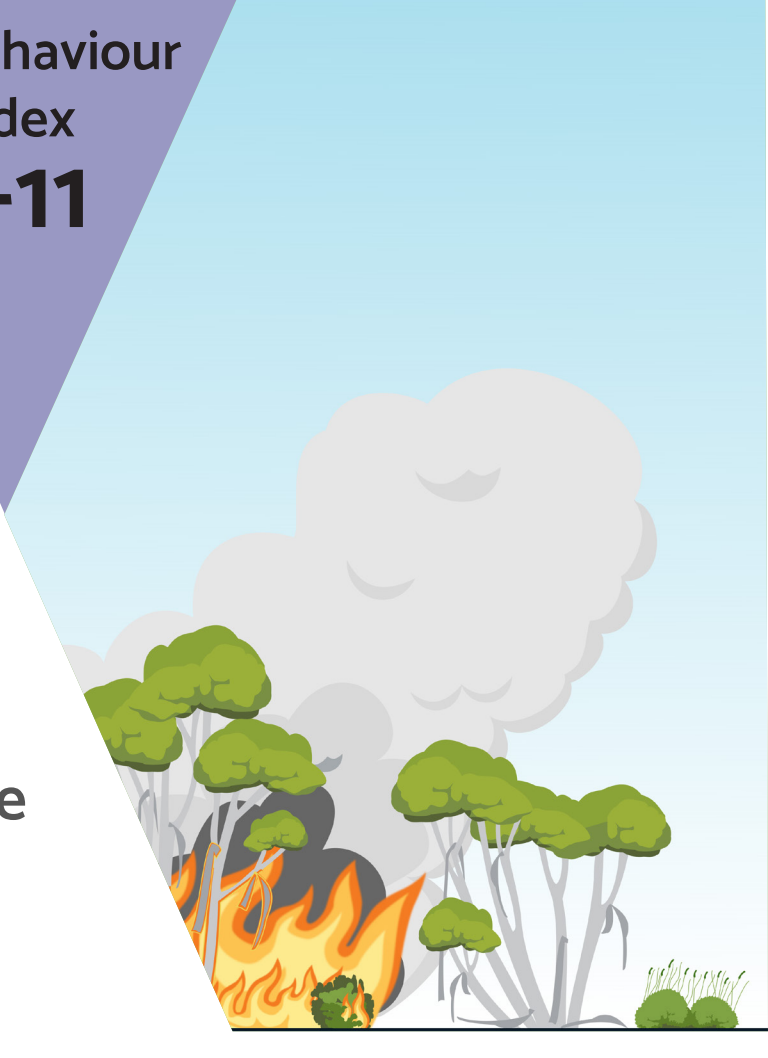
Fire Behaviour Index
6-11



- Typical prescribed burning conditions.
- Fires generally spread as surface fires.
- Fires mostly contained within road networks, fuel breaks (including scrub roll buffers) and recent fire scars.

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

Surface fires whereby the flame front is able to overcome fine scale fuel discontinuities. Isolated torching of overstorey fuels.

Probability of self-sustained surface fire higher than 50%.

Probability of crown fire occurrence is lower than 33%.

- Rate of Spread: <2 km/hr
- Max. Flame Height: Flame heights and lengths <5 m
- Spotting Potential: Short range spotting possible up to 10 m

IMPLICATIONS FOR PRESCRIBED BURNING

Typical prescribed burning conditions for hazard reduction.

Simple burns with adequate fuel breaks, often going out overnight with higher humidity and fuel moisture.

FIRE SUPPRESSION AND CONTAINMENT

Fires typically contained within road networks, fuel breaks (including recent fire scars) and buffers >3-4 m wide with active fire suppression.

CREDIBLE WORST CASE
MAX. POTENTIAL in 4 hr

AREA
<1,500 ha

PERIMETER
<17 km

POTENTIAL FOR IMPACT

Community losses are unlikely however, unattended or poorly prepared assets and infrastructure may be at risk.

CONDITIONS TO CONSIDER

MALLEE-HEATH

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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Fire Behaviour Index
12-23

- Fires are typically vigorous surface fires with intermittent crowning possible.
- Fires are typically controlled within established road networks, wide fuel breaks (and scrub roll buffers) and recent fire scars.

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

Intermittent crown fire. The passage of the flame front on surface fuels is followed by torching of overstorey fuels. Canopy fuel combustion occurs somewhat behind the leading edge of the flame front. Average flame front properties not affected by the level of torching and rate of fire spread largely determined by surface phase.

Probability of crown fire occurrence between 33 and 66%.

- Rate of Spread: 1-3 km/hr
- Max. Flame Height: Flame heights and lengths <6 m
- Spotting Potential: Short range spotting up to 50 m likely, allowing fire to cross small areas of fuel discontinuity such as roads or small fuel breaks

IMPLICATIONS FOR PRESCRIBED BURNING

Prescribed burning opportunities exist for complex burn plans with adequate resourcing and well established, wide boundaries/edges.

Opportunities may exist away from the peak of the day when conditions are suitable to achieve prescribed burn objectives.

FIRE SUPPRESSION AND CONTAINMENT

Fire containment generally requiring wider roads, fuel breaks (including recent fire scars) or buffers (>10 m) together with active suppression.

Active suppression around assets generally not necessary with adequate fuel breaks.

Onset of crown fire activity can lead to rapid increase in rate of spread and intensity (2-3 x surface fire spread rate).

CREDIBLE WORST CASE
MAX. POTENTIAL in 4 hr

AREA
<3,000 ha

PERIMETER
<25 km

POTENTIAL FOR IMPACT

Community losses are unlikely however, unattended or poorly prepared assets and infrastructure may be at risk.

CONDITIONS TO CONSIDER

- C-Haines >95th percentile (approx. >10)
- Wind change forecast during the peak of the afternoon

MALLEE-HEATH

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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Fire Behaviour Index
24-49

- Fires are typically active crown fires that may escalate very quickly.
- Fires may require active suppression around assets with insufficient break widths.

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

Active or dependent crown fires with crown phase determining the overall rate of spread. Fire propagates faster than observed for a surface or intermittent crown fire under same environmental conditions. A reduction of the surface phase heat output below a certain level will lead the fire to an intermittent crown fire regime.

Probability of crown fire occurrence is between 66 and 100%.

- Rate of Spread: 1.5-5.5 km/hr
- Max. Flame Height: Flame heights and lengths <8 m
- Spotting Potential: Escalation in fire activity is typically accompanied by an increase in the number of firebrands generated and possible distances >50 m ahead of the flame front.

IMPLICATIONS FOR PRESCRIBED BURNING

Conditions are unlikely to be suitable for prescribed burning.

Potential rates of spread, long flame lengths and short distance spotting pose a serious risk of burn escapes. Fire intensity may be inconsistent with land management objectives.

FIRE SUPPRESSION AND CONTAINMENT

Fires quickly becoming large and difficult to contain within existing road networks, fuel breaks (including scrub roll buffers) and fire scars. Fuel breaks (or buffers) >100 m are likely to be effective.

Conditions on the fireground are likely to be extremely windy.

Active suppression including indirect attack or machines may be required to protect areas of population, high conservation value and on high value built and cultural assets.

CREDIBLE WORST CASE
MAX. POTENTIAL in 4 hr

AREA
<12,000 ha

PERIMETER
<50 km

POTENTIAL FOR IMPACT

High likelihood of pasture/crop/stock loss together with loss of rural assets such as fencing, machinery and buildings.

Increasing risk of damaging impacts on the environment. Fires often producing large amounts of smoke. Visibility is likely to be limited due to smoke and dust, potentially impacting traffic management.

CONDITIONS TO CONSIDER

- C-Haines >95th percentile (approx. >10)
- Wind change forecast during the peak of the afternoon, potential conditions for 'dead man zone'

MALLEE-HEATH

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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Fire Behaviour Index
50+

- Elevated risk to the safety of visitors and local communities.
- Fires typically damaging crown fires with extremely rapid fire growth.
- Fires may require additional containment and active suppression around assets with insufficient break widths.
- High levels of threat to the environment and when in close proximity to people, assets and property.

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

Active or dependent crown fire.

Probability of crown fire occurrence is 100%.

- Rate of Spread: >3 km/hr can be expected and possibly >5.5 km/hr
- Max. Flame Height: Long flame heights and lengths possibly >8 m
- Spotting Potential: Escalation in fire activity is typically accompanied by an increase in the number of firebrands generated and possible distances >50 m ahead of the flame front.

IMPLICATIONS FOR PRESCRIBED BURNING

Conditions will be unsuitable for prescribed burning.

Potential fireline intensity and rates of spread pose a serious risk to firefighter safety and the community.

FIRE SUPPRESSION AND CONTAINMENT

Fires quickly becoming large, complex and difficult to contain within existing road networks, fuel breaks (including scrub roll buffers) and fire scars.

Fuel breaks (or buffers) >500 m are likely to be effective.

Conditions on the fireground are likely to be extremely windy.

Active suppression including indirect attack, scrub rolling or machines may be required to protect areas of population, high conservation value and on high value built and cultural assets.

CREDIBLE WORST CASE
MAX. POTENTIAL
in 4 hr

AREA
>12,000 ha

PERIMETER
>50 km

POTENTIAL FOR IMPACT

Extremely high likelihood of pasture/crop/stock loss together with loss of rural assets such as fencing, machinery and buildings. Very high risk of damaging impacts on the environment.

Fires often producing large amounts of smoke and associated carbon emissions. Visibility is likely to be limited due to smoke and dust, potentially impacting traffic management.

CONDITIONS TO CONSIDER

- C-Haines >95th percentile (approx. >10)
- Wind change forecast during the peak of the afternoon, potential conditions for 'dead man zone'

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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MALLEE-HEATH

FIRE BEHAVIOUR INDEX				
0-5		MAX FLAME HEIGHT <1 m RATE OF SPREAD 0-40 m/hr	Probability of self-sustained, surface fire is low.	**SPOTTING POTENTIAL** Potential for any spotting is extremely limited
6-11		<5 m <2 km/hr	Surface fires whereby the flame front is able to overcome fine scale fuel discontinuities. Isolated torching of overstorey fuels.	Short range spotting possible up to 10 m
12-23		<6 m 1-3 km/hr	Intermittent crown fire. The passage of the flame front on surface fuels is followed by torching of overstorey fuels. Canopy fuel combustion occurs somewhat behind the leading edge of the flame front. Average flame front properties not affected by the level of torching and rate of fire spread largely determined by surface phase.	Short range spotting up to 50 m likely, allowing fire to cross small areas of fuel discontinuity such as roads or small fuel breaks
24-49		<8 m 1.5-5.5 km/hr	Active or dependent crown fires with crown phase determining the overall rate of spread. Fire propagates faster than observed for a surface or intermittent crown fire under same environmental conditions. A reduction of the surface phase heat output below a certain level will lead the fire to an intermittent crown fire regime1.	Escalation in fire activity is typically accompanied by an increase in the number of firebrands generated and possible distances >50 m ahead of the flame front
50+		>8m >3 and likely >5.5 km/hr	Active or dependent crown fire.	Escalation in fire activity is typically accompanied by an increase in the number of firebrands generated and possible distances >50 m ahead of the flame front

IMPLICATIONS FOR PRESCRIBED BURNING

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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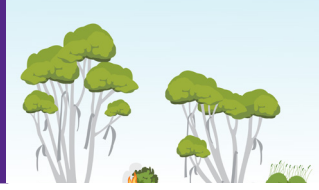
MALLEE-HEATH

FIRE BEHAVIOUR INDEX

MARGINAL	0-5	 Marginal prescribed burning conditions, even at peak of the day.
GENERALLY SUITABLE	6-11	 Typical prescribed burning conditions for hazard reduction. Simple burns with adequate fuel breaks, often going out overnight with higher humidity and fuel moisture.
MARGINAL	12-23	 Prescribed burning opportunities exist for complex burn plans with adequate resourcing and well established, wide boundaries/edges. Opportunities may exist away from the peak of the day when conditions are suitable to achieve prescribed burn objectives.
GENERALLY UNSUITABLE	24-49	 Conditions are unlikely to be suitable for prescribed burning. Potential rates of spread, long flame lengths and short distance spotting pose a serious risk of burn escapes. Fire intensity may be inconsistent with land management objectives.
UNSUITABLE	50+	 Conditions will be unsuitable for prescribed burning. Potential fireline intensity and rates of spread pose a serious risk to firefighter safety and the community.

FIRE SUPPRESSION AND CONTAINMENT

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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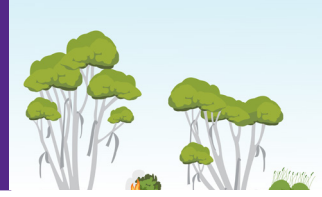
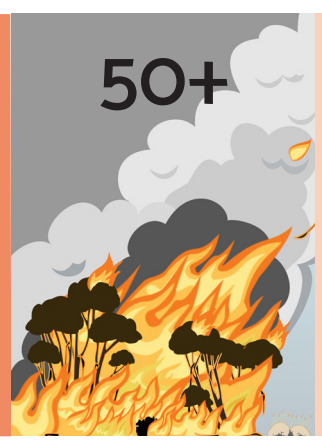
FIRE BEHAVIOUR INDEX		CREDIBLE WORST CASE
0-5 	Fire containment relatively simple and typically contained within simple road networks, fuel breaks and buffers without the need for active fire suppression.	MAX. POTENTIAL in 4 hr AREA <1 ha PERIMETER <0.5 km
6-11 	Fires typically contained within road networks, fuel breaks (including recent fire scars) and buffers >3-4 m wide with active fire suppression.	AREA <1,500 ha PERIMETER <17 km
12-23 	Fire containment generally requiring wider roads, fuel breaks (including recent fire scars) or buffers (>10 m) together with active suppression. Active suppression around assets generally not necessary with adequate fuel breaks. Onset of crown fire activity can lead to rapid increase in rate of spread and intensity (2-3 x surface fire spread rate).	AREA <3,000 ha PERIMETER <25 km
24-49 	Fires quickly becoming large and difficult to contain within existing road networks, fuel breaks (including scrub roll buffers) and fire scars. Fuel breaks (or buffers) >100 m are likely to be effective. Conditions on the fireground are likely to be extremely windy. Active suppression including indirect attack or machines may be required to protect areas of population, high conservation value and on high value built and cultural assets.	AREA <12,000 ha PERIMETER <50 km
50+ 	Fires quickly becoming large, complex and difficult to contain within existing road networks, fuel breaks (including scrub roll buffers) and fire scars. Fuel breaks (or buffers) >500 m are likely to be effective. Conditions on the fireground are likely to be extremely windy. Active suppression including indirect attack, scrub rolling or machines may be required to protect areas of population, high conservation value and on high value built and cultural assets.	AREA >12,000 ha PERIMETER >50 km

POTENTIAL FOR IMPACT

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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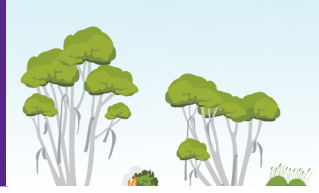
MALLEE-HEATH

FIRE BEHAVIOUR INDEX

UNLIKELY	0-5		Community losses are unlikely.
UNLIKELY	6-11		Community losses are unlikely however, unattended or poorly prepared assets and infrastructure may be at risk.
MINIMAL	12-23		Community losses are unlikely however, unattended or poorly prepared assets and infrastructure may be at risk.
INCREASING	24-49		High likelihood of pasture/crop/stock loss together with loss of rural assets such as fencing, machinery and buildings. Increasing risk of damaging impacts on the environment. Fires often producing large amounts of smoke. Visibility is likely to be limited due to smoke and dust, potentially impacting traffic management.
HIGH	50+		Extremely high likelihood of pasture/crop/stock loss together with loss of rural assets such as fencing, machinery and buildings. Very high risk of damaging impacts on the environment. Fires often producing large amounts of smoke and associated carbon emissions. Visibility is likely to be limited due to smoke and dust, potentially impacting traffic management.

SUPPLEMENTARY INFORMATION
FOR MALLEE-HEATH FUELS

To define each category against modelled outputs within the Fire Behaviour Index (FBI) scale, various methodologies and assumptions are applied. These are outlined below.

FLAME HEIGHT

Flame heights are based on Cruz flame height equation for mallee-heath (Pers. Comm. Cruz 2017)

RATE OF SPREAD

Rates of spread are back-calculated from FBI model outputs based on Byram's fireline intensity and a range of fuel load varying from 7-14 t/ha.

SPOTTING DISTANCE

Spotting distances are based on pers. Comm. with Ryan Butler 2017

FIRE AREA AND PERIMETER

Potential fire area and perimeter are based on a 4-hour fire run under maximum fire danger with a range of length-breadth ratio as determined by wind speeds ranging from 10-40 km/hr (as per Cruz et al (2015)) and a fuel load varying from 7-14 t/ha.
The values assume no suppression.

IMPACT RELATED THRESHOLDS AND DESCRIPTIONS

Impact related thresholds and descriptions have been based largely on the work of Kilinc et al (2013), Harris et al (2011) and Blanchi et al (2010).

PROJECT DOCUMENTATION

A comprehensive list of project documentation for the Australian Fire Danger Rating System is available via the AFAC website at: https://www.afac.com.au/initiative/afdrs/afdrs-publications.

SUPPORTING REFERENCES AND FURTHER READING

Blanchi, R., et al. (2010). Meteorological conditions and wildfire-related house loss in Australia. International Journal of Wildland Fire 19(7): 914-926.

Byram, G. M. (1959). Combustion of forest fuels. Forest Fire: Control and Use. K. P. Davis. New York, McGraw-Hill: 61-89.

Cruz, M. G., et al. (2015). A Guide to Rate of Fire Spread Models for Australian Vegetation. Melbourne, Victoria, CSIRO Land and Water Flagship, Canberra, ACT, and AFAC.

Cruz, M.G., Matthews, S., Gould, J., Ellis, P., Henderson, M., Knight, I., Watters, J. (2010). Fire dynamics in mallee-heath. Fuel, weather and fire behaviour in South Australian semi-arid shrublands. CSIRO, Canberra.

Cruz, M.G., McCaw, W.L., Anderson, W.R., Gould, J.S. (2013). Fire behaviour modelling in semi-arid mallee-heath shrublands of southern Australia. Environmental Modelling & Software 40, 21-34.

Harris, S., et al. (2011). Establishing a link between the power of fire and community loss: The first steps towards developing a bushfire severity scale. Melbourne, Victoria, Victorian Government Department of Sustainability and Environment.

Kilinc, M., et al. (2013). Project title: A scale for determining the destructive potential of bushfires. Milestone report for the period 2013. Technical Report 1. Monash University, Geography and Environmental Science and University of New South Wales, Canberra.

Noble, I. R., et al. (1980). McArthur's fire-danger meters expressed as equations. Australian Journal of Ecology 5: 201-203.

VERSION

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Administrator: NSW Rural Fire Service

CONTACT

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THE AFDRS PROJECT IS BEING LED BY:

NSW RURAL FIRE SERVICE

Australian Government
Bureau of Meteorology

afac

PRIMARILY FUNDED BY:

Australian Government
National Recovery and Resilience Agency

PARTNER AGENCIES:

A.C.T. RURAL FIRE SERVICE

CFS

EMV EMERGENCY MANAGEMENT VICTORIA

BUSHFIRES NT

NORTHERN TERRITORY GOVERNMENT

QUEENSLAND FIRE AND EMERGENCY SERVICES

GOVERNMENT OF WESTERN AUSTRALIA
Department of Biodiversity, Conservation and Attractions

GOVERNMENT OF WESTERN AUSTRALIA
DFES
Department of Fire & Emergency Services

Tasmanian Government

Tasmania Fire Service

SUPPORTING BODIES:

AUSTRALIAN CAPITAL TERRITORY EMERGENCY SERVICES AGENCY

ACT FIRE & RESCUE

ACT Government
Environment, Planning and Sustainable Development

CFA

RURAL FIRE SERVICE QUEENSLAND

Government of South Australia
South Australian Fire and Emergency Services Commission

Government of South Australia
Department for Environment and Water

VICTORIA State Government
Environment, Land, Water and Planning

WALGA

PINE

QUICK GUIDE

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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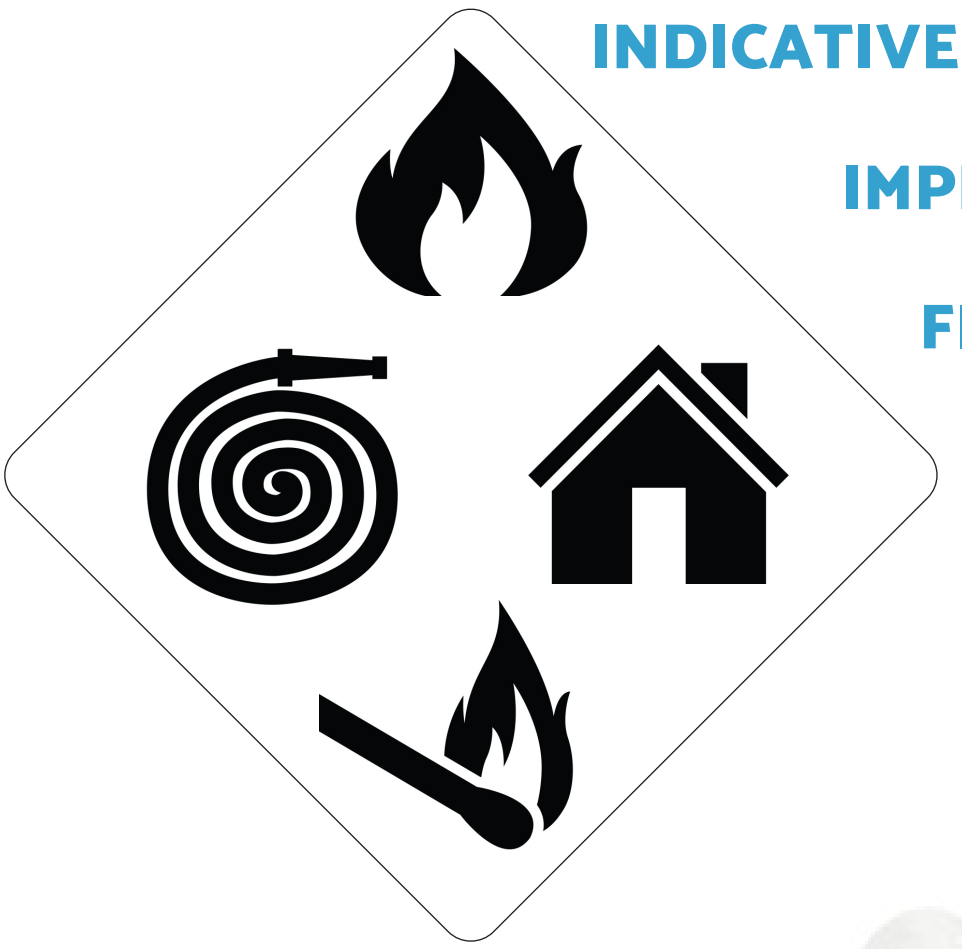
Australian Fire Danger Rating System



INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

IMPLICATIONS FOR PRESCRIBED BURNING

FIRE SUPPRESSION AND CONTAINMENT

POTENTIAL FOR IMPACT

PINE FUELS
IN THE AUSTRALIAN FIRE DANGER RATING SYSTEM

In the Australian Fire Danger Rating System (AFDRS), fuel types have been grouped by application of the most relevant fire spread model. Industrial pine plantations encompass a range of plantations of the genus *Pinus*, established in different areas of the country.

PINE FUEL STRUCTURE

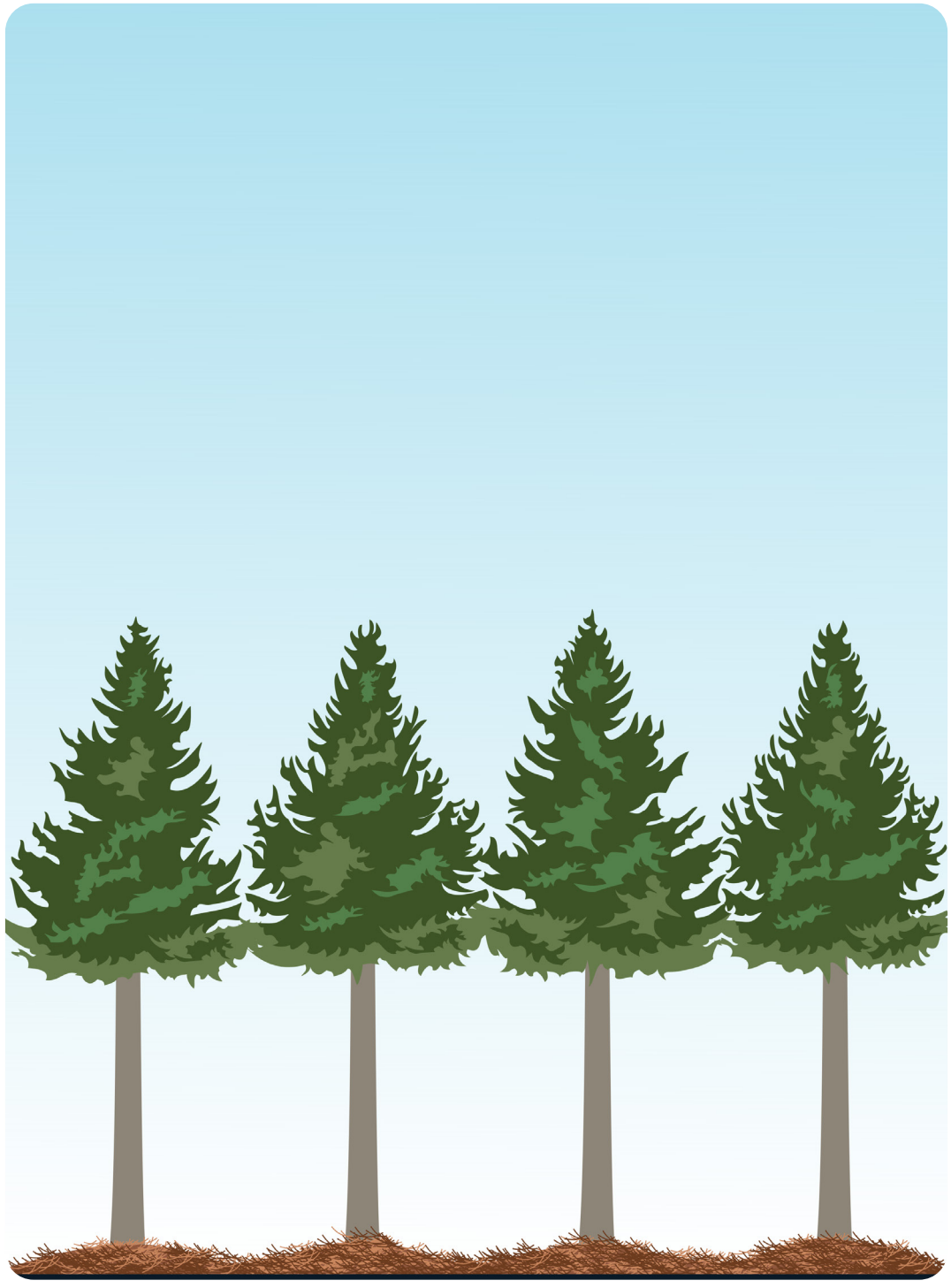
Pine plantations are often planted in productive areas. These plantations often have a notable fuel complex dynamic, with stands changing their structure and inherent flammability in relatively short time intervals (5 to 10 years). The main fuel features affecting fire behaviour are (1) a well-developed understorey fuel layer typically dominated by litter, at times with other vegetation such as grasses or shrubs; (2) marked height growth and the definition of a gap between the surface and canopy fuel layer; (3) the presence or absence of ladder fuels (e.g., dead bole branches and dead suspended needles) and (4) a significant amount of canopy foliage that sustain crown fire development. The vertical distance between surface and canopy fuels, which is reduced by the presence of the ladder fuels, will dictate the likelihood a surface fire will transition into a high intensity crown fire.

Three main plantation species occur in Australia with general fuel characteristics varying with the plantation type and the silvicultural management.

(1) Radiata pine: this is the most common pine plantation species in Australia, established throughout the southern regions of the continent. Fuel structure evolves over time. From mostly grass/ activity fuels in the years after establishment, to a more flammable condition in the years after crown closure, followed by a less flammable state as tree matures and vertical discontinuity between the surface and canopy fuels increase. Understorey fuels are mostly litter with the addition of thinning residues.

(2) Maritime pine: established in plantations in Western Australia. Fuel structure similar to radiata plantations until thinning operations and prescribed burning is introduced. Stands tend to be more open than radiata pine ones. Fuel management with prescribed burning maintain understorey fuel quantities at low levels.

(3) Southern pine: planted in subtropical regions of eastern Australia, namely southeast Queensland and northeast New South Wales. These plantations tend to have a grass dominated understorey in the first 5-10 years. Prescribed burning and silvicultural treatments



CONTENTS

remove ladder fuels and keep a clear separation between surface and canopy fuels. Later in the rotation the understorey can be dominated by shrubs and grasses.

Typically a pine plantation estate will have a broad range of stand ages and fuel complex structures. This variability is not incorporated in the AFDRS where the calculation unit requires broad assumptions on fuel structure to be made.

FOR MORE INFORMATION ON FUELS REFER TO:
***A GUIDE TO RATE OF FIRE SPREAD MODELS FOR AUSTRALIAN VEGETATION* (2015 EDITION)**

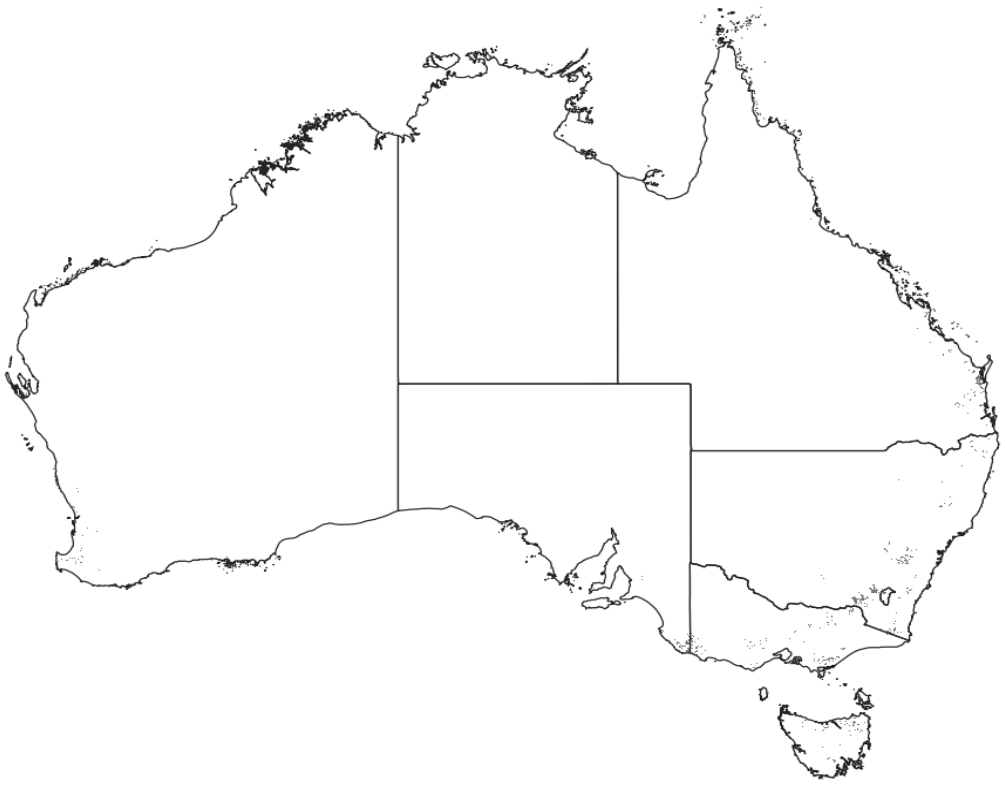
FIRE SPREAD
IN PINE FUELS

Rate of fire spread is the foundation variable for all calculations in the Australian Fire Danger Rating System. The Pine Plantation Pyrometrics (PPPY) model is applied to determine fire behaviour in pine plantations.

BACKGROUND

The PPPY model system was developed to predict the spread and intensity of fires in pine plantations over the full range of burning conditions. The system encompasses a number of fire environment and fire behaviour models that describe the relevant processes occurring within and above a spreading fire, with a focus on the transition from a surface to a crown fire, and the ensuing crown fire propagation.

WHERE IS THE MODEL APPLIED?



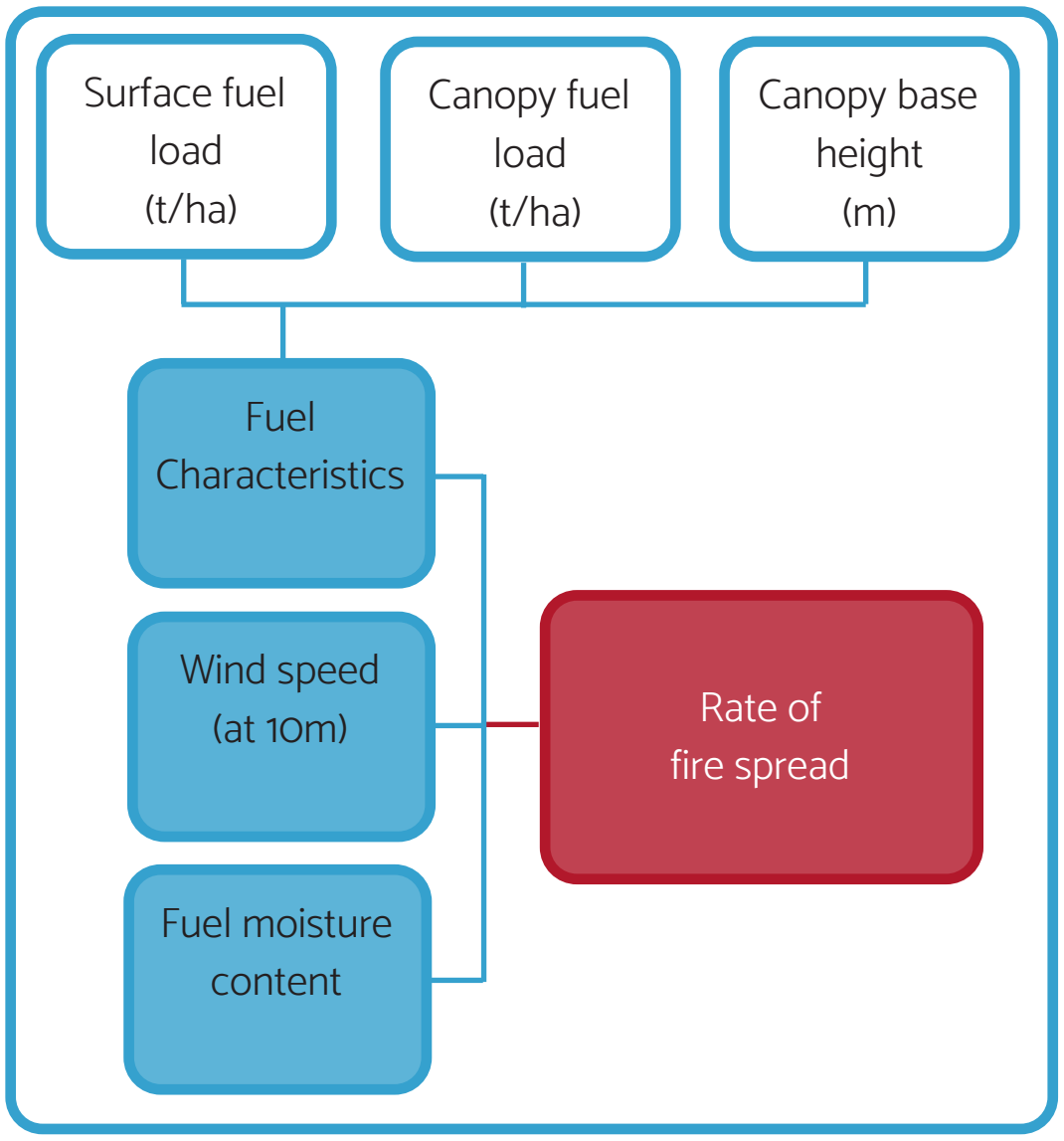
The PPPY model is applied to pine plantations (Genus Pinus) established throughout Australia. These plantations are typically established in productive areas being surrounded by native forest or agricultural lands.

HOW IS THE MODEL APPLIED?

The PPPY model was developed for dry summer conditions. The primary inputs into the PPPY model system are wind speed (either the 10-m open standard or with-in stand), litter and live foliage moisture content, the distance between the surface fuel layer and the bottom of the canopy layer, the canopy fuel load and a description of understorey fuels (litter only vs litter with understorey grasses or shrubs) and associated fuel load.

The AFDRS applies a fuel availability function based on the Drought Factor to allow the application of the model to situations where not all fuels are available for combustion, such as after significant rain. The system makes assumptions about the fuel characteristics by plantation type and age based on published studies.

WHAT ARE THE MAIN INPUTS?



Rate of fire spread in Pine is calculated as a function of the surface and canopy fuel characteristics, 10-m open wind speed and fine fuel moisture content.

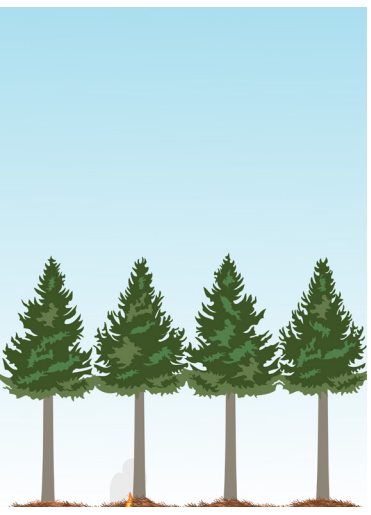
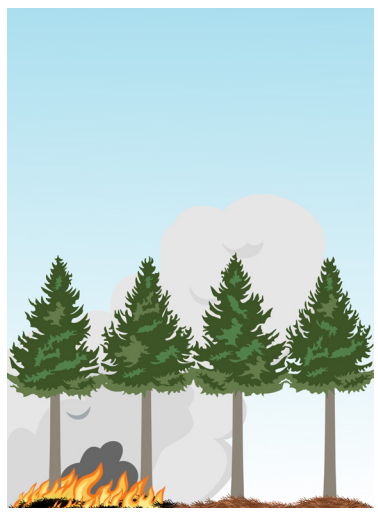
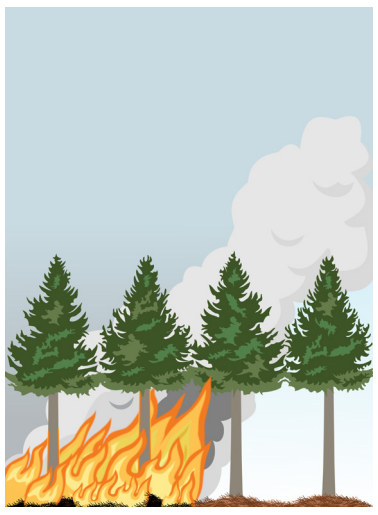
WHAT IS THE MODEL SENSITIVE TO?

The PPPY model system incorporates the propagation of surface and crown fires, which makes its sensitivity to environment conditions to vary with the burning conditions. Overall, the system is most sensitive to wind speed, dead fuel moisture content and the compounded effect of the structure of the forest plantation.

Changes in wind speed cause slightly larger changes in rate of fire spread and intensity. The effect of dead fuel moisture content is more pronounced under marginal burning conditions. Stand age has a strong control on fire behaviour, with younger stands being highly flammable, whereas older stands require severe or higher burning conditions for crown fires to occur.

MORE DETAIL ON THE MODEL CAN BE FOUND IN: *A GUIDE TO RATE OF FIRE SPREAD MODELS FOR AUSTRALIAN VEGETATION* (2015 EDITION)

UNDERSTANDING THE
FIRE BEHAVIOUR INDEX
IN PINE FUELS

Fire Behaviour Index 0-5	6-11	12-23	24-49	50-99	100+
					
No rating		**Moderate**	**High**	**Extreme**	**Catastrophic**
fire behaviour		fire behaviour	suppression	impact	impact
Fires are likely to self-extinguish	Typical prescribed burning conditions Fires are likely to be mostly self-sustaining	Fires typically suppressed with offensive fire management strategies	Increasing focus on defensive suppression strategies Transition to medium distance spotting Aerial suppression less likely to be effective at controlling fire	Increased likelihood of community loss and significant consequences	High probability of loss of life and property

A SCALE OF POTENTIAL FIRE DANGER

The Fire Behaviour Index (FBI) was developed to assist operational decision making, while the Fire Danger Ratings provide the broad categories needed to communicate fire danger to the community.

The FBI provides a scale of potential fire danger (should a fire start) based on the predicted rate of fire spread. In pine fuels, rate of fire spread together with fuel load, are used to determine the fireline intensity and this value is used to categorise fire danger on the FBI scale.

TRANSITIONS AND CATEGORIES

The FBI is made up of step-ups or transitions, where an increase in category is triggered by a change in:

1. fire behaviour,
2. suppression response, or
3. potential impacts.

Each category is defined in terms of:

1. indicative fire behaviour and fire weather,
2. implications for prescribed burning,
3. fire suppression and containment, and
4. potential impacts.

PINE

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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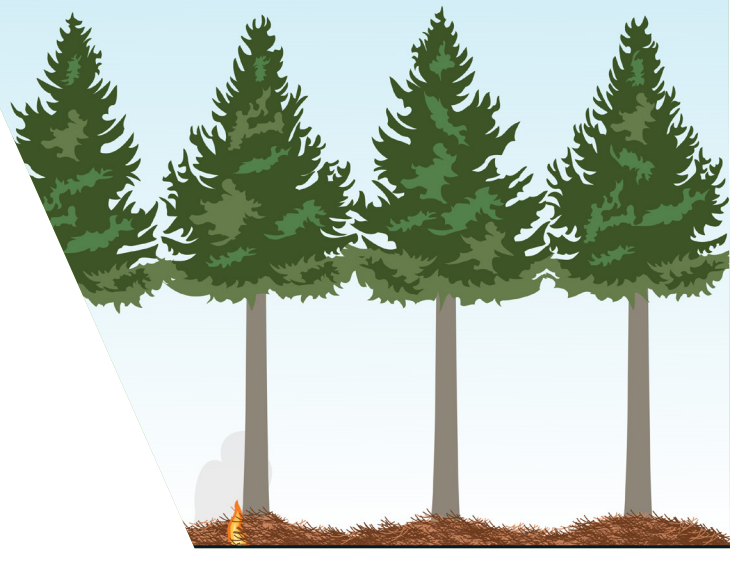
Fire Behaviour Index
0-5



- Mostly self-extinguishing, trouble-free fires.

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

Fire difficult to ignite and sustain.

Fires generally unlikely to spread and likely to self-extinguish.

- Rate of Spread: 0-40m/hr
- Max. Flame Height: <0.5 m
- Spotting Potential: Potential for any spotting is very limited.

IMPLICATIONS FOR PRESCRIBED BURNING

Marginal prescribed burning conditions, even at peak of the day.

Opportunities may arise where burn objectives target very low intensity and fuel consumption, patchy burns or for debris burning (broadcast, slash, windrow and piles) with particularly heavy or dry fuels.

FIRE SUPPRESSION AND CONTAINMENT

Fire control relatively simple.

Delayed containment possible with suitable conditions.

Head-fire readily suppressed with offensive, direct attack techniques.

Initial attack success is typically very high.

TIME TO 5 ha

12 hrs

CREDIBLE WORST CASE
MAX. POTENTIAL
in 4 hr (30 min)

AREA

<1.5 ha (<0.2 ha)

PERIMETER

<0.5 km (<0.1 km)

POTENTIAL FOR IMPACT

Community losses are unlikely.

CONDITIONS TO CONSIDER

PINE

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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Fire Behaviour Index
6-11

- Typically slow moving, surface fires.
- Fires generally easy to suppress and contain.

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

Slow spreading fires, typically involving surface and near-surface fuels and sometimes into the elevated, ladder fuels. Spotting is sporadic and limited to short-distances.

- Rate of Spread: 20-150 m/hr
- Max. Flame Height: <4 m
- Spotting Potential: Potential for spotting is limited. Possible isolated spotting up to 60 m under very dry fuel moisture conditions

IMPLICATIONS FOR PRESCRIBED BURNING

Optimal conditions for prescribed burning (underburning and debris burning).

Typically confined within control lines. Simple fuel reduction burning with adequate resourcing subject to the presence and characteristics of ladder fuels and the sensitivity of the stand to fire.

Suitable seasonal and profile moisure content (particularly duff) should be considered in the context of conditions for likely overnight extinguishment and possible re-ignition.

Conditions at the upper end of the range may not be suitable for immauture stands due to high flame and scorch heights.

FIRE SUPPRESSION AND CONTAINMENT

TIME TO 5 ha

3 hrs

Fire control mostly simple with sufficient resources and becoming more complex at higher intensities.

Offensive, direct attack techniques on head-fire or flanks largely successful in fire control.

Delayed containment sometimes possible with suitable conditions.

CREDIBLE WORST CASE
MAX. POTENTIAL in 4 hr (30 min)

AREA
<20 ha (<2.2 ha)

PERIMETER
<1.5 km (<0.2 km)

POTENTIAL FOR IMPACT

Community losses are unlikely however unattended or poorly prepared houses and infrastructure may be at risk.

CONDITIONS TO CONSIDER

- Strong wind gusts
- Dry fuel moisture makes overnight extinguishment unlikely and high potential of re-ignition (KBDI > 63, SDI >250 (spring) or a fall of 500 (autumn))

PINE

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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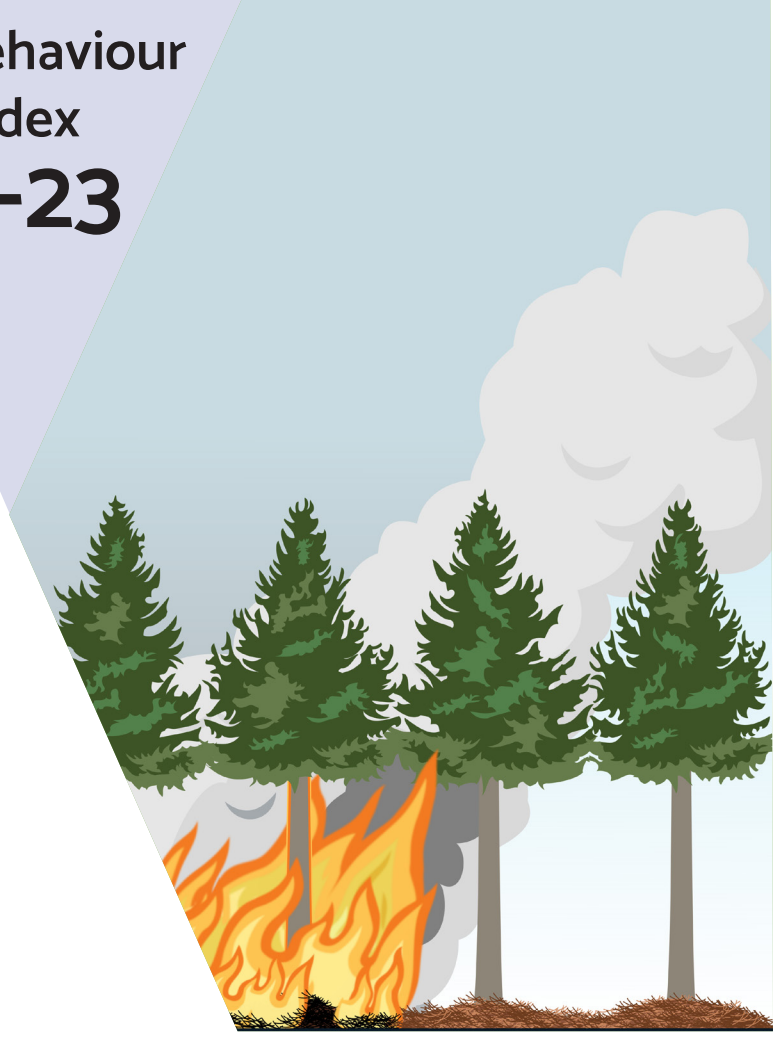
Fire Behaviour Index
12-23



- Most bushfires in this category.
- Fires typically suppressed with direct, parallel or indirect attack.

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

Actively spreading fires typically involving surface, near-surface and elevated fuel layers and occasionally canopy fuels. Isolated short range spotting can occur under dry fuel moisture conditions.

- Rate of Spread: 70-800 m/hr
- Max. Flame Height: 2-10 m
- Spotting Potential: Potential for isolated spotting is limited to short distances up to around 300 m under dry fuel moisture conditions.

IMPLICATIONS FOR PRESCRIBED BURNING

Fire is likely to carry from surface fuels into the crowns of shrubs and trees. Flame and scorch heights are likely to injure cambium and overstorey foliage. Increased likelihood of tree mortality and impacts on forest floor dynamics such as soil productivity and stability. Conditions may be suitable for more complex prescribed burning subject to adequate resourcing and patrolling with well-established boundaries/edges. Prescribed burning may be conducted away from the peak of the day when conditions are optimal and lighting techniques are suitable to achieve objectives. Conditions may present significant risk of re-ignition.

FIRE SUPPRESSION AND CONTAINMENT

TIME TO 5 ha

35 mins

Fires generally becoming more complex and require more resources to control.

Combinations of direct, indirect or parallel attack may be necessary for fire control.

CREDIBLE WORST CASE
MAX. POTENTIAL in 4 hr (30 min)

AREA

<500 ha (<65 ha)

PERIMETER

<8 km (<1 km)

POTENTIAL FOR IMPACT

Unattended or poorly prepared houses and infrastructure may be at risk.

Potential for impacts on tree health in fire sensitive species and young forest stands, particularly at the upper end of the range.

CONDITIONS TO CONSIDER

- C-Haines >95th percentile (approx. >10)
- Wind change forecast during the peak of the afternoon, potential conditions for ‘dead man zone’
- Strong wind gusts
- Dry fuel moisture makes overnight extinguishment unlikely and high potential of re-ignition (KBDI > 63, SDI >250 (spring) or a fall of 500 (autumn))

PINE

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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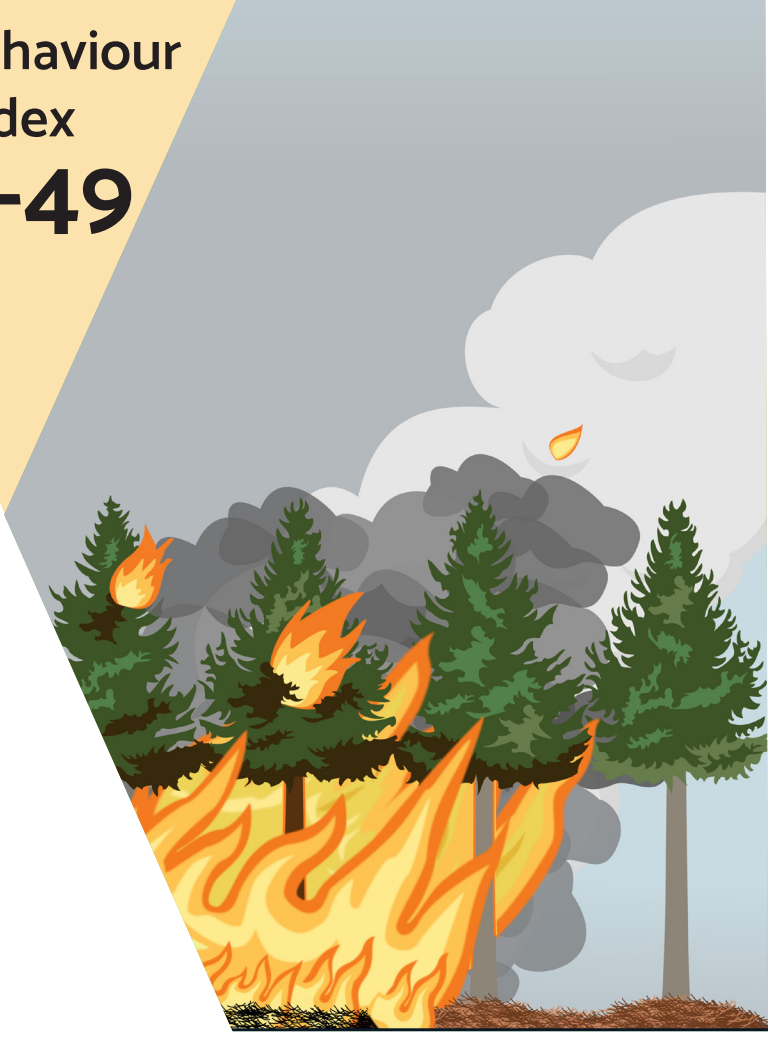
Fire Behaviour Index
24-49



- Increasing focus on defensive suppression strategies.
- Initial attack success critical to prevent large fire development.

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

Rapidly spreading fires with potential for development into large burn areas within burning period. Fires typically involving most fuel layers. Short-range spotting is prevalent, with possibility of medium range and occasional long-range distance spotting.

- Rate of Spread: 400m - 1 km/hr
- Max. Flame Height: 8-12 m
- Spotting Potential: Potential for short distance spotting occurring with increasing frequency with possible spotting up to 400 m

IMPLICATIONS FOR PRESCRIBED BURNING

Conditions are unlikely to be suitable for prescribed burning.

Potential fireline intensity and spotting activity pose a serious risk for burn escapes.

Fire intensity, crown consumption and cambium injury are likely to be inconsistent with forest management objectives, impacting stand growth and woody quality even in older stands.

Conditions present significant risk of re-ignition.

FIRE SUPPRESSION AND CONTAINMENT

TIME TO 5 ha

30 mins

Both ground and aerial resources using offensive strategies likely to be unsuccessful during the peak of the day, with focus largely centred on the rear and flanks.

Suppression increasingly focused on defensive strategies.

Fire control is likely to be difficult and require increased resourcing.

Increased risk to firefighter safety.

CREDIBLE WORST CASE
MAX. POTENTIAL in 4 hr (30 min)

AREA
<700 ha (<90 ha)

PERIMETER
<10 km (<1.2 km)

POTENTIAL FOR IMPACT

6 % of house loss has occurred under these conditions.

Increased potential for long term impacts on commercial forest productivity, pasture/crop/stock losses as well as rural assets such as fencing, machinery and buildings.

Potential for house loss exists when homes and properties are adjacent to crown fire prone plantations.

CONDITIONS TO CONSIDER

- C-Haines >95th percentile (approx. >10)
- Wind change forecast during the peak of the afternoon, potential conditions for 'dead man zone'
- Strong wind gusts

8

PINE

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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Fire Behaviour Index **50-99**

- High levels of threat to life and property.
- Conditions limit strategic suppression options.
- Elevated risk to firefighter safety.
- Initial attack success critical to prevent large fire development.

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

Fires likely to quickly transition to crowning. Possibility for fire behaviour to become erratic and plume driven. Strong convective column formation. Wind speed and direction likely to be erratic at times.

- Rate of Spread: 600m - 3 km/hr
- Max. Flame Height: 10 m - approx. double forest height
- Spotting Potential: Short and medium range spotting possible up to 1 km

IMPLICATIONS FOR PRESCRIBED BURNING

Conditions will be unsuitable for prescribed burning.

Potential fireline intensity and spotting activity pose a serious risk to firefighter safety and the community.

FIRE SUPPRESSION AND CONTAINMENT

TIME TO 5 ha

10 mins

Control of developed fires is extremely difficult and unlikely until conditions ease.
Suppression will be largely based on defensive strategies, ensuring firefighter and community preparedness and safety.
Offensive strategies could position crews in danger, however safe opportunities may exist for direct, indirect or parallel attack on the rear and flanks.
Important initial attack opportunities may exist for new ignitions.
Conditions on the fireground are likely to be extremely windy and smoky limiting visibility and restricting aviation and access.
Aerial resources are likely to be ineffective at holding fire.
Increased risk to firefighter safety.

CREDIBLE WORST CASE
MAX. POTENTIAL
in 4 hr (30 min)

AREA
<6,500 ha (<800 ha)

PERIMETER
<30 km (<3.7 km)

POTENTIAL FOR IMPACT

Increased risk of long term economic and environmental impacts. 24% of house loss has occurred under these conditions. High risk to the community related to inappropriate pre-considered plans, inadequate sheltering. High likelihood of plantation asset loss together with loss of rural assets such as pasture, crop, stock, fencing, machinery and buildings. Limited visibility due to smoke and dust.
Strong winds are likely to impact infrastructure (e.g. power lines) and fall trees increasing the likelihood of new ignitions as well as obstructed roads and power outages.

CONDITIONS TO CONSIDER

- C-Haines >95th percentile (approx. >10)
- Wind change forecast during the peak of the afternoon, potential conditions for 'dead man zone'

PINE

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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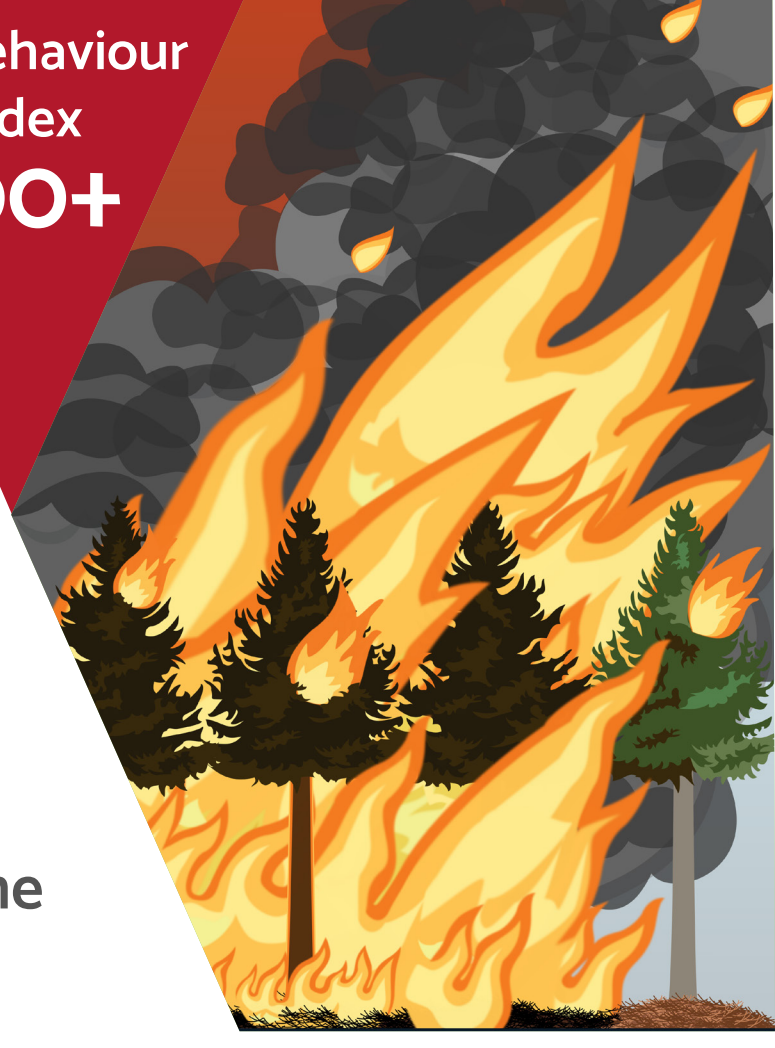
Fire Behaviour Index **100+**



- High probability of loss of life and property.
- Elevated risk to firefighter safety.
- Initial attack success critical to prevent large fire development.
- Conditions limit strategic suppression options.
- Wind speed and limited visibility may ground some aviation resources.

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

Fires likely to quickly transition to crowning. Possibility for fire behaviour to become erratic and plume driven. Strong convective column formation. Wind speed and direction likely to be erratic at times.

- Rate of Spread: >2 km/hr can be expected and possibly >3 km/hr
- Max. Flame Height: Up to 35 m (approx. double forest height)
- Spotting Potential: Short and medium range with possible long distance spotting occurring 2-3 km ahead of the main fire front

IMPLICATIONS FOR PRESCRIBED BURNING

Conditions will be unsuitable for prescribed burning.

Potential fireline intensity and spotting activity pose a serious risk to firefighter safety and the community.

FIRE SUPPRESSION AND CONTAINMENT

TIME TO 5 ha

<10 mins

Fire control of developed fires is extremely difficult and unlikely until conditions ease. Focus will be largely based on defensive strategies, ensuring firefighter and community preparedness and safety. Offensive strategies could position crews in danger, however safe opportunities may exist for direct, indirect or parallel attack on the rear and flanks. Important initial attack opportunities may exist for new ignitions. Conditions on the fireground are likely to be extremely windy and smoky limiting visibility and restricting aviation and access. Conditions are likely to impact performance and effectiveness of aerial resources with a high probability that some aircraft will be unable to operate due to high winds and limited visibility. Systems such as communications, will be heavily challenged with a likelihood of difficulties and outages. Extreme risk to firefighter safety.

CREDIBLE WORST CASE

MAX. POTENTIAL in 4 hr (30 min)

AREA

>6,500 ha (>800 ha)

PERIMETER

>30 km (>4 km)

POTENTIAL FOR IMPACT

Very high risk of long term economic and environmental impacts. 70% of house loss has occurred under these conditions. Very high risk to the community related to inappropriate pre-considered plans, inadequate sheltering. Extremely high likelihood of plantation asset loss together with loss of rural assets such as pasture, crop, stock, fencing, machinery and buildings. Very limited visibility due to smoke and dust.
Extremely strong winds are likely to impact infrastructure (e.g. power lines) and fall trees increasing the likelihood of new ignitions as well as obstructed roads and power outages.

CONDITIONS TO CONSIDER

- C-Haines >95th percentile (approx. >10)
- Wind change forecast during the peak of the afternoon, potential conditions for 'dead man zone'

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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PINE

FIRE BEHAVIOUR INDEX

0-5		**MAX FLAME HEIGHT** <0.5 m	**RATE OF SPREAD** 0-40 m/hr	Fire difficult to ignite and sustain. Fires generally unlikely to spread and likely to self-extinguish.	**SPOTTING POTENTIAL** Potential for any spotting is very limited.
6-11		<4 m	20-150 m/hr	Slow spreading fires, typically involving surface and near-surface fuels and sometimes into the elevated, ladder fuels. Spotting is sporadic and limited to short-distances.	Potential for spotting is limited. Possible isolated spotting up to 60 m under very dry fuel moisture conditions
12-23		2-10 m	70-800 m/hr	Actively spreading fires typically involving surface, near-surface and elevated fuel layers and occasionally canopy fuels. Isolated short range spotting can occur under dry fuel moisture conditions.	Potential for isolated spotting is limited to short distances up to around 300 m under dry fuel moisture conditions.
24-49		8-12 m	0.4-1 km/hr	Rapidly spreading fires with potential for development into large burn areas within burning period. Fires typically involving most fuel layers. Short-range spotting is prevalent, with possibility of medium range and occasional long-range distance spotting.	Potential for short distance spotting occurring with increasing frequency with possible spotting up to 400 m
50-99		10 m or up to twice forest height	0.6-3 km/hr	Fires likely to quickly transition to crowning. Possibility for fire behaviour to become erratic and plume driven. Strong convective column formation. Wind speed and direction likely to be erratic at times.	Short and medium range spotting possible up to 1 km .
100+		up to 35m twice forest height	>2 km/hr can be expected, possibly >3 km/hr	Fires likely to quickly transition to crowning. Possibility for fire behaviour to become erratic and plume driven. Strong convective column formation. Wind speed and direction likely to be erratic at times.	Short and medium range with possible long distance spotting occurring 2-3 km ahead of the main fire front

IMPLICATIONS FOR PRESCRIBED BURNING

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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FIRE BEHAVIOUR INDEX

MARGINAL

0-5

Marginal prescribed burning conditions, even at peak of the day. Opportunities may arise where burn objectives target very low intensity and fuel consumption, patchy burns or for debris burning (broadcast, slash, windrow and piles) with particularly heavy or dry fuels.

GENERALLY SUITABLE

6-11

Optimal conditions for prescribed burning (underburning and debris burning). Typically confined within control lines. Simple fuel reduction burning with adequate resourcing subject to the presence and characteristics of ladder fuels and the sensitivity of the stand to fire. Suitable seasonal and profile moisture content (particularly duff) should be considered in the context of conditions for likely overnight extinguishment and possible re-ignition. Conditions at the upper end of the range may not be suitable for immature stands due to high flame and scorch heights.

MARGINAL

12-23

Fire is likely to carry from surface fuels into the crowns of shrubs and trees. Flame and scorch heights are likely to injure cambium and overstorey foliage. Increased likelihood of tree mortality and impacts on forest floor dynamics such as soil productivity and stability. Conditions may be suitable for more complex prescribed burning subject to adequate resourcing and patrolling with well established boundaries/edges. Prescribed burning may be conducted away from the peak of the day when conditions are optimal and lighting techniques are suitable to achieve objectives. Conditions may present significant risk of re-ignition.

GENERALLY UNSUITABLE

24-49

Conditions are unlikely to be suitable for prescribed burning. Potential fireline intensity and spotting activity pose a serious risk for burn escapes. Fire intensity, crown consumption and cambium injury are likely to be inconsistent with forest management objectives, impacting stand growth and woody quality even in older stands. Conditions present significant risk of re-ignition.

UNSUITABLE

50-99

Conditions will be unsuitable for prescribed burning. Potential fireline intensity and spotting activity pose a serious risk to firefighter safety and the community.

UNSUITABLE

100+

Conditions will be unsuitable for prescribed burning. Potential fireline intensity and spotting activity pose a serious risk to firefighter safety and the community.

FIRE SUPPRESSION AND CONTAINMENT

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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FIRE BEHAVIOUR INDEX			CREDIBLE WORST CASE
TIME TO 5 HA 12 hrs	0-5 	Fire control relatively simple. Delayed containment possible with suitable conditions. Head-fire readily suppressed with offensive, direct attack techniques. Initial attack success is typically very high.	MAX. POTENTIAL in 4 hr (30 min) **AREA** <1.5 ha (<0.2 ha) **PERIMETER** <0.5 km (<0.1 km)
3 hrs	6-11 	Fire control mostly simple with sufficient resources and becoming more complex at higher intensities. Offensive, direct attack techniques on head-fire or flanks largely successful in fire control. Delayed containment sometimes possible with suitable conditions.	**AREA** <20 ha (2 ha) **PERIMETER** <1.5 km (10.2 km)
35 mins	12-23 	Fires generally becoming more complex and require more resources to control. Combinations of direct, indirect or parallel attack may be necessary for fire control.	**AREA** <500 ha (65 ha) **PERIMETER** <8 km (1 km)
30 mins	24-49 	Both ground and aerial resources using offensive strategies likely to be unsuccessful during the peak of the day, with focus largely centred on the rear and flanks. Suppression increasingly focused on defensive strategies. Fire control is likely to be difficult and require increased resourcing.	**AREA** <700 ha (90 ha) **PERIMETER** <10 km (1.2 km)
10 mins	50-99 	Control of developed fires is extremely difficult and unlikely until conditions ease. Suppression will be largely based on defensive strategies, ensuring firefighter and community preparedness and safety. Offensive strategies could position crews in danger, however safe opportunities may exist for direct, indirect or parallel attack on the rear and flanks. Important initial attack opportunities may exist for new ignitions. Conditions on the fireground are likely to be extremely windy and smoky limiting visibility and restricting aviation and access. Aerial resources are likely to be ineffective at holding fire.	**AREA** <6,500 ha (800 ha) **PERIMETER** <30 km (4 km)
<10 mins	100+ 	Fire control of developed fires is extremely difficult and unlikely until conditions ease. Focus will be largely based on defensive strategies, ensuring firefighter and community preparedness and safety. Offensive strategies could position crews in danger, however safe opportunities may exist for direct, indirect or parallel attack on the rear and flanks. Important initial attack opportunities may exist for new ignitions. Conditions on the fireground are likely to be extremely windy and smoky limiting visibility and restricting aviation and access. Conditions are likely to impact performance and effectiveness of aerial resources with a high probability that some aircraft will be unable to operate due to high winds and limited visibility. Systems such as communications, will be heavily challenged with a likelihood of difficulties and outages.	**AREA** >6,500 ha (>800 ha) **PERIMETER** >30 km (>4 km)

POTENTIAL FOR IMPACT

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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PINE

FIRE BEHAVIOUR INDEX

UNLIKELY	0-5 	Community losses are unlikely.
UNLIKELY	6-11 	Community losses are unlikely however unattended or poorly prepared houses and infrastructure may be at risk.
MINIMAL	12-23 	Unattended or poorly prepared houses and infrastructure may be at risk. Potential for impacts on tree health in fire sensitive species and young forest stands, particularly at the upper end of the range.
INCREASING	24-49 	6 % of house loss has occurred under these conditions1. Increased potential for long term impacts on commercial forest productivity, pasture/crop/stock losses as well as rural assets such as fencing, machinery and buildings. Potential for house loss exists when homes and properties are adjacent to crown fire prone plantations.
HIGH	50-99 	Increased risk of long term economic and environmental impacts. 24% of house loss has occurred under these conditions1. High risk to the community related to inappropriate pre-considered plans, inadequate sheltering2. High likelihood of plantation asset loss together with loss of rural assets such as pasture, crop, stock, fencing, machinery and buildings. Limited visibility due to smoke and dust. Strong winds are likely to impact infrastructure (e.g. power lines) and fall trees increasing the likelihood of obstructed roads and power outages.
VERY HIGH	100+ 	Very high risk of long term economic and environmental impacts. 70% of house loss has occurred under these conditions1. Very high risk to the community related to inappropriate pre-considered plans, inadequate sheltering2. Extremely high likelihood of plantation asset loss together with loss of rural assets such as pasture, crop, stock, fencing, machinery and buildings. Very limited visibility due to smoke and dust. Extremely strong winds are very likely to impact infrastructure (e.g. power lines) and fall trees resulting in a high likelihood of obstructed roads and power outages.

SUPPLEMENTARY INFORMATION
FOR PINE FUELS

To define each category against modelled outputs within the Fire Behaviour Index (FBI) scale, various methodologies and assumptions are applied. These are outlined below.

FLAME HEIGHT

Flame heights are based on McArthur's equation for flame height (Noble, 1980)

RATE OF SPREAD

Rates of spread are back-calculated from FBI model outputs based on Byram's fireline intensity and a range of fuel load varying from 10-20 t/ha.

SPOTTING DISTANCE

Spotting distances are based on a generalisation that pine spotting distances are 0.1 x McArthur's spotting equation (FFMG (2007), Douglas (1964, 1973)).

FIRE AREA AND PERIMETER

Potential fire area and perimeter are based on a 4 hour fire run under maximum fire danger with a range of length-breadth ratio as determined by wind speeds ranging from 10-40 km/hr (as per Cruz et al (2015)) and a fuel load varying from 10-20 t/ha.
The values assume no suppression.

FUEL LOAD

The lowest FBI category assumes that only 50% of the fuel load is available for burning, and this is represented in flame heights, rates of spread and potential fire size.

For FBI above 24 an additional 11 t/ha is available (contributed by canopy fuel layer).

REFERENCE TIME TO 5 HA

Reference time to 5 ha is based on the shortest time for the category under following conditions: wind speed 25 km/hr, L:B ratio of 3:3 and a fuel load of 10 t/ha.

IMPACT RELATED THRESHOLDS AND DESCRIPTIONS

Impact related thresholds and descriptions have been based largely on the work of Kilinc et al (2013), Harris et al (2011) and Blanchi et al (2010).

PROJECT DOCUMENTATION

A comprehensive list of project documentation for the Australian Fire Danger Rating System is available via the AFAC website at: https://www.afac.com.au/initiative/afdrs/afdrs-publications.

SUPPORTING REFERENCES AND FURTHER READING

Blanchi, R., et al. (2010). Meteorological conditions and wildfire-related house loss in Australia. International Journal of Wildland Fire 19(7): 914-926.

Byram, G. M. (1959). Combustion of forest fuels. Forest Fire: Control and Use. K. P. Davis. New York, McGraw-Hill: 61-89.

Cruz, M. G., et al. (2015). A Guide to Rate of Fire Spread Models for Australian Vegetation. Melbourne, Victoria, CSIRO Land and Water Flagship, Canberra, ACT, and AFAC.

Harris, S., et al. (2011). Establishing a link between the power of fire and community loss: The first steps towards developing a bushfire severity scale. Melbourne, Victoria, Victorian Government Department of Sustainability and Environment.

Kilinc, M., et al. (2013). Project title: A scale for determining the destructive potential of bushfires. Milestone report for the period 2013. Technical Report 1. Monash University, Geography and Environmental Science and University of New South Wales, Canberra.

Noble, I. R., et al. (1980). McArthur's fire-danger meters expressed as equations. Australian Journal of Ecology 5: 201-203.

VERSION

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THE AFDRS PROJECT IS BEING LED BY:

NSW RURAL FIRE SERVICE

Australian Government
Bureau of Meteorology

afac

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National Recovery and Resilience Agency

PARTNER AGENCIES:

A.C.T. RURAL FIRE SERVICE

CFS

EMV EMERGENCY MANAGEMENT VICTORIA

BUSHFIRES NT

NORTHERN TERRITORY GOVERNMENT

QUEENSLAND FIRE AND EMERGENCY SERVICES

GOVERNMENT OF WESTERN AUSTRALIA
Department of Biodiversity, Conservation and Attractions

GOVERNMENT OF WESTERN AUSTRALIA
DFES
Department of Fire & Emergency Services

Tasmanian Government

Tasmania Fire Service

SUPPORTING BODIES:

AUSTRALIAN CAPITAL TERRITORY EMERGENCY SERVICES AGENCY

ACT FIRE & RESCUE

ACT Government
Environment, Planning and Sustainable Development

CFA

RURAL FIRE SERVICE QUEENSLAND

Government of South Australia
South Australian Fire and Emergency Services Commission

Government of South Australia
Department for Environment and Water

VICTORIA State Government
Environment, Land, Water and Planning

WALGA

SAVANNA

QUICK GUIDE

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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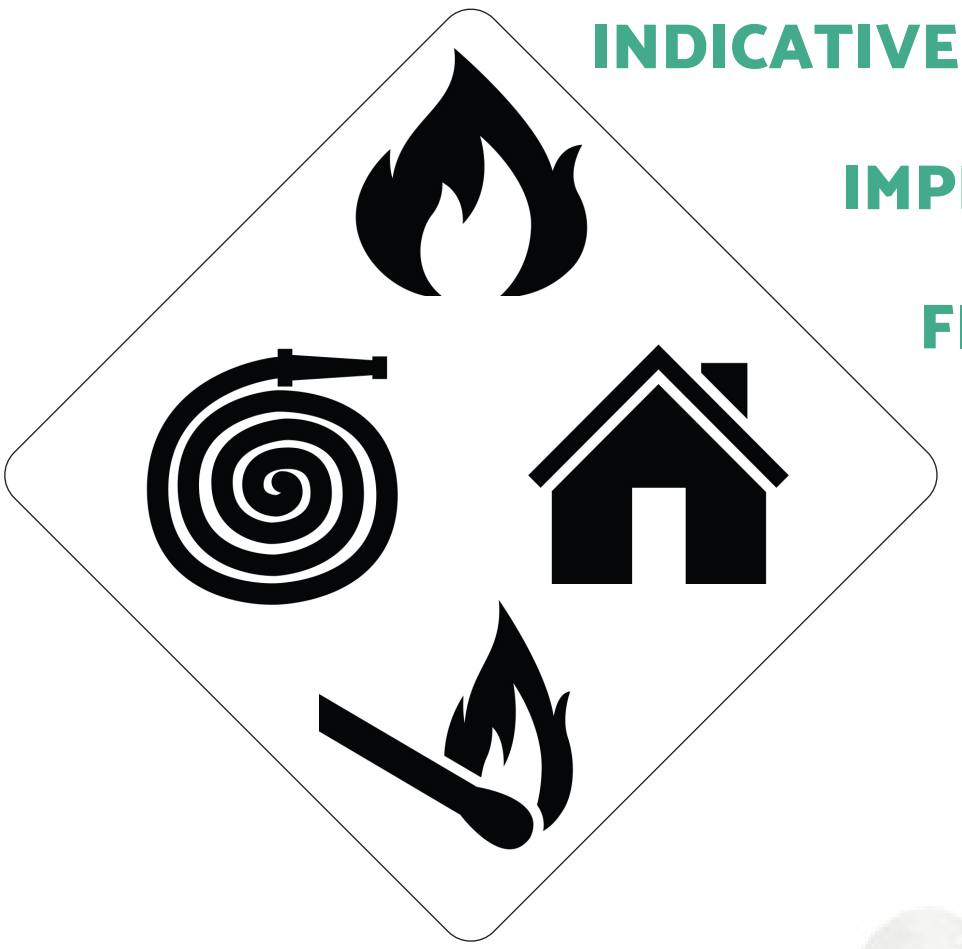
Australian Fire Danger Rating System



INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

IMPLICATIONS FOR PRESCRIBED BURNING

FIRE SUPPRESSION AND CONTAINMENT

POTENTIAL FOR IMPACT

SAVANNA FUELS

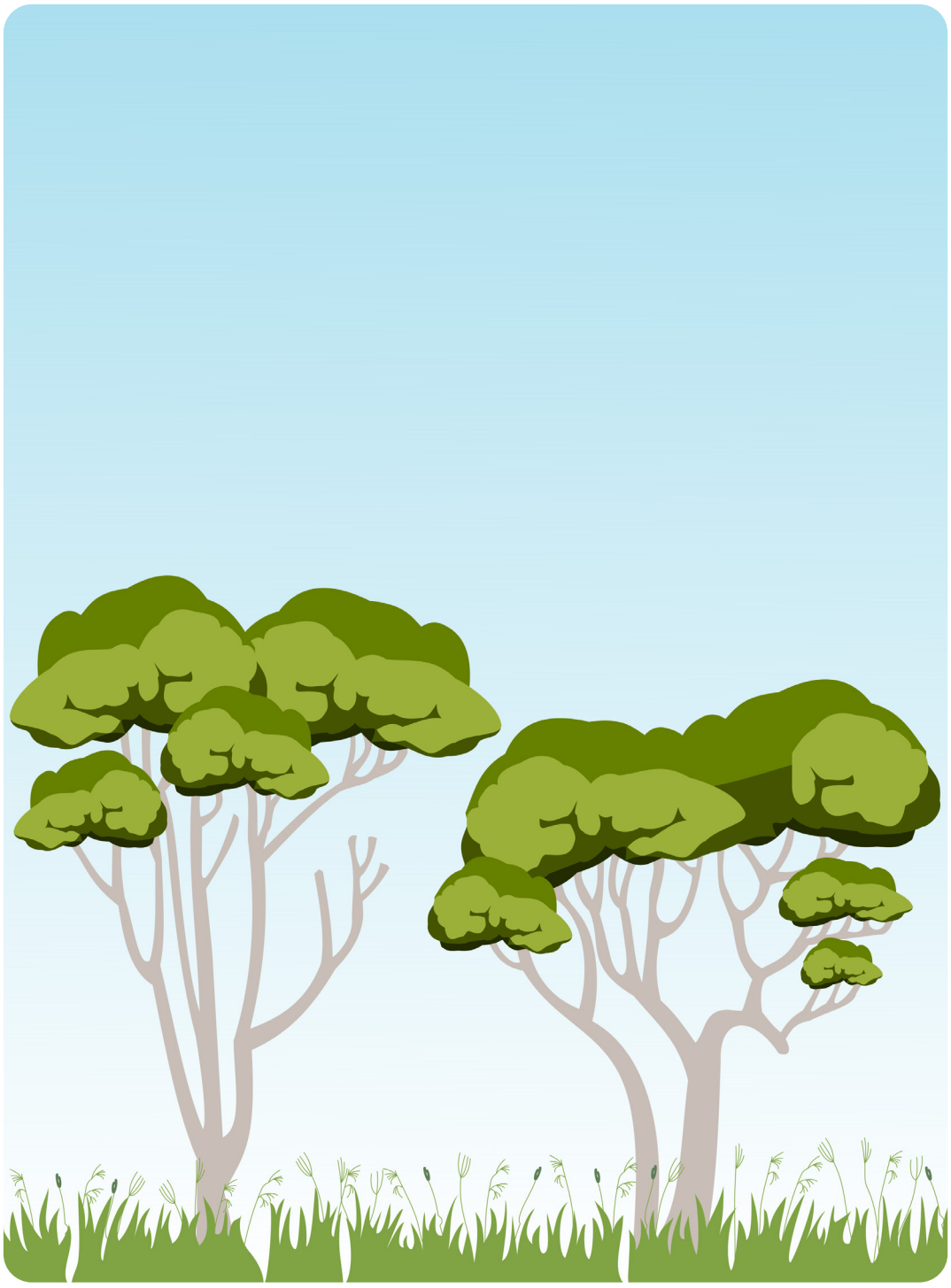
IN THE AUSTRALIAN FIRE DANGER RATING SYSTEM

In the Australian Fire Danger Rating System (AFDRS), fuel types have been grouped by application of the most relevant fire spread model. The savanna fuel type is associated with grasslands where a low density treed overstorey canopy exists. Eucalypt species generally dominate this overstorey component that can be characterised as a woodland or open forest. Savannas typically occur in tropical areas with high rainfall, typically higher than 750 mm annual average precipitation, although this fuel type also describes grassy woodlands in areas of lower rainfall.

SAVANNA FUEL STRUCTURE

The savanna fuel type considers two distinct overstorey conditions: woodland – overstorey cover up to 30% and open forest – overstorey cover between 30 and 70%. The dominant fuel in the savanna fuel type is the understorey grass layer. A variety of different annual and perennial grass species can occur throughout the savanna regions. Grass height development can reach 3 or more meters in some areas, but the fuel bed height will be lower during the dry season due to collapse of the grass stalks as the grass cures. Shorter grasses are also common. Soil substrate and precipitation will determine the density and development of this grass fuel layer, although it can be expected that these grassy fuels will have higher fuel loads than found in southern Australia grasslands. In particular, the occurrence of exotic grasses, such as gamba grass, can result in fuel loads that are two to three times higher than observed in southern grasslands. The presence of trees, either in a low density overstorey such as found in an open woodland, or in a denser open forest, affects fire behaviour by reducing the wind speed driving the grass fire propagation. The tree component tends to grow up to a height of 10 - 15 meters. Depending on the tree density, the trees can contribute fuel in the form of leaf litter. The presence of trees will also increase the occurrence of short-range spotting from ignited bark fuel.

In savannas the grass fuel layer is typically considered to be in an undisturbed state as the grazing pressures are absent or low. The taller grass fuel beds and generally high fuel loads associated with tropical savannas allow fires in these fuels to develop tall flame heights and high intensities, with the associated increased suppression difficulty.



CONTENTS

FOR MORE INFORMATION ON FUELS REFER TO:
***A GUIDE TO RATE OF FIRE SPREAD MODELS FOR AUSTRALIAN VEGETATION* (2015 EDITION)**

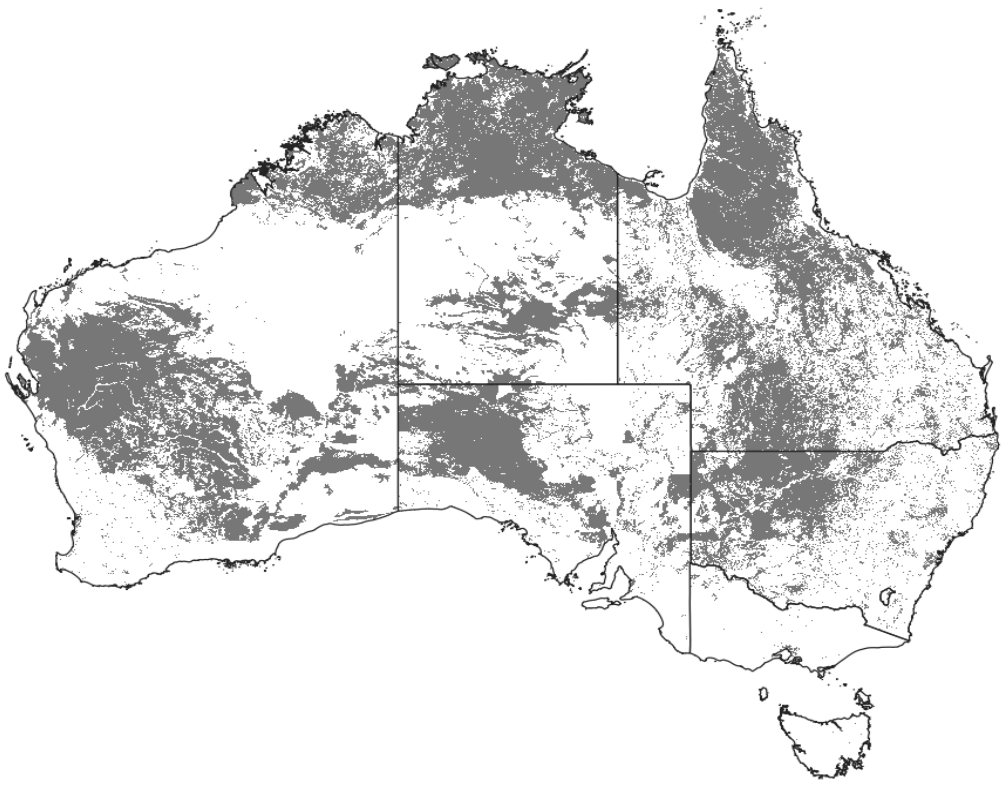
FIRE SPREAD
IN SAVANNA FUELS

Rate of fire spread is the foundation variable for all calculations in the Australian Fire Danger Rating System. In savanna fuels the CSIRO grassland fire spread prediction system for Northern Australia is applied to determine the rate of fire spread.

BACKGROUND

The Northern Australia CSIRO grassland fire spread prediction models are based on the CSIRO Grassland fire spread prediction models that were developed from the combined analysis of moderate to high-intensity experimental fires conducted in Northern Territory grasslands and wildfires from southern Australia. The CSIRO grassland fire spread models are used to describe the effect of environmental variables on fire propagation, with an adjustment applied to account for the effect of the tree overstorey in reducing the wind speed at the grass fuel level.

WHERE IS THE MODEL APPLIED?

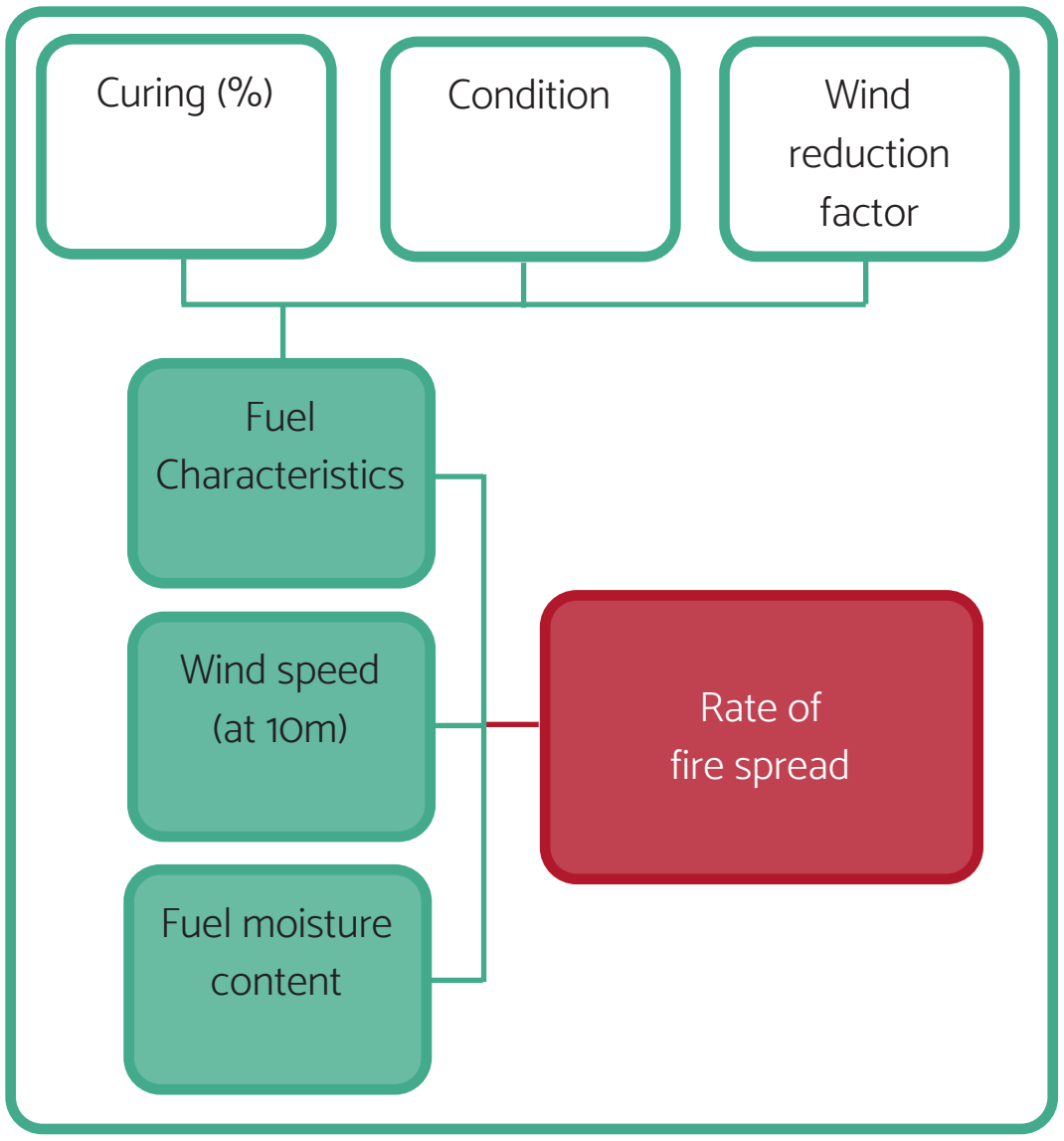


The Northern Australia CSIRO grassland model is applied to tropical savanna grasslands of northern Australia including invasinve gamba grass, and open woodland areas throughout the country with a grass dominated understorey. It is also applied to some arid shrubland with very sparese fuel where fire can be carried only by ephermal grasses following rain.

HOW IS THE MODEL APPLIED?

The model inputs are the type of overstorey cover (absent, woodland or open forest), the 10-m open wind speed, dead fuel moisture content and the degree of curing. In the AFDRS, savanna grasslands are considered to have the grass fuel layer in an undisturbed condition. The moisture content of dead grass swards is estimated from air temperature and relative humidity on an hourly basis. The degree of

WHAT ARE THE MAIN INPUTS?



Rate of fire spread in Savanna is calculated as a function of the grass characteristics, 10-m open wind speed, wind reduction factor and fine fuel moisture content.

WHAT IS THE MODEL SENSITIVE TO?

Model outputs are most sensitive to the savanna overstorey cover level that is mapped. Rate of spread in woodland and open forest savannas will be respectively 50% and 30% of the predicted value for a treeless savanna, all other variables being equal. Variation in the open wind speed results in a comparable response in the model output. Under marginal burning conditions with high dead fuel moisture contends, the model becomes increasingly sensitive to changes in this variable. The model is also quite sensitive to variation in the curing level when curing is between 30 and 70%. The effect of this sensitivity to curing and dead fuel moisture is restricted to low fire danger conditions.

MORE DETAIL ON THE MODEL CAN BE FOUND IN: *A GUIDE TO RATE OF FIRE SPREAD MODELS FOR AUSTRALIAN VEGETATION* (2015 EDITION)

UNDERSTANDING THE
FIRE BEHAVIOUR INDEX
IN SAVANNA FUELS

Fire Behaviour Index 0-5	6-11	12-49	50+
			
No rating	Moderate	High	Extreme	Catastrophic
fire behaviour	fire behaviour		suppression	impact
Fires are likely to self-extinguish	Typical prescribed burning conditions A mosaic of burnt and unburnt patches are created	Fires generally escalate in size very quickly. Fires typically consume all available fuel. Fires mostly controlled within wide fuel breaks and recent fire scars, mostly without the need for additional containment support	Elevated risk to the safety of visitors and local communities. Damaging wildfires with extremely rapid growth. Additional containment and active suppression may be required.	Increased likelihood of community loss and significant consequences

A SCALE OF POTENTIAL FIRE DANGER

The Fire Behaviour Index (FBI) was developed to assist operational decision making, while the Fire Danger Ratings provide the broad categories needed to communicate fire danger to the community.

The FBI provides a scale of potential fire danger (should a fire start) based on the predicted rate of fire spread. In savanna fuels, rate of fire spread together with fuel load, are used to determine the fireline intensity and this value is used to categorise fire danger on the FBI scale.

TRANSITIONS AND CATEGORIES

The Fire Behaviour Index is made up of step-ups or transitions, where an increase in category is triggered by a change in:

1. fire behaviour,
2. suppression response, or
3. potential impacts.

Each category is defined in terms of:

1. indicative fire behaviour and fire weather,
2. implications for prescribed burning,
3. fire suppression and containment, and
4. potential impacts.

SAVANNA

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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Fire Behaviour Index
0-5

- Mostly self-extinguishing fires.
- Fires typically quickly contained within simple fuel breaks and landscape features.

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

Fire difficult to ignite and sustain.

Fires generally unlikely to spread and likely to self-extinguish.

- Rate of Spread: 0-50 m/hr
- Max. Flame Height: <0.5 m
- Spotting Potential: Potential for any spotting is extremely limited

IMPLICATIONS FOR PRESCRIBED BURNING

Marginal prescribed burn conditions, even at peak of the day.

Long line ignitions may be useful to increase acceleration.

FIRE SUPPRESSION AND CONTAINMENT

Suppression is generally not necessary and delayed containment possible with suitable conditions.

Fire containment relatively simple and mostly contained within simple road networks, fuel breaks or landscape characteristics.

Head-fire readily suppressed with offensive, direct attack techniques.

Initial attack success is typically very high.

Fires may be allowed to spread within an extended (time and area) containment objective.

CREDIBLE WORST CASE
MAX. POTENTIAL
in 4 hr

AREA
<0.5 ha

PERIMETER
<0.5 km

POTENTIAL FOR IMPACT

Community losses are unlikely.

CONDITIONS TO CONSIDER

SAVANNA

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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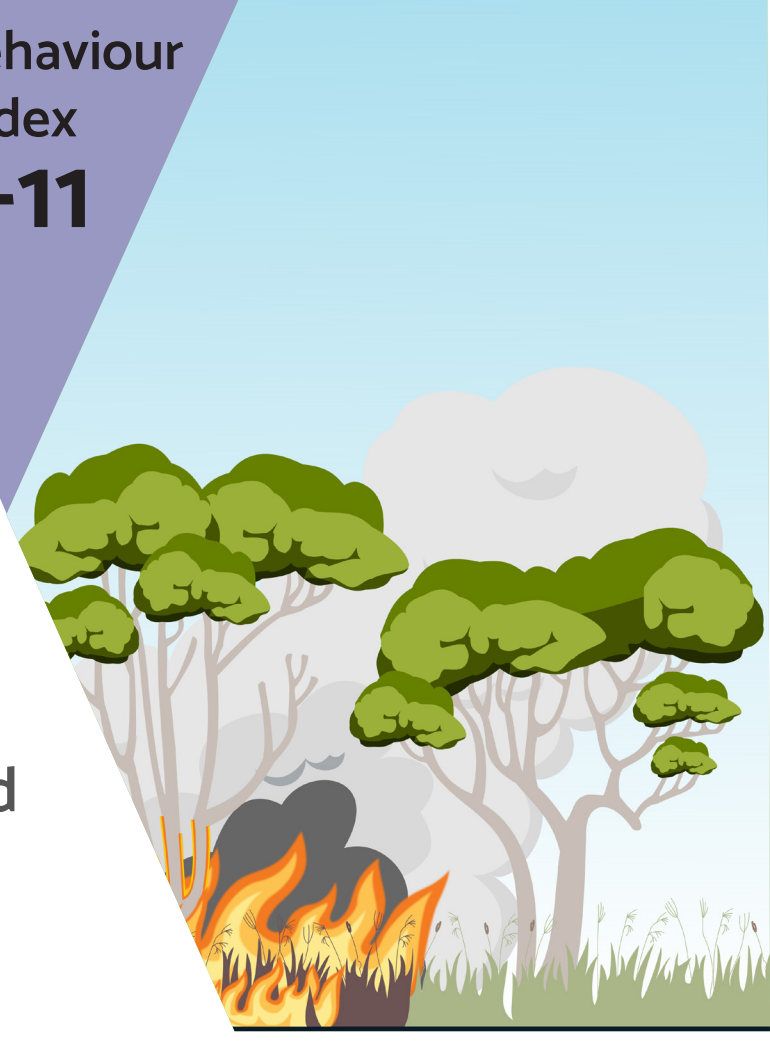
Fire Behaviour Index
6-11



- Typical prescribed burning conditions whereby a mosaic of burnt and unburnt patches are created.
- Fires generally easily contained within simple road networks, fuel breaks and recent fire scars.

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

Fire easily sustained. Typically wind driven fires that can spread quickly. Fires mostly only partially consuming fuels, typically creating a mosaic of burnt and unburnt patches (decreasing patchiness with increasing intensity).

- Rate of Spread: <1.5 km/hr
- Max. Flame Height: <1.5 m
- Spotting Potential: Potential for short distance spotting is limited

IMPLICATIONS FOR PRESCRIBED BURNING

Typical prescribed burning conditions for hazard reduction and pasture management. Mostly simple burns with adequate fuel breaks, often going out overnight with higher humidity and fuel moisture. Above 2,000 kW/m, opportunities may exist for prescribed burns with adequate resourcing and well established, wide boundaries/edges.

Prescribed burn opportunities may exist away from the peak of the day when conditions are suitable to achieve objectives. Point source ignitions may be useful to reduce acceleration at higher intensities. Suitable conditions for controlling woody vegetation structure and exotic weeds. Upper limit for private landholder burning provided there is adequate resourcing, training, necessary approvals and permits.

FIRE SUPPRESSION AND CONTAINMENT

Fire containment mostly simple and delayed containment possible with suitable conditions.

Fires typically contained within road networks, fuel breaks and recent fire scars (>10 m).

Fires may be allowed to spread within an extended (time and area) containment objective.

CREDIBLE WORST CASE
MAX. POTENTIAL in 4 hr

AREA
<1,000 ha

PERIMETER
<13 km

POTENTIAL FOR IMPACT

Community losses are unlikely however, unattended or poorly prepared assets and infrastructure may be at risk.

CONDITIONS TO CONSIDER

SAVANNA

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

v. 2022_6

Fire Behaviour Index
12-49

- Fires generally escalate in size very quickly.
- Fires typically consuming all available fuels.
- Fires mostly controlled within wide fuel breaks and recent fire scars, mostly without the need for additional containment support.

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

Wind driven, rapidly spreading fires with potential for development into large fire area/size and with the potential for short distance spotting and long flame lengths. Fires typically consuming all available fuel. Increasing scorch height of tree canopy (up to 20-25 m) and char height (up to 3-4 m).

- Rate of Spread: 1-8 km/hr
- Max. Flame Height: 1.5-2.5 m
- Spotting Potential: Possible short distance spotting occurring

IMPLICATIONS FOR PRESCRIBED BURNING

Conditions are unlikely to be suitable for prescribed burning. Potential rates of spread, long flame lengths and short distance spotting pose a serious risk of burn escapes. Fires typically burning large areas without suitable internal patchiness. Fires often don't go out overnight and fire intensity is likely to be inconsistent with land management objectives. Prescribed burn opportunities may exist in line with burn objectives and away from the peak of the day provided adequate resourcing and well established, wide boundaries/edges. Point source ignitions may be useful to reduce acceleration.

FIRE SUPPRESSION AND CONTAINMENT

Fires quickly becoming large and generally requiring fuel breaks (or buffers) or recent fire scars (>100 m) for containment. Active suppression around assets generally not necessary with adequate fuel breaks, buffers or recent fire scars. Conditions are likely to be extremely windy. Active suppression including indirect attack and/or machines may be required to protect areas of population, high conservation value and on high value built, agricultural and cultural assets.

CREDIBLE WORST CASE
MAX. POTENTIAL in 4 hr

AREA
<24,000 ha

PERIMETER
<70 km

POTENTIAL FOR IMPACT

High likelihood of pasture/crop/stock loss together with loss of rural assets such as fencing, machinery and buildings. Often producing large amounts of smoke and associated carbon emissions. Visibility is likely to be limited due to smoke and dust, potentially impacting traffic management. Fires are often associated with reduced biodiversity and habitat damage including loss of food supply for native fauna and traditional owners. Stem survival < 80%.

CONDITIONS TO CONSIDER

- C-Haines >95th percentile (approx. >12)
- Wind change forecast during the peak of the afternoon, potential conditions for 'dead man zone'
- Strong wind gusts forecast

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UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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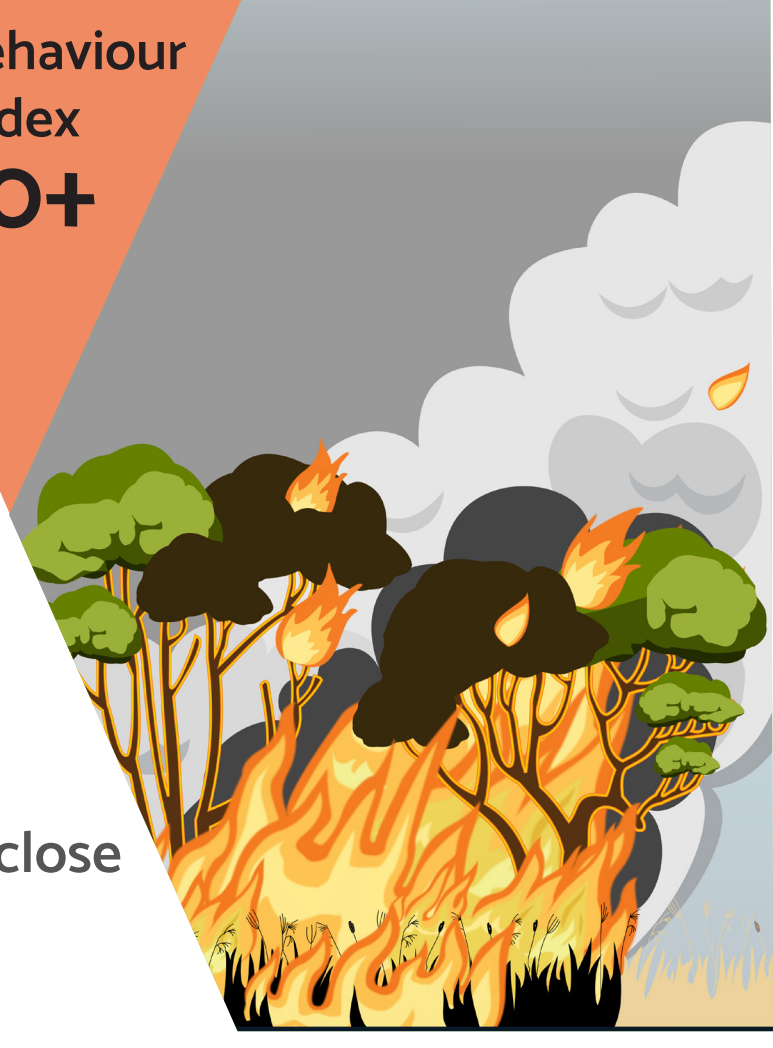
Fire Behaviour Index
50+



- Elevated risk to the safety of visitors and local communities.
- Damaging wildfires with extremely rapid fire growth.
- Additional containment and active suppression may be required.
- High levels of threat to the environment and when in close proximity to people, assets and property.

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

Extremely rapid fire growth and increasing likelihood of large final fire area/size. Possibility for fire behaviour to become erratic and plume driven. Strong convective column formation. Wind speed and direction likely to be erratic at times. Fires consuming all available fuel.

- Rate of Spread: >5 km/hr can be expected and possibly >8 km/hr
- Max. Flame Height: >2.5 m
- Spotting Potential: Likely short distance spotting

IMPLICATIONS FOR PRESCRIBED BURNING

Conditions will be unsuitable for prescribed burning.

Potential fireline intensity and rates of spread pose a serious risk to firefighter safety and the community.

FIRE SUPPRESSION AND CONTAINMENT

Fires quickly becoming large and generally requiring fuel breaks (or buffers) or recent fire scars (>500 m) for containment.

Active suppression around assets may be required where fuel breaks are inadequate.

Conditions are likely to be extremely windy.

Active suppression including indirect attack and/or machines may be required to protect areas of population, high conservation value and on high value built, agricultural and cultural assets.

CREDIBLE WORST CASE
MAX. POTENTIAL in 4 hr

AREA
>24,000 ha

PERIMETER
>70 km

POTENTIAL FOR IMPACT

Extremely high likelihood of pasture/crop/stock loss together with loss of rural assets such as fencing, machinery and buildings. Often producing large amounts of smoke and associated carbon emissions.

Visibility is likely to be limited due to smoke and dust, potentially impacting traffic management. Fires are often associated with reduced biodiversity and habitat damage including loss of food supply for native fauna and traditional owners. Stem survival < 20%.

CONDITIONS TO CONSIDER

- C-Haines >95th percentile (approx. >12)
- Wind change forecast during the peak of the afternoon, potential conditions for 'dead man zone'
- Strong wind gusts forecast

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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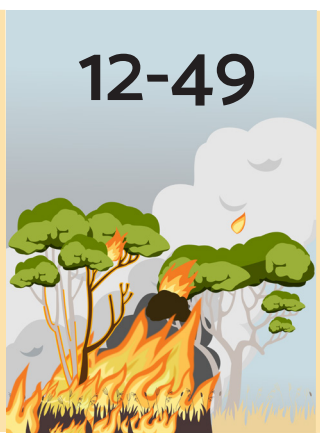
FIRE BEHAVIOUR INDEX

0-5	**MAX FLAME HEIGHT** <0.5 m		**RATE OF SPREAD** 0-50 m/hr	Fire difficult to ignite and sustain. Fires generally unlikely to spread and likely to self-extinguish.
6-11	<0.5-1.5 m		<1.5km/hr	Fire easily sustained. Typically wind driven fires that can spread quickly. Fires mostly only partially consuming fuels, typically creating a mosaic of burnt and unburnt patches (decreasing patchiness with increasing intensity).
12-49	1.5-2.5 m		1-8 km/hr	Wind driven, rapidly spreading fires with potential for development into large fire area/size and with the potential for short distance spotting and long flame lengths. Fires typically consuming all available fuel. Increasing scorch height of tree canopy (up to 20-25 m) and char height (up to 3-4 m).
50+	>2.5m		>5 and likely >8 km/hr	Extremely rapid fire growth and increasing likelihood of large final fire area/size. Possibility for fire behaviour to become erratic and plume driven. Strong convective column formation. Wind speed and direction likely to be erratic at times. Fires consuming all available fuel.

SPOTTING POTENTIAL

Potential for any spotting is extremely limited

Potential for spotting is limited

Possible short distance spotting occurring

Likely short distance spotting

IMPLICATIONS FOR PRESCRIBED BURNING

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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FIRE BEHAVIOUR INDEX

MARGINAL

0-5

Marginal prescribed burn conditions, even at peak of the day. Long line ignitions may be useful to increase acceleration.

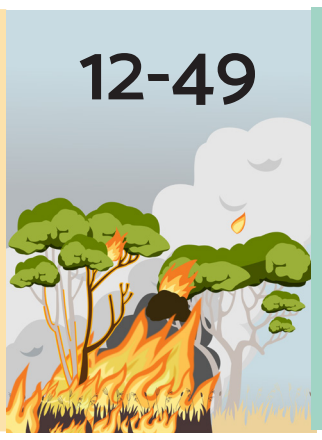
GENERALLY SUITABLE

6-11

Typical prescribed burning conditions for hazard reduction and pasture management. Mostly simple burns with adequate fuel breaks, often going out overnight with higher humidity and fuel moisture. Above 2,000 kW/m, opportunities may exist for prescribed burns with adequate resourcing and well established, wide boundaries/edges1. Prescribed burn opportunities may exist away from the peak of the day when conditions are suitable to achieve objectives. Point source ignitions may be useful to reduce acceleration at higher intensities. Suitable conditions for controlling woody vegetation structure and exotic weeds. Upper limit for private landholder burning provided there is adequate resourcing, training, necessary approvals and permits.

GENERALLY UNSUITABLE

12-49



Conditions are unlikely to be suitable for prescribed burning. Potential rates of spread, long flame lengths and short distance spotting pose a serious risk of burn escapes. Fires typically burning large areas without suitable internal patchiness. Fires often don't go out overnight and fire intensity is likely to be inconsistent with land management objectives. Prescribed burn opportunities may exist in line with burn objectives and away from the peak of the day provided adequate resourcing and well established, wide boundaries/edges. Point source ignitions may be useful to reduce acceleration.

UNSUITABLE

50+

Conditions will be unsuitable for prescribed burning. Potential fireline intensity and rates of spread pose a serious risk to firefighter safety and the community.

FIRE SUPPRESSION AND CONTAINMENT

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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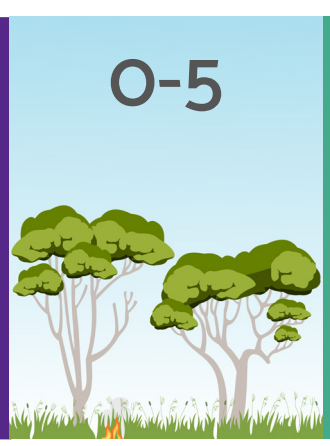
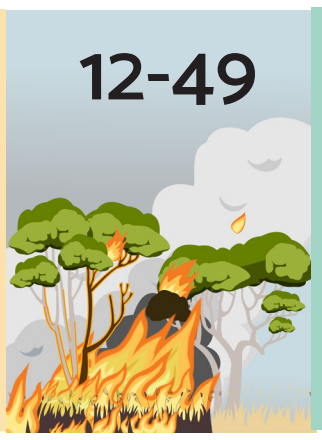
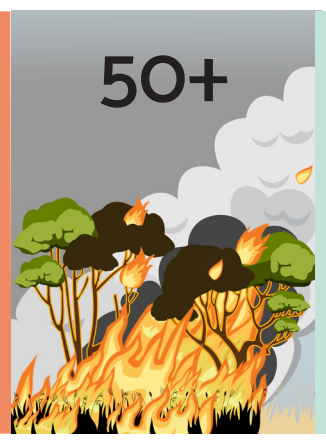
SAVANNA

FIRE BEHAVIOUR INDEX		CREDIBLE WORST CASE
0-5 	Suppression is generally not necessary and delayed containment possible with suitable conditions. Fire containment relatively simple and mostly contained within simple road networks, fuel breaks or landscape characteristics. Head-fire readily suppressed with offensive, direct attack techniques. Initial attack success is typically very high.	MAX. POTENTIAL in 4 hr AREA <0.5 ha PERIMETER <0.5 km
6-11 	Fire containment mostly simple and delayed containment possible with suitable conditions. Fires typically contained within road networks, fuel breaks and recent fire scars (>10 m)2.	AREA <1000 ha PERIMETER <13 km
12-49 	Fires quickly becoming large and generally requiring fuel breaks (or buffers) or recent fire scars (>100 m) for containment. Active suppression around assets generally not necessary with adequate fuel breaks, buffers or recent fire scars. Conditions are likely to be extremely windy. Active suppression including indirect attack and/or machines may be required to protect areas of population, high conservation value and on high value built, agricultural and cultural assets.	AREA <24,000 ha PERIMETER <70 km
50+ 	Fires quickly becoming large and generally requiring fuel breaks (or buffers) or recent fire scars (>500 m) for containment. Active suppression around assets may be required where fuel breaks are inadequate. Conditions are likely to be extremely windy. Active suppression including indirect attack and/or machines may be required to protect areas of population, high conservation value and on high value built, agricultural and cultural assets.	AREA >24,000 ha PERIMETER >70 km

POTENTIAL FOR IMPACT

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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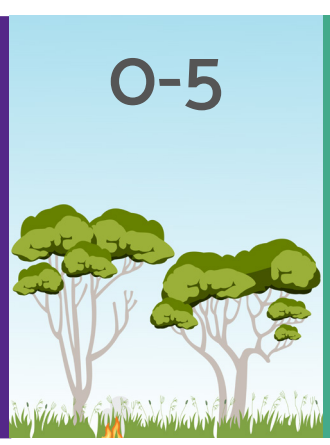
SAVANNA

FIRE BEHAVIOUR INDEX

UNLIKELY

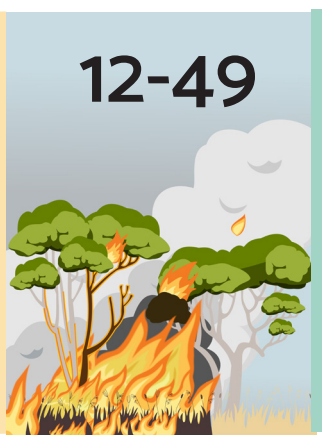


Community losses are unlikely.

UNLIKELY

Community losses are unlikely however, unattended or poorly prepared assets and infrastructure may be at risk.

INCREASING



High likelihood of pasture/crop/stock loss together with loss of rural assets such as fencing, machinery and buildings. Often producing large amounts of smoke and associated carbon emissions. Visibility is likely to be limited due to smoke and dust, potentially impacting traffic management. Fires are often associated with reduced biodiversity and habitat damage including loss of food supply for native fauna and traditional owners. Stem survival < 80%.

HIGH

Extremely high likelihood of pasture/crop/stock loss together with loss of rural assets such as fencing, machinery and buildings. Often producing large amounts of smoke and associated carbon emissions. Visibility is likely to be limited due to smoke and dust, potentially impacting traffic management. Fires are often associated with reduced biodiversity and habitat damage including loss of food supply for native fauna and traditional owners. Stem survival < 20%.

SUPPLEMENTARY INFORMATION
FOR SAVANNA FUELS

To define each category against modelled outputs within the Fire Behaviour Index (FBI) scale, various methodologies and assumptions are applied. These are outlined below.

FLAME HEIGHT

Flame heights are based on figure for 'grazed' grassland in Cheney & Sullivan (2008)

RATE OF SPREAD

Rates of spread are back-calculated from FBI model outputs based on Byram's fireline intensity and a range of fuel load varying from 6-30 t/ha.

FIRE AREA AND PERIMETER

Potential fire area and perimeter are based on a 4-hour fire run under maximum fire danger with a range of length breadth ratio as determined by wind speeds ranging from 10-40 km/hr (as per Cruz et al (2015)) and a fuel load varying from 2-8 t/ha. The values assume no suppression.

IMPACT RELATED THRESHOLDS AND DESCRIPTIONS

Impact related thresholds and descriptions have been based largely on the work of Kilinc et al (2013), Harris et al (2011) and Blanchi et al (2010).

PROJECT DOCUMENTATION

A comprehensive list of project documentation for the Australian Fire Danger Rating System is available via the AFAC website at: https://www.afac.com.au/initiative/afdrs/afdrs-publications.

SUPPORTING REFERENCES AND FURTHER READING

Blanchi, R., et al. (2010). Meteorological conditions and wildfire-related house loss in Australia. International Journal of Wildland Fire 19(7): 914-926.

Byram, G. M. (1959). Combustion of forest fuels. Forest Fire: Control and Use. K. P. Davis. New York, McGraw-Hill: 61-89.

Cruz, M. G., et al. (2015). A Guide to Rate of Fire Spread Models for Australian Vegetation. Melbourne, Victoria, CSIRO Land and Water Flagship, Canberra, ACT, and AFAC.

Harris, S., et al. (2011). Establishing a link between the power of fire and community loss: The first steps towards developing a bushfire severity scale. Melbourne, Victoria, Victorian Government Department of Sustainability and Environment.

Kilinc, M., et al. (2013). Project title: A scale for determining the destructive potential of bushfires. Milestone report for the period 2013. Technical Report 1. Monash University, Geography and Environmental Science and University of New South Wales, Canberra.

Noble, I. R., et al. (1980). McArthur's fire-danger meters expressed as equations. Australian Journal of Ecology 5: 201-203.

VERSION

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Administrator: NSW Rural Fire Service

CONTACT

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afdrs@rfs.nsw.gov.au

THE AFDRS PROJECT IS BEING LED BY:

NSW RURAL FIRE SERVICE

Australian Government
Bureau of Meteorology

afac

PRIMARILY FUNDED BY:

Australian Government
National Recovery and Resilience Agency

PARTNER AGENCIES:

A.C.T. RURAL FIRE SERVICE

CFS

EMV EMERGENCY MANAGEMENT VICTORIA

BUSHFIRES NT

NORTHERN TERRITORY GOVERNMENT

QUEENSLAND FIRE AND EMERGENCY SERVICES

GOVERNMENT OF WESTERN AUSTRALIA
Department of Biodiversity, Conservation and Attractions

GOVERNMENT OF WESTERN AUSTRALIA
DFES
Department of Fire & Emergency Services

Tasmanian Government

Tasmania Fire Service

SUPPORTING BODIES:

AUSTRALIAN CAPITAL TERRITORY EMERGENCY SERVICES AGENCY

ACT FIRE & RESCUE

ACT Government
Environment, Planning and Sustainable Development

CFA

RURAL FIRE SERVICE QUEENSLAND

Government of South Australia
South Australian Fire and Emergency Services Commission

Government of South Australia
Department for Environment and Water

VICTORIA State Government
Environment, Land, Water and Planning

WALGA

SHRUBLAND

QUICK GUIDE

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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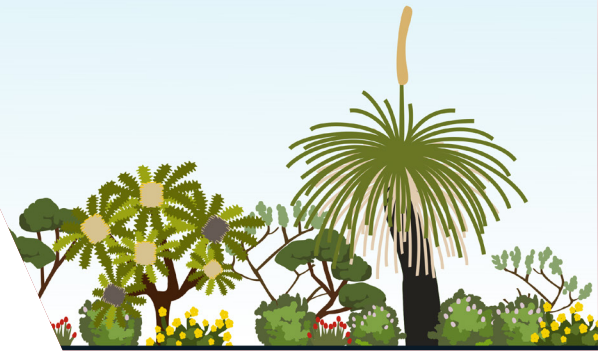


Australian Fire Danger Rating System

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

IMPLICATIONS FOR PRESCRIBED BURNING

FIRE SUPPRESSION AND CONTAINMENT

POTENTIAL FOR IMPACT

SHRUBLAND FUELS

IN THE AUSTRALIAN FIRE DANGER RATING SYSTEM

In the Australian Fire Danger Rating System (AFDRS), fuel types have been grouped by application of the most relevant fire spread model. Australian shrublands extend over a broad range of climates ranging from alpine to arid. The shrubland fuel type encompasses vegetation types where the density and prevalence of shrub vegetation has a strong control on fire behaviour processes.

SHRUBLAND FUEL STRUCTURE

Fuels in shrublands typically comprise a combination of dead and live components, with the proportion of each component being mostly dependent on the time since fire. The older the shrubland, the higher the proportion of dead fuels and the more flammable the fuel type tends to be. Under drought conditions a large proportion of live fuels can be transferred to the dead fuel component. The bulk of the biomass is elevated and vertically oriented and it is this fuel layer that typically allows for the sustained propagation of fire. The litter layer in shrubland fuel types tend to be discontinuous and marginal in fuel quantity. The separation between the ground and the elevated fuel layer leads to discontinuous fire behaviour. Under mild to moderate burning conditions fire propagation will often be limited to the litter layer with reduced spread rates and intensity, at times self-extinguishing. But small increases in wind speed or decrease in fuel moisture can result in the fire in litter fuels to propagate vertically and involve the elevated fuel layer in flaming combustion, turning a low intensity fire into a high intensity, fast spreading one involving all the fuel complex.

This fuel type includes several different shrubland types. Temperate and coastal shrublands are characterized by dense fuel layers comprising a rich diversity of plant species and high fuel loads, in excess of 30 t/ha in some situations. In certain soil-climate combinations, the fuel type is characterised as an open woodland with a continuous shrub understorey, where the tree component has an indirect effect on fire propagating.

Average shrub heights, can vary between less than 0.5 m in poor soils to up to 5 m in coastal shrublands. Shrublands in drier environments tend to have a lower stature, cover and overall fuel loads. These shrublands then to have noticeable gaps in fuel cover, most pronounced in sandy subtracts, that limit fire propagation and require higher wind speeds to maintain sustained fire propagation.

As aridity increases, so the shrub height and cover decreases, up to a point where the shrub fuel has a marginal influence on fire propagation. For low density shrublands, such as those occurring in arid and semi-arid regions where the shrub component is not the key fuel component, see the Spinifex fuel type

Not all shrubland vegetation types are included in this fuel type. For the specific cases of Mallee-heath and sedgelands with a shrub component, see the Mallee-heath and the bottom-grass moorlands fuel types.

CONTENTS

FOR MORE INFORMATION ON FUELS REFER TO:
***A GUIDE TO RATE OF FIRE SPREAD MODELS FOR AUSTRALIAN VEGETATION* (2015 EDITION)**

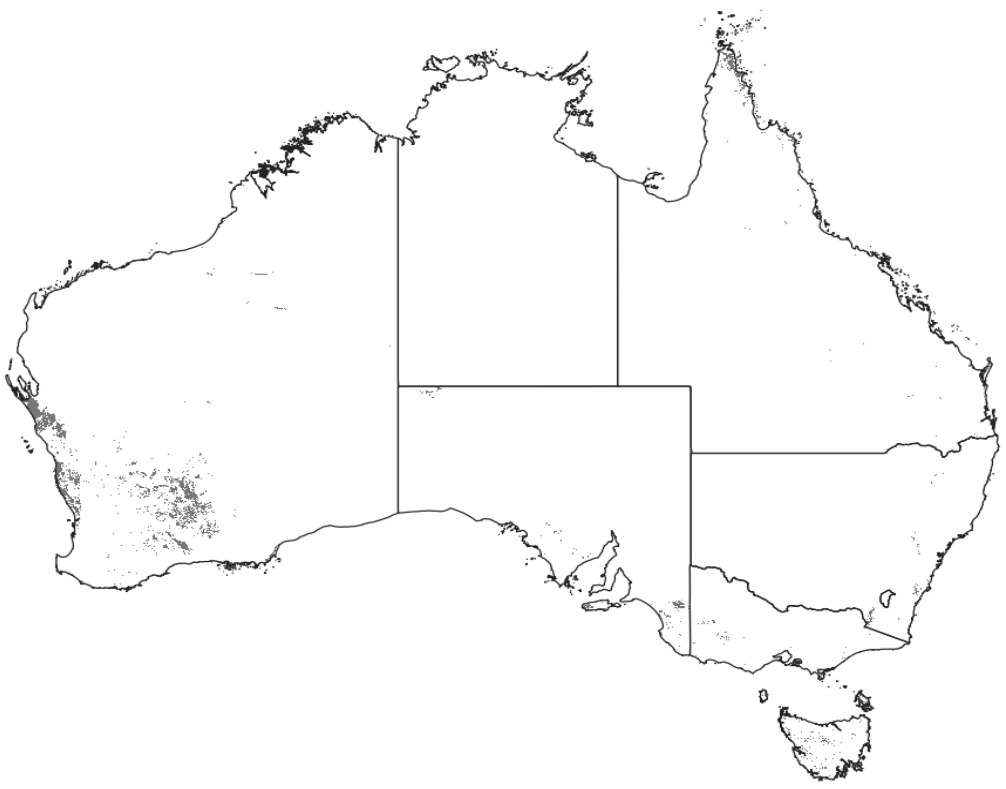
FIRE SPREAD
IN SHRUBLAND FUELS

Rate of fire spread is the foundation variable for all calculations in the Australian Fire Danger Rating System. The shrubland model is applied to for the estimation of the potential rate of fire spread in a range of shrubland fuel types.

BACKGROUND

The shrubland model was developed from the analysis of a fire behaviour dataset covering a wide range of heathland and shrubland species associations and vegetation structures, enabling the development of a generic fire spread rate model for shrubland vegetation. The fires in the dataset range from low intensity experimental and prescribed fires to high intensity fires spreading under extreme burning conditions. No wildfires were used in development of the model, but the model has been evaluated against wildfire data with very good results.

WHERE IS THE MODEL APPLIED?

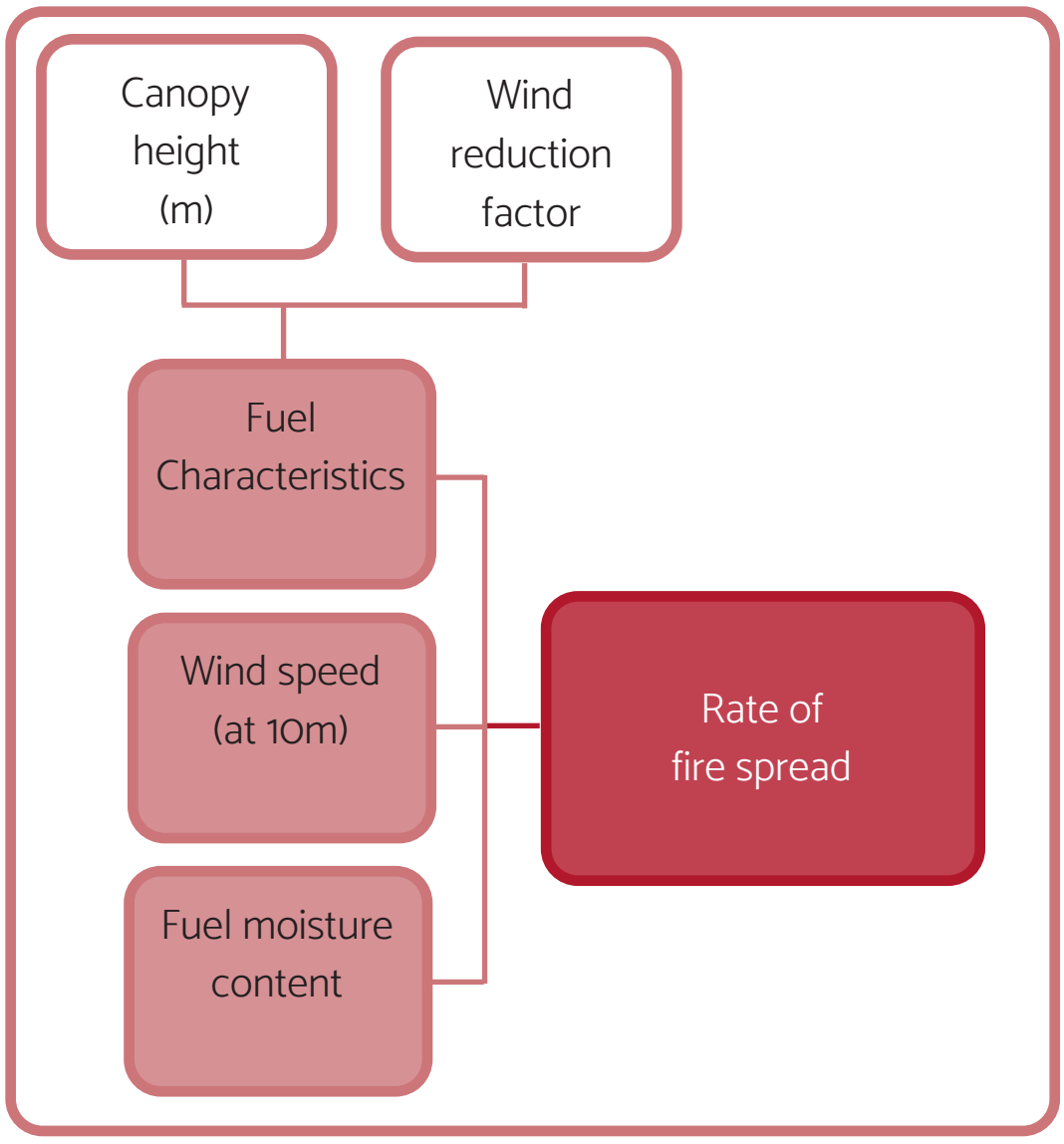


The shrubland model is applied to shrubland dominated ecosystems over a broad climatic range, from subtropical to temperate coastal shrublands on the east and south coast of the continent, to drier regions where average rainfall exceeds 300 mm annually.

HOW IS THE MODEL APPLIED?

The shrubland model can be applied over the full range of fire danger conditions from knowledge of 10-m open wind speed, moisture content of fine dead elevated fuels, and the height of the shrub fuel layer. If the shrubland is within an open woodland an adjustment to the wind profile is required. The moisture content of fine dead fuels is estimated from air temperature and relative humidity.

WHAT ARE THE MAIN INPUTS?



Rate of fire spread in Shrublands is calculated as a function of the surface and near-surface fuel characteristics, 10-m open wind speed and fine fuel moisture content.

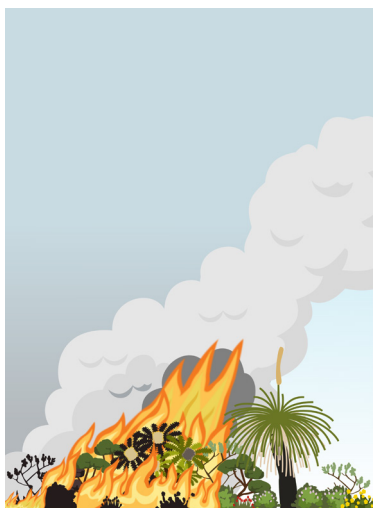
The model does not calculate if a fire will spread under marginal burning conditions characterised by high dead fuel moistures and low wind speeds. Under such conditions a fire might fail to sustain propagation or self-extinguish, but the model will predict the fire to be spreading.

WHAT IS THE MODEL SENSITIVE TO?

The shrubland model is most sensitive to changes in wind speed, followed by dead fuel moisture content and shrub fuel height. The variation in wind speed causes a comparable response in the model rate of fire spread output. For example, a doubling in wind speed will cause approximately a doubling in the rate of fire spread. The sensitivity of the model due to variation in dead fuel moisture depends on the moisture content value, with the model being less sensitive in lower fuel moisture conditions typical of bushfire activity. An increase in shrub fuel height causes an increase in rate of spread, but the relative effect is lower than observed for the other variables.

MORE DETAIL ON THE MODEL CAN BE FOUND IN: *A GUIDE TO RATE OF FIRE SPREAD MODELS FOR AUSTRALIAN VEGETATION* (2015 EDITION)

UNDERSTANDING THE
FIRE BEHAVIOUR INDEX
IN SHRUBLAND FUELS

Fire Behaviour Index 0-5	6-11	12-23	24-49	50+
				
No rating	**Moderate**	**High**	**Extreme**	**Catastrophic**
Fires are likely to self-extinguish	Typical prescribed burning conditions including scrub rolled firebreaks.	Fires are typically contained within established road networks, fuel breaks and buffers.	Rapidly growing crown fires that are difficult to contain and quickly become large. Mostly contained within established road networks, fuel breaks and buffers but may require active suppression where fuel breaks are insufficient around assets.	Elevated risk to the safety of visitors and local communities. Damaging wildfires with extremely rapid fire growth. High levels of threat to the environment and when in close proximity to people, assets and property.	Increased likelihood of community loss and significant consequences
fire behaviour	fire behaviour	suppression	impact	

A SCALE OF POTENTIAL FIRE DANGER

The Fire Behaviour Index (FBI) was developed to assist operational decision making, while the Fire Danger Ratings provide the broad categories needed to communicate fire danger to the community.

The FBI provides a scale of potential fire danger (should a fire start) based on the predicted rate of fire spread. In shrubland fuels, rate of fire spread together with fuel load, are used to determine the fireline intensity and this value is used to categorise fire danger on the FBI scale.

TRANSITIONS AND CATEGORIES

The FBI is made up of step-ups or transitions, where an increase in category is triggered by a change in:

1. fire behaviour,
2. suppression response, or
3. potential impacts.

Each category is defined in terms of:

1. indicative fire behaviour and fire weather,
2. implications for prescribed burning,
3. fire suppression and containment, and
4. potential impacts.

SHRUBLAND

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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Fire Behaviour Index
0-5

- Fire is unlikely to spread.

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

Flame dimensions are generally insufficient to breach sparse and discontinuous fuels or inter-hummock gaps.

- Rate of Spread: <20 m/hr
- Max. Flame Height: <0.5 m
- Spotting Potential: Potential for any spotting is extremely limited

IMPLICATIONS FOR PRESCRIBED BURNING

Marginal conditions even at the peak of the day.

The probability of sustained spread is minimal.

FIRE SUPPRESSION AND CONTAINMENT

Fire containment relatively simple.

Mostly contained within simple road networks, fuel breaks and buffers.

Suppression generally not necessary.

CREDIBLE WORST CASE
MAX. POTENTIAL in 4 hr

AREA
<0.5 ha

PERIMETER
<0.5 km

POTENTIAL FOR IMPACT

Community losses are unlikely.

CONDITIONS TO CONSIDER

SHRUBLAND

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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Fire Behaviour Index
6-11

- Typical prescribed burning conditions including scrub rolled firebreaks.
- Spreading surface fires, generally easily contained within simple road networks, fuel breaks and buffers.

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

Sustained spread of fire.

- Rate of Spread: <150 m/hr
- Max. Flame Height: 0.5-1.5 m
- Spotting Potential: Potential for spotting is limited

IMPLICATIONS FOR PRESCRIBED BURNING

Typical prescribed burning conditions (including within scrub rolled firebreaks) where the fire will sustain spread.

FIRE SUPPRESSION AND CONTAINMENT

Fire containment mostly simple.

Fires typically contained within simple road networks, fuel breaks or buffers >3-4 m wide.

Offensive, direct attack techniques on head-fire or flanks largely successful if fire control is necessary.

CREDIBLE WORST CASE
MAX. POTENTIAL in 4 hr

AREA
<22 ha

PERIMETER
<2 km

POTENTIAL FOR IMPACT

Community losses are unlikely.

CONDITIONS TO CONSIDER

- Wind change forecast during the peak of the afternoon

SHRUBLAND

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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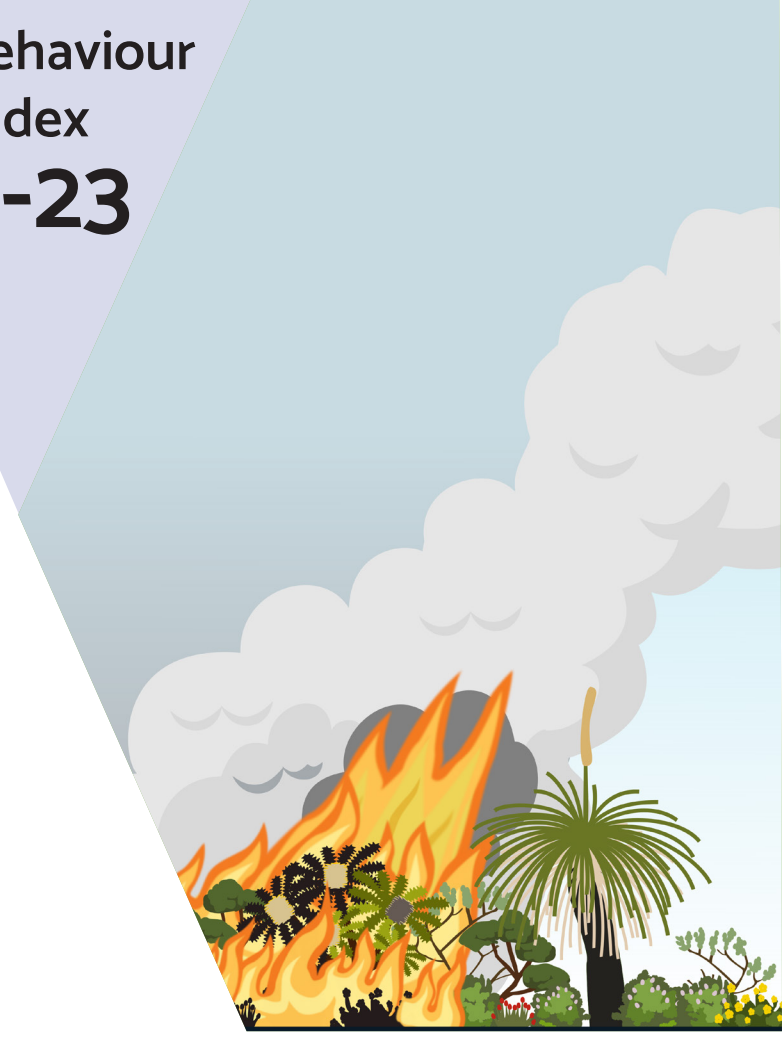
Fire Behaviour Index
12-23



- Fast moving, wind driven fires mostly crowning.
- Fires are typically contained within established road networks, fuel breaks and buffers.
- Active suppression may be required where fuel breaks are insufficient around assets.

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

Fast moving, wind-driven fires that are mostly actively crowning.

- Rate of Spread: <1.3 km/hr
- Max. Flame Height: 1-4 m
- Spotting Potential: Potential for spotting is limited except where eucalypt/mallee trees are present where spotting is likely to be minimal and limited to short distances (<50 m). Any spot fires are typically overrun by the main headfire

IMPLICATIONS FOR PRESCRIBED BURNING

Prescribed burn opportunities may exist away from assets and with well established, wide (>10 m) boundaries/ edges.

Opportunities may exist away from the peak of the day when conditions are optimal and lighting techniques are suitable to achieve burn objectives.

FIRE SUPPRESSION AND CONTAINMENT

Fires generally becoming more complex and requiring wider roads, larger fuel breaks or buffers >10 m for containment.

Active suppression around assets generally not necessary unless fuel breaks around assets are inadequate.

Combinations of direct, indirect or parallel attack may be necessary where fuel breaks are inadequate.

CREDIBLE WORST CASE
MAX. POTENTIAL
in 4 hr

AREA
<1,500 ha

PERIMETER
<15 km

POTENTIAL FOR IMPACT

Community losses are unlikely however, unattended or poorly prepared assets and infrastructure may be at risk.

CONDITIONS TO CONSIDER

- C-Haines >95th percentile (approx. >10)
- Wind change forecast during the peak of the afternoon

SHRUBLAND

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

v. 2022_6

Fire Behaviour Index
24-49

- Rapidly growing crown fires that are difficult to contain and quickly become large.
- Mostly contained within established road networks, fuel breaks and buffers but may require active suppression where fuel breaks are insufficient around assets.

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

Fast moving, wind-driven, crown fires with high potential for large fire areas. Mostly complete combustion of fuels and few unburnt patches.

- Rate of Spread: 300 m - 6.5 km/hr
- Max. Flame Height: 2-8 m
- Spotting Potential: Possible short distance spotting mostly <20 m or where eucalypt/mallee trees are present where spotting is likely to be minimal and limited to short distances (<100 m). Any spot fires are typically overrun by the main headfire

IMPLICATIONS FOR PRESCRIBED BURNING

Conditions are likely to be unsuitable for prescribed burning, however opportunities may exist away from assets and with well established, wide (>100 m) boundaries/edges or away from the peak of the day when conditions are optimal and lighting techniques are suitable to achieve burn objectives.

FIRE SUPPRESSION AND CONTAINMENT

Fires quickly becoming large and difficult to contain with fuel breaks (or buffers) >100 m likely to be effective.

Conditions on the fireground are likely to be extremely windy.

Active suppression including indirect attack or machines may be required to protect areas of population, high conservation value and on high value built, agricultural and cultural assets.

Increased risk to firefighter safety.

CREDIBLE WORST CASE
MAX. POTENTIAL in 4 hr

AREA
<35,000 ha

PERIMETER
<68 km

POTENTIAL FOR IMPACT

High likelihood of pasture/crop/stock loss together with loss of rural assets such as fencing, machinery and buildings.

Increasing risk of damaging impacts on the environment.

Fires often producing large amounts of smoke. Visibility is likely to be limited due to smoke and dust, potentially impacting traffic management.

CONDITIONS TO CONSIDER

- C-Haines >95th percentile (approx. >10)
- Wind change forecast during the peak of the afternoon

SHRUBLAND

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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Fire Behaviour Index **50+**

- Elevated risk to the safety of visitors and local communities.
- Damaging wildfires with extremely rapid fire growth.
- Active suppression may be required.
- High levels of threat to the environment and when in close proximity to people, assets and property.

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

Rapid fire growth, extremely fast moving, wind-driven fires. High potential for large fire areas with complete combustion of fuels and few unburnt patches.

- Rate of Spread: >1.5 km/hr and possibly >6.5 km/hr
- Max. Flame Height: >4 m and likely >8 m
- Spotting Potential: Possible short distance spotting mostly <40 m except where eucalypt/mallee trees are present where spotting may be up to 200 m with spot fires typically quickly overrun by the main headfire

IMPLICATIONS FOR PRESCRIBED BURNING

Conditions are likely to be unsuitable for prescribed burning.

FIRE SUPPRESSION AND CONTAINMENT

Fires quickly becoming large, complex and difficult to contain within existing road networks, fuel breaks and buffers.

Fuel breaks typically need to be >200 m to be effective.

Conditions are likely to be extremely windy.

Active suppression including indirect attack or machines may be required to protect areas of population, high conservation value and on high value built, agricultural and cultural assets.

Increased risk to firefighter safety.

CREDIBLE WORST CASE
MAX. POTENTIAL in 4 hr

AREA
>35,000 ha

PERIMETER
>68 km

POTENTIAL FOR IMPACT

Extremely high likelihood of pasture/crop/stock loss together with loss of rural assets such as fencing, machinery and buildings.

Very high risk of damaging impacts on the environment.

Fires often producing large amounts of smoke and associated carbon emissions. Visibility is likely to be limited due to smoke and dust, potentially impacting traffic management.

CONDITIONS TO CONSIDER

- C-Haines >95th percentile (approx. >10)
- Wind change forecast during the peak of the afternoon

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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SHRUBLAND

FIRE BEHAVIOUR INDEX			
0-5	<0.5 m	0-20 m/hr	Flame dimensions are generally insufficient to breach sparse and discontinuous fuels or inter-hummock gaps.	**SPOTTING POTENTIAL** Potential for any spotting is extremely limited
6-11	<0.5-1.5 m	20-150 m/hr	Sustained spread of fire.	Potential for spotting is limited
12-23	1-4 m	150-1300 m/hr	Fast moving, wind-driven fires that are mostly actively crowning.	Potential for spotting is limited except where eucalypt/mallee trees are present where spotting is likely to be minimal and limited
24-49	2-8 m	up to 6.5 km/hr	Fast moving, wind-driven, crown fires with high potential for large fire areas. Mostly complete combustion of fuels and few unburnt patches.	Possible short distance spotting mostly <20 m or where eucalypt/mallee trees are present where spotting is likely to be minimal and limited to short distances (<100 m). Any spot fires are typically overrun by the main head fire
50+	>4m and likely >8m	>1.5 and likely >6.5 km/hr	Rapid fire growth, extremely fast moving, wind-driven fires. High potential for large fire areas with complete combustion of fuels and few unburnt patches.	Possible short distance spotting mostly <40 m except where eucalypt/ mallee trees are present where spotting may be up to 200 m with spot fires typically quickly overrun by the main head fire

IMPLICATIONS FOR PRESCRIBED BURNING

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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SHRUBLAND

FIRE BEHAVIOUR INDEX

MARGINAL	0-5	Marginal conditions even at the peak of the day. The probability of sustained spread is minimal.
GENERALLY SUITABLE	6-11	Typical prescribed burning conditions (including within scrub rolled firebreaks) where the fire will sustain spread.
MARGINAL	12-23	Prescribed burn opportunities may exist away from assets and with well established, wide (>10 m) boundaries/edges. Opportunities may exist away from the peak of the day when conditions are optimal and lighting techniques are suitable to achieve burn objectives.
GENERALLY UNSUITABLE	24-49	Conditions are likely to be unsuitable for prescribed burning however, opportunities may exist away from assets and with well established, wide (>100 m) boundaries/edges or away from the peak of the day when conditions are optimal and lighting techniques are suitable to achieve burn objectives.
UNSUITABLE	50+	Conditions are likely to be unsuitable for prescribed burning.

FIRE SUPPRESSION AND CONTAINMENT

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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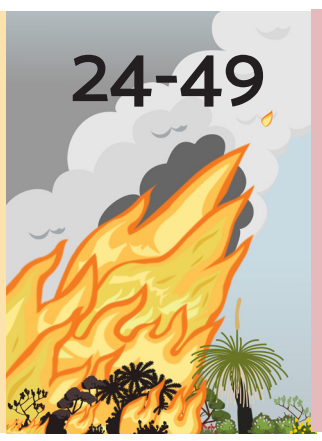
SHRUBLAND

FIRE BEHAVIOUR INDEX		CREDIBLE WORST CASE
0-5 	Fire control relatively simple. Delayed containment possible with suitable conditions. Head fire readily suppressed with offensive, direct attack techniques. Initial attack success is typically very high.	MAX. POTENTIAL in 4 hr AREA <0.5 ha PERIMETER <0.5 km
6-11 	Fire control mostly simple with sufficient resources and becoming more complex at higher intensities. Offensive, direct attack techniques on head fire or flanks largely successful in fire control. Delayed containment sometimes possible with suitable conditions.	AREA <22 ha PERIMETER <2 km
12-23 	Fires generally becoming more complex and require more resources to control. Combinations of direct, indirect or parallel attack may be necessary for fire control.	AREA <1500 ha PERIMETER <15 km
24-49 	Both ground and aerial resources using offensive strategies likely to be unsuccessful during the peak of the day, with focus largely centred on the rear and flanks. Suppression increasingly focused on defensive strategies. Fire control is likely to be difficult and require increased resourcing.	AREA <35,000 ha PERIMETER <68 km
50+ 	Control of developed fires is extremely difficult and unlikely until conditions ease. Suppression will be largely based on defensive strategies, ensuring firefighter and community preparedness and safety. Offensive strategies could position crews in danger, however safe opportunities may exist for direct, indirect or parallel attack on the rear and flanks. Important initial attack opportunities may exist for new ignitions. Conditions on the fireground are likely to be extremely windy and smoky limiting visibility and restricting aviation and access. Aerial resources are likely to be ineffective at holding fire.	AREA >35,000 ha PERIMETER >68 km

POTENTIAL FOR IMPACT

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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SHRUBLAND

FIRE BEHAVIOUR INDEX

UNLIKELY	0-5	Community losses are unlikely.
UNLIKELY	6-11	Community losses are unlikely.
MINIMAL	12-23	Community losses are unlikely however, unattended or poorly prepared assets and infrastructure may be at risk.
INCREASING	24-49	High likelihood of pasture/crop/stock loss together with loss of rural assets such as fencing, machinery and buildings. Increasing risk of damaging impacts on the environment. Fires often producing large amounts of smoke. Visibility is likely to be limited due to smoke and dust, potentially impacting traffic management.
HIGH	50+	Extremely high likelihood of pasture/crop/stock loss together with loss of rural assets such as fencing, machinery and buildings. Very high risk of damaging impacts on the environment. Fires often producing large amounts of smoke and associated carbon emissions. Visibility is likely to be limited due to smoke and dust, potentially impacting traffic management.

SUPPLEMENTARY INFORMATION
FOR SHRUBLAND FUELS

To define each category against modelled outputs within the Fire Behaviour Index (FBI) scale, various methodologies and assumptions are applied. These are outlined below.

FLAME HEIGHT

Flame heights are based on Cruz flame height equation for mallee-heath (Pers. Comm. Cruz 2017)

RATE OF SPREAD

Rates of spread are back-calculated from FBI model outputs based on Byram's fireline intensity and a range of fuel load varying from 6-30 t/ha.

SPOTTING DISTANCE

Spotting distances are based on pers. Comm. with Ryan Butler 2017

FIRE AREA AND PERIMETER

Potential fire area and perimeter are based on a 4 hour fire run under maximum fire danger with a range of length breadth ratio as determined by wind speeds ranging from 10-40 km/hr (as per Cruz et al (2015)) and a fuel load varying from 6-30 t/ha.
The values assume no suppression.

IMPACT RELATED THRESHOLDS AND DESCRIPTIONS

Impact related thresholds and descriptions have been based largely on the work of Kilinc et al (2013), Harris et al (2011) and Blanchi et al (2010).

PROJECT DOCUMENTATION

A comprehensive list of project documentation for the Australian Fire Danger Rating System is available via the AFAC website at: https://www.afac.com.au/initiative/afdrs/afdrs-publications.

SUPPORTING REFERENCES AND FURTHER READING

Blanchi, R., et al. (2010). Meteorological conditions and wildfire-related house loss in Australia. International Journal of Wildland Fire 19(7): 914-926.

Byram, G. M. (1959). Combustion of forest fuels. Forest Fire: Control and Use. K. P. Davis. New York, McGraw-Hill: 61-89.

Cruz, M. G., et al. (2015). A Guide to Rate of Fire Spread Models for Australian Vegetation. Melbourne, Victoria, CSIRO Land and Water Flagship, Canberra, ACT, and AFAC.

Harris, S., et al. (2011). Establishing a link between the power of fire and community loss: The first steps towards developing a bushfire severity scale. Melbourne, Victoria, Victorian Government Department of Sustainability and Environment.

Kilinc, M., et al. (2013). Project title: A scale for determining the destructive potential of bushfires. Milestone report for the period 2013. Technical Report 1. Monash University, Geography and Environmental Science and University of New South Wales, Canberra.

Noble, I. R., et al. (1980). McArthur's fire-danger meters expressed as equations. Australian Journal of Ecology 5: 201-203.

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THE AFDRS PROJECT IS BEING LED BY:

NSW RURAL FIRE SERVICE

Australian Government
Bureau of Meteorology

afac

PRIMARILY FUNDED BY:

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National Recovery and Resilience Agency

PARTNER AGENCIES:

A.C.T. RURAL FIRE SERVICE

CFS

EMV EMERGENCY MANAGEMENT VICTORIA

BUSHFIRES NT

NORTHERN TERRITORY GOVERNMENT

QUEENSLAND FIRE AND EMERGENCY SERVICES

GOVERNMENT OF WESTERN AUSTRALIA
Department of Biodiversity, Conservation and Attractions

GOVERNMENT OF WESTERN AUSTRALIA
DFES
Department of Fire & Emergency Services

Tasmanian Government

Tasmania Fire Service

SUPPORTING BODIES:

AUSTRALIAN CAPITAL TERRITORY EMERGENCY SERVICES AGENCY

ACT FIRE & RESCUE

ACT Government
Environment, Planning and Sustainable Development

CFA

RURAL FIRE SERVICE QUEENSLAND

Government of South Australia
South Australian Fire and Emergency Services Commission

Government of South Australia
Department for Environment and Water

VICTORIA State Government
Environment, Land, Water and Planning

WALGA

SPINIFEX

QUICK GUIDE

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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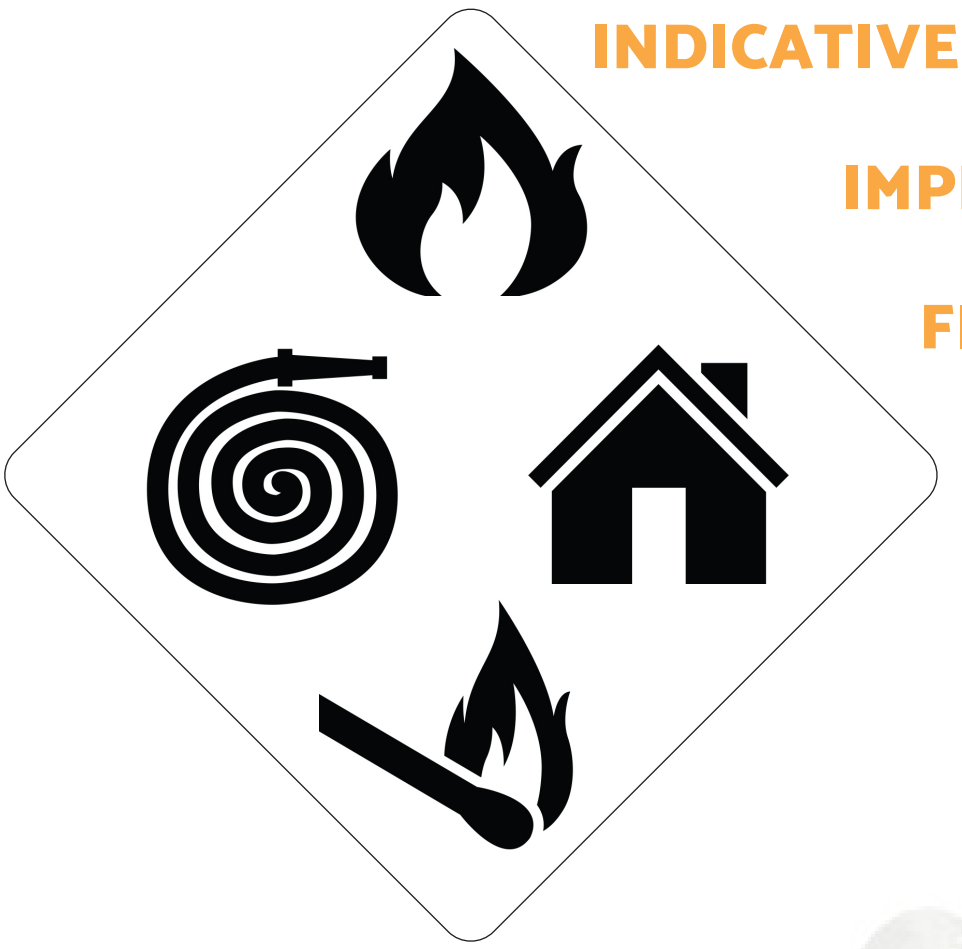
Australian
Fire Danger
Rating System



INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

IMPLICATIONS FOR PRESCRIBED BURNING

FIRE SUPPRESSION AND CONTAINMENT

POTENTIAL FOR IMPACT

SPINIFEX FUELS

IN THE AUSTRALIAN FIRE DANGER RATING SYSTEM

In the Australian Fire Danger Rating System, fuel types have been grouped by application of the most relevant fire spread model. Spinifex grasslands have an extensive distribution across semi-arid and arid regions of Australia, typically where the average annual precipitation varies between 200 and 400 mm.

SPINIFEX FUEL STRUCTURE

Spinifex grasses are evergreen perennials that form mounds (hummocks) of up to 1.0 m in height, but commonly shorter, with bare ground separating the hummocks. Hummock grasslands appear as the dominant cover type in approximately 30% of the Australian landmass. As a fuel type, Spinifex grasslands are a simple fuel type, with the spinifex clumps constituting the main fuel. Spinifex cover and the association with other species will vary with rainfall and soil type. At the higher end of the rainfall range, the spinifex cover will be higher and it will be associated with an overstorey, typically of eucalyptus or acacia (but other species are possible). This understorey will typically have low cover (<5%). If the cover of the overstorey is relatively high, then the fuel type is considered to be a spinifex woodland, such as in a mallee-spinifex vegetation type. In general, the higher the aridity, the higher the fuel discontinuity with larger gaps between spinifex clumps. As a perennial grass, the proportion of dead fuel in the spinifex clump increases with time since last fire. The dead fuel component can be quite significant in older, senescing clumps. In these older fuels, the higher proportion of dead fuels will increase the flammability of the fuel type.

CONTENTS

FOR MORE INFORMATION ON FUELS REFER TO:
A GUIDE TO RATE OF FIRE SPREAD MODELS FOR AUSTRALIAN VEGETATION (2015 EDITION)

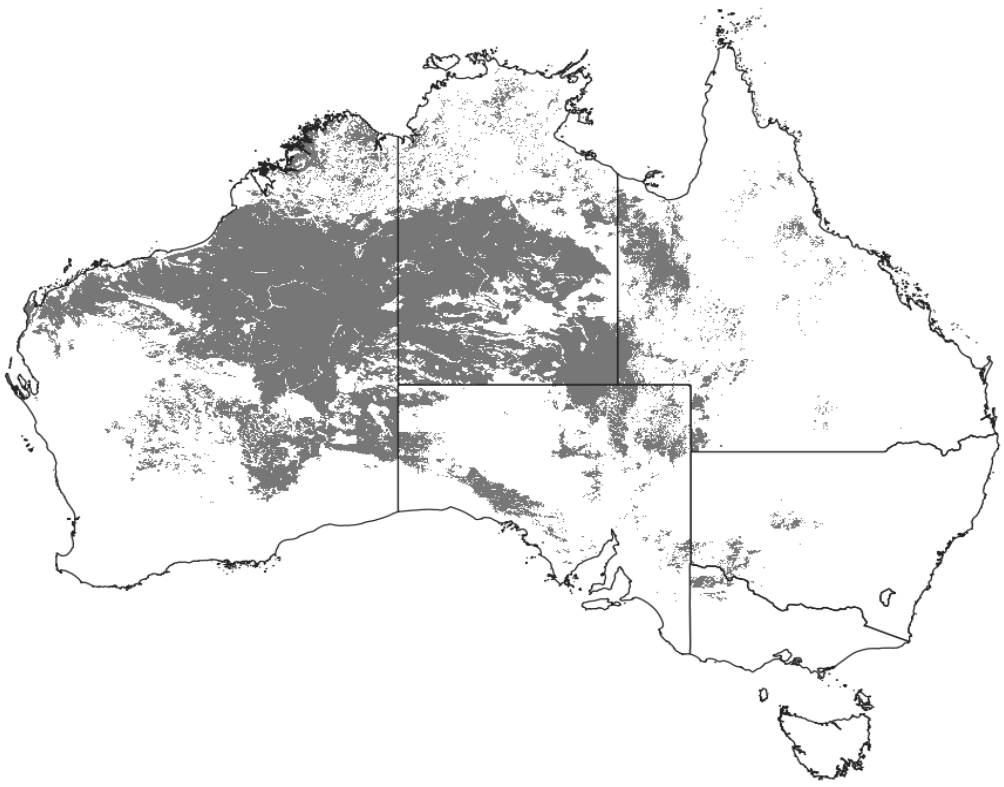
FIRE SPREAD
IN SPINIFEX FUELS

Rate of fire spread is the foundation variable for all calculations in the Australian Fire Danger Rating System. The Spinifex model is applied to the estimation of the potential rate of fire spread in this fuel type.

BACKGROUND

The Spinifex model was developed from data from experimental fires across a wide range of fuel and weather conditions. The data came mostly from a long-standing program of fire behaviour research in spinifex fuels carried out in arid Western Australia, with addition of further data from Queensland.

WHERE IS THE MODEL APPLIED?



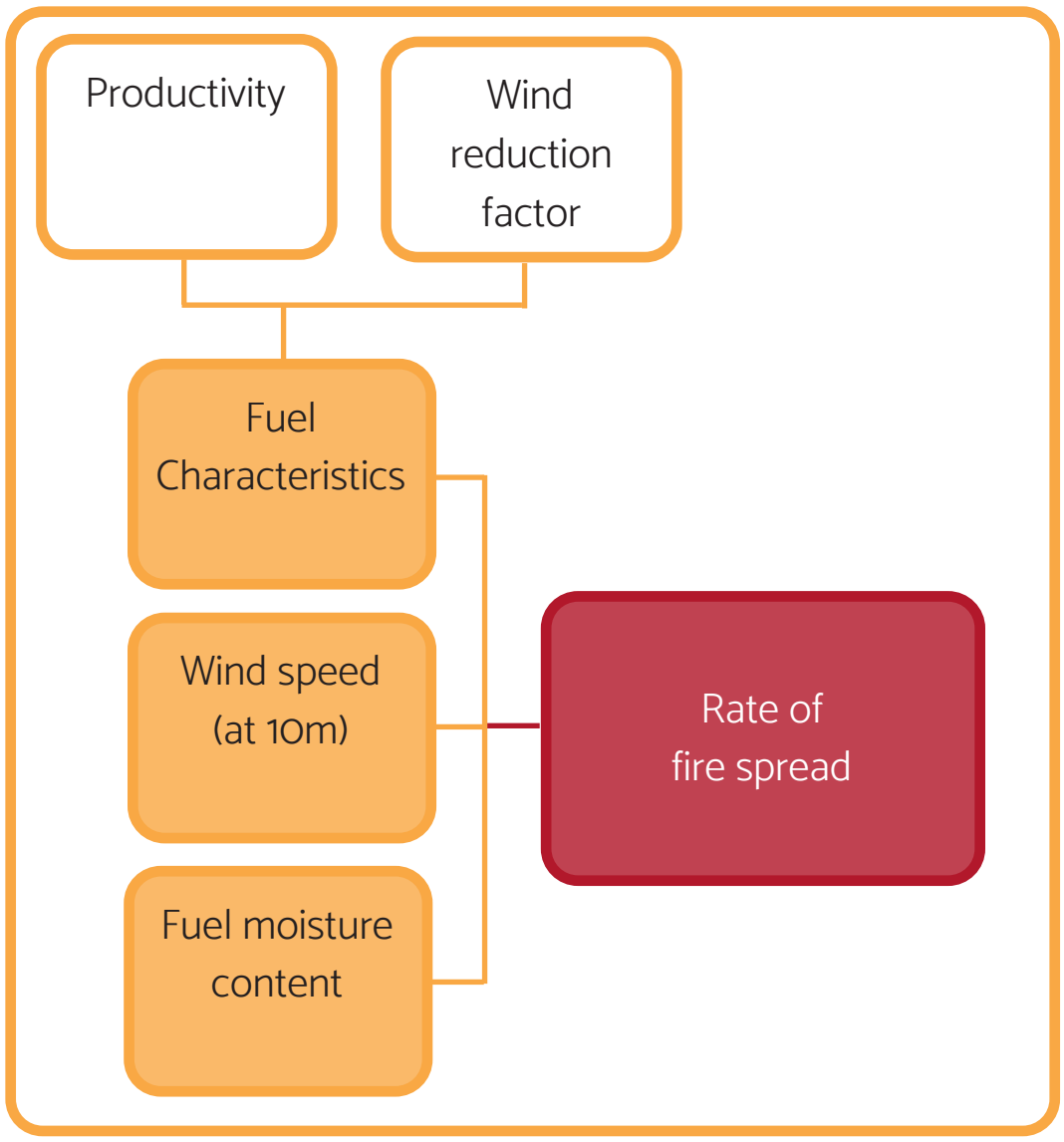
The spinifex model is applied to areas dominated by spinifex fuels, either as the sole fuel type, or in association with scattered overstorey vegetation, such as acacia and eucalyptus shrubs or low trees.

HOW IS THE MODEL APPLIED?

The spinifex model can be applied over the full range of fire danger conditions from knowledge of 10-m open wind speed, the spinifex clump fuel moisture content averaging the dead and live components, and plant cover, comprising the cover of live and dead spinifex and other lower vegetation such as grasses. The moisture content of the spinifex clump is estimated from soil moisture and fuel age. Spinifex fuel characteristics such as fuel load and cover are calculated in the AFDRS from the general climate information taking into account the aridity and time since fire.

The modelling of fire behaviour characteristics follows a two-step process. A first step calculates the probability of sustained fire propagation occurring. If the model identifies that fire will self-sustain, a second step involves the calculation of the rate of fire spread.

WHAT ARE THE MAIN INPUTS?



Rate of fire spread in Spinifex is calculated as a function of fuel characteristics including productivity and canopy cover, 10-m open wind speed and fine fuel moisture content.

If the model identifies that a fire will not be self-sustaining, then the system will classify the fire danger conditions as nil or not rateable.

Given the nonlinear characteristics of fire behaviour in this fuel type, in some combinations of fuel moisture, cover and wind speed, the model will identify sudden changes in fire propagation, such as going from a situation of no propagation to high intensity, fast spreading propagation, from small changes in wind speed or fuel cover.
In areas classified as savanna with spinifex understorey, the wind speed is modified to account of the effect for the overstorey vegetation in reducing the fuel level wind speed.

WHAT IS THE MODEL SENSITIVE TO?

The spinifex model is most sensitive to changes in wind speed, fuel cover and clump fuel moisture content. The stepwise changes associated with the onset of sustained fire propagation make the model quite sensitive to changes in wind speed and fuel cover. After sustained propagation is identified, the model output response is proportional to the changes in wind speed and fuel moisture.

MORE DETAIL ON THE MODEL CAN BE FOUND IN: *A GUIDE TO RATE OF FIRE SPREAD MODELS FOR AUSTRALIAN VEGETATION* (2015 EDITION)

UNDERSTANDING THE
FIRE BEHAVIOUR INDEX
IN SPINIFEX FUELS

A SCALE OF POTENTIAL FIRE DANGER

The Fire Behaviour Index (FBI) was developed to assist operational decision making, while the Fire Danger Ratings provide the broad categories needed to communicate fire danger to the community.

The FBI provides a scale of potential fire danger (should a fire start) based on the predicted rate of fire spread. In spinifex fuels, rate of fire spread is used to categorise fire danger on the FBI scale.

TRANSITIONS AND CATEGORIES

The FBI is made up of step-ups or transitions, where a increase in category is triggered by a change in:

1. fire behaviour,
2. suppression response, or
3. potential impacts.

Each category is defined in terms of:

1. indicative fire behaviour and fire weather,
2. implications for prescribed burning,
3. fire suppression and containment, and
4. potential impacts.

SPINIFEX

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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Fire Behaviour Index

0-5

- Fire is unlikely to spread.

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

SPREAD INDEX

≤0

Likelihood of spread is largely a function of fuel cover and wind speed (see Spread Index).

If fuel cover <50 % and wind speed <12 km/hr, flame dimensions are generally insufficient to breach inter-hummock gaps.

- Rate of Spread: <50 m/hr
- Max. Flame Height: <2 m
- Spotting Potential: Potential for any spotting is extremely limited

IMPLICATIONS FOR PRESCRIBED BURNING

Marginal conditions even at the peak of the day.

The probability of sustained spread is minimal.

FIRE SUPPRESSION AND CONTAINMENT

Fire containment relatively simple.

Mostly contained within simple road networks, fuel breaks and buffers.

Suppression generally not necessary.

CREDIBLE WORST CASE

MAX. POTENTIAL in 4 hr

AREA

<5 ha

PERIMETER

<1 km

POTENTIAL FOR IMPACT

Community losses are unlikely.

CONDITIONS TO CONSIDER

SPINIFEX

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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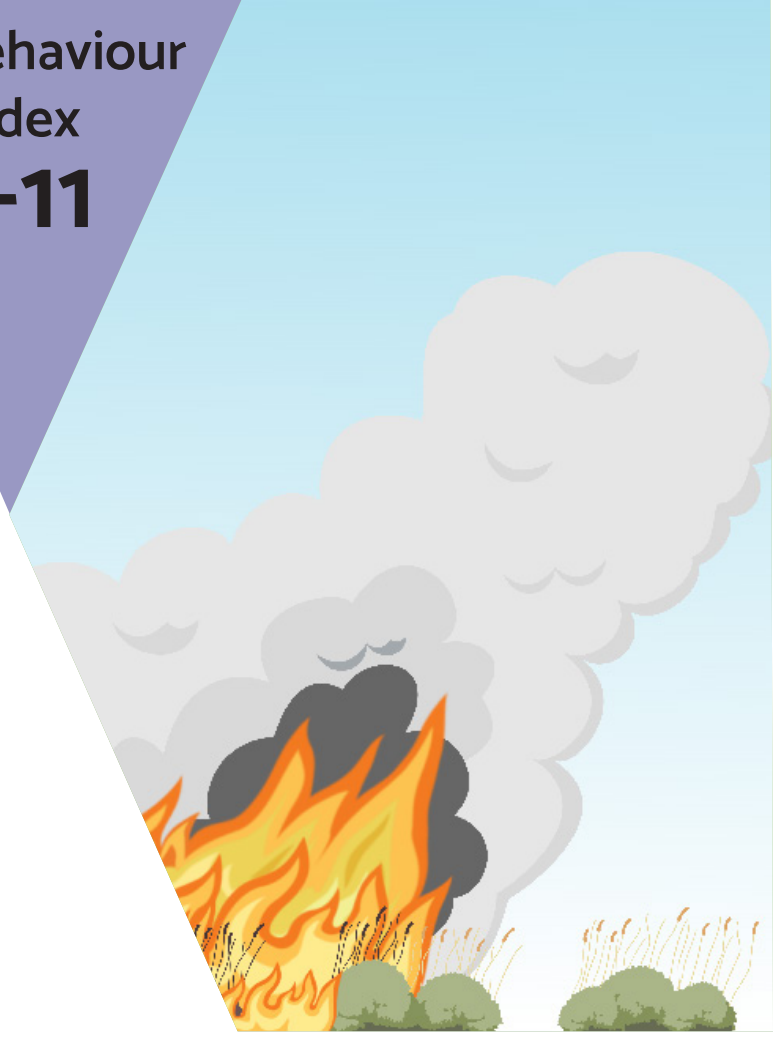
Fire Behaviour Index
6-11



- Typical prescribed burning conditions.
- Spreading fires, generally easily contained within simple road networks and fuel breaks.

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

SPREAD INDEX
>0 and ≤2

Winds speeds (2 m) 12-17 km/hr enabling sustained spread of fire.

Largely wind driven head-fires burning in narrow strips and classic 'finger' shapes.

- Rate of Spread: 50 m - 1.3 km/hr
- Max. Flame Height: <3.5 m
- Spotting Potential: Potential for spotting is limited

IMPLICATIONS FOR PRESCRIBED BURNING

Typical prescribed burning conditions.

Sustained spread likely and largely dependent on wind speed, fuel quantity and fuel moisture content.

Head-fires commonly fragment and go out under low wind speeds and diurnal/evening conditions.

FIRE SUPPRESSION AND CONTAINMENT

Fire containment mostly simple.

Fires typically contained within road networks, fuel breaks or buffers >5 m wide (including spinifex fuel age classes 1 and 2 with fuel cover below 40%).

CREDIBLE WORST CASE
MAX. POTENTIAL in 4 hr
AREA
<2,500 ha
PERIMETER
<20 km

POTENTIAL FOR IMPACT

Community losses are unlikely.

CONDITIONS TO CONSIDER

- Wind change forecast

SPINIFEX

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

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Fire Behaviour Index
12-49

- Rapid fire growth.
- Typically contained within established road networks and fuel breaks mostly without the need for additional suppression.

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

SPREAD INDEX
>2 and ≤10

Rapid fire growth, especially when Spread Index >6 or wind speed >25 km/hr. Often reaching 'quasi steady state' within 5-10 mins of ignition. Largely wind-driven head-fires becoming increasingly large with shifts in wind direction. Increased potential for burning hummocks on flanks to develop into smaller fires following changes in wind direction.

Fire behaviour (speed and direction) highly responsive to wind shifts and positive slope.

- Rate of Spread: 1.3-7.5 km/hr
- Max. Flame Height: 3-4.5 m
- Spotting Potential: Potential for spotting is limited except where eucalypt/mallee trees are present where spotting is likely to be minimal and limited to short distances (<100 m). Any spot fires are typically overrun by the main head fire

IMPLICATIONS FOR PRESCRIBED BURNING

Opportunities may exist for prescribed burning away from assets and with well established, wide (>10 m) boundaries/edges. Opportunities may exist away from the peak of the day when conditions are optimal and lighting techniques are suitable to achieve burn objectives.

FIRE SUPPRESSION AND CONTAINMENT

Fires generally becoming more complex.

Requiring wide roads, large fuel breaks or buffers (including spinifex fuel age classes 1 and 2 with fuel cover below 40%) >15 m for containment.

Active suppression around assets generally not necessary unless fuel breaks around assets are inadequate.

Increased risk to firefighters.

CREDIBLE WORST CASE
MAX. POTENTIAL in 4 hr
AREA
<9,000 ha
PERIMETER
<45 km

POTENTIAL FOR IMPACT

Very high risk of damaging impacts on the environment over large areas (threats to fauna, habitat loss, e.g. loss of hollow-bearing trees, hollow logs, shrub cover, mulga groves) as well as very high likelihood of pasture/crop/stock loss together with loss of rural assets such as fencing, machinery and buildings.

CONDITIONS TO CONSIDER

- C-Haines >95th percentile (approx. >10)
- Wind change forecast during the peak of the afternoon

SPINIFEX

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

v. 2022_6

Fire Behaviour Index **50+**

- Elevated risk to the safety of visitors and local communities.
- Damaging wildfires with extremely rapid fire growth.
- Active suppression may be required.
- High levels of threat to the environment and when in close proximity to people, assets and property.

INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

SPREAD INDEX

>10

Rapid fire growth (<5 mins to steady state), extremely fast moving, wind-driven fires. High potential for large fire areas with complete combustion of fuels and few unburnt patches. Burning hummocks often developing into smaller fires following changes in wind direction.

Fire behaviour (speed and direction) highly responsive to wind shifts and positive slope.

- Rate of Spread: >7.5 km/hr
- Max. Flame Height: >3.5 m
- Spotting Potential: Possible short distance spotting if eucalypt/mallee trees are present (mostly <200 m) with spot fires typically quickly overrun by the main head fire

IMPLICATIONS FOR PRESCRIBED BURNING

Conditions are likely to be unsuitable for prescribed burning however opportunities may be exist immediately before storm/rain events or away from the peak of the day when conditions are optimal and lighting techniques are suitable to achieve burn objectives.

FIRE SUPPRESSION AND CONTAINMENT

Fires quickly becoming large, complex and difficult to contain within existing road networks, fuel breaks and buffers (including spinifex fuel class 1 and 2: fuel cover <40 %).

Fuel breaks typically need to be >200 m to be effective.

Conditions are likely to be extremely windy.

Active suppression including indirect attack or machines may be required to protect areas of population, high conservation value and on high value built, agricultural and cultural assets.

Heightened risk to firefighters.

CREDIBLE WORST CASE
MAX. POTENTIAL in 4 hr

AREA
>9,000 ha

PERIMETER
>45 km

POTENTIAL FOR IMPACT

Very high risk of damaging impacts on the environment over large areas (threats to fauna, habitat loss, e.g. loss of hollow-bearing trees, hollow logs, shrub cover, mulga groves) as well as very high likelihood of pasture/crop/stock loss together with loss of rural assets such as fencing, machinery and buildings.

CONDITIONS TO CONSIDER

- C-Haines >95th percentile (approx. >10)
- Wind change forecast during the peak of the afternoon

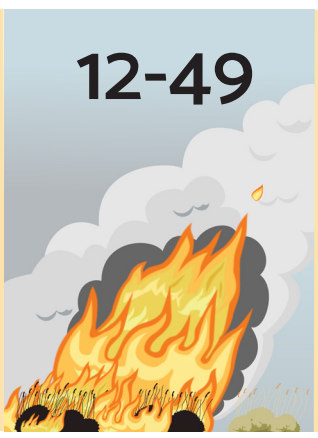
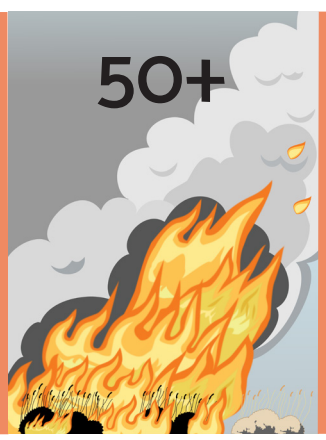
INDICATIVE FIRE BEHAVIOUR AND FIRE WEATHER

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

v. 2022_6

SPINIFEX

FIRE BEHAVIOUR INDEX

0-5	<2 m		0-50 m/hr	Likelihood of spread is largely a function of fuel cover and wind speed. If fuel cover is less than 50 % and wind speed <12 km/hr, flame dimensions are generally insufficient to breach inter-hummock gaps.	**SPOTTING POTENTIAL** Potential for any spotting is extremely limited
6-11	<3.5 m		<1.3km/hr	Winds speeds (2 m) 12-17 km/hr enabling sustained spread of fire. Largely wind driven head-fires burning in narrow strips and classic 'finger' shapes.	Potential for spotting is limited
12-49	3-4.5 m		1.3-7.5 km/hr	Rapid fire growth, especially when SI >6 or wind speed > 25 km/h. Often reaching 'quasi steady state' within 5-10 mins of ignition. Largely wind-driven head-fires becoming increasingly large with shifts in wind direction. Increased potential for burning hummocks on flanks to develop into smaller fires following changes in wind direction.	Potential for spotting is limited except where eucalypt/mallee trees are present where spotting is likely to be minimal and limited to short distances (<100 m). Any spot fires are typically overrun by the main head fire
50+	>3.5m		>7.5 km/hr	Rapid fire growth (<5 mins to steady state), extremely fast moving, wind-driven fires. High potential for large fire areas with complete combustion of fuels and few unburnt patches. Burning hummocks often developing into smaller fires following changes in wind direction.	Possible short distance spotting if eucalypt/mallee trees are present (mostly <200 m) with spot fires typically quickly overrun by the main head fire

IMPLICATIONS FOR PRESCRIBED BURNING

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

v. 2022_6

SPINIFEX

FIRE BEHAVIOUR INDEX

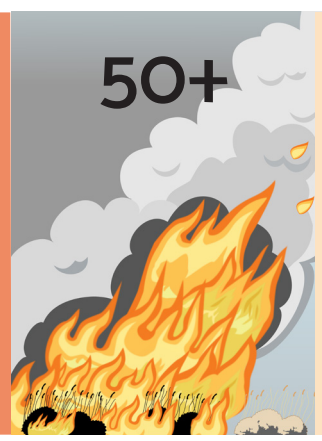
MARGINAL	0-5	Marginal conditions even at the peak of the day. The probability of sustained spread is minimal.
GENERALLY SUITABLE	6-11	Typical prescribed burning conditions. Sustained spread likely and largely dependent on wind speed, fuel quantity and fuel moisture content. Head-fires commonly fragment and go out under low wind speeds and diurnal/evening conditions.
GENERALLY UNSUITABLE	12-49	Opportunities may exist for prescribed burning away from assets and with well established, wide (>10 m) boundaries/edges. Opportunities may exist away from the peak of the day when conditions are optimal and lighting techniques are suitable to achieve burn objectives.
UNSUITABLE	50+	Conditions are likely to be unsuitable for prescribed burning however opportunities may be exist immediately before storm/rain events or away from the peak of the day when conditions are optimal and lighting techniques are suitable to achieve burn objectives.

FIRE SUPPRESSION AND CONTAINMENT

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

v. 2022_6

SPINIFEX

FIRE BEHAVIOUR INDEX		CREDIBLE WORST CASE
0-5 	Fire containment relatively simple. Mostly contained within simple road networks, fuel breaks and buffers. Suppression generally not necessary.	MAX. POTENTIAL in 4 hr AREA <5 ha PERIMETER <1 km
6-11 	Fire containment mostly simple. Fires typically contained within road networks, fuel breaks or buffers >5 m wide (including spinifex fuel age classes 1 and 2 with fuel cover below 40%)	AREA <2,500 ha PERIMETER <20 km
12-49 	Fires generally becoming more complex. Requiring wide roads, large fuel breaks or buffers (including spinifex fuel class 1 and 2: fuel cover <40 %) >15 m for containment. Active suppression around assets generally not necessary unless fuel breaks around assets are inadequate.	AREA <9,000 ha PERIMETER <45 km
50+ 	Fires quickly becoming large, complex and difficult to contain within existing road networks, fuel breaks and buffers (including spinifex fuel class 1 and 2: fuel cover <40 %). Fuel breaks typically need to be >200 m to be effective. Conditions are likely to be extremely windy. Active suppression including indirect attack or machines may be required to protect areas of population, high conservation value and on high value built, agricultural and cultural assets.	AREA >9,000 ha PERIMETER >45 km

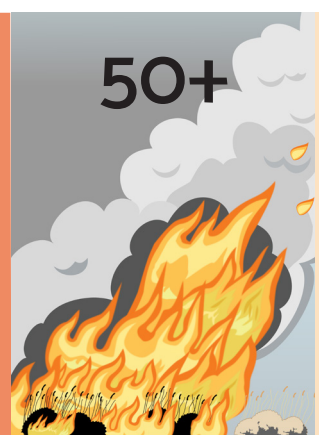
POTENTIAL FOR IMPACT

UNDERSTANDING THE FIRE BEHAVIOUR INDEX

v. 2022_6

SPINIFEX

FIRE BEHAVIOUR INDEX

UNLIKELY	0-5		Community losses are unlikely.
UNLIKELY	6-11		Community losses are unlikely.
INCREASING	12-49		Potentially damaging impacts on the environment (threats to fauna, habitat loss, e.g. loss of hollow-bearing trees, hollow logs, shrub cover, mulga groves) as well as potential pasture/crop/stock loss together with loss of rural/structural assets such as fencing, machinery and buildings.
HIGH	50+		Very high risk of damaging impacts on the environment over large areas (threats to fauna, habitat loss, e.g. loss of hollow-bearing trees, hollow logs, shrub cover, mulga groves) as well as very high likelihood of pasture/crop/stock loss together with loss of rural assets such as fencing, machinery and buildings.

SUPPLEMENTARY INFORMATION
FOR SPINIFEX FUELS

To define each category against modelled outputs within the Fire Behaviour Index (FBI) scale, various methodologies and assumptions are applied. These are outlined below.

FLAME HEIGHT

Flame heights are based on Burrows et al. (2017)

RATE OF SPREAD

Rates of spread is the primary output of the Burrows et al. (2018) model.

SPOTTING DISTANCE

Spotting distances are based on descriptions from Burrows et al (1991, 2006, 2015)

FIRE AREA AND PERIMETER

Potential fire area and perimeter are based on a 4 hour fire run under maximum fire danger with a range of length breadth ratio as determined by wind speeds ranging from 10-40 km/hr (as per Cruz et al (2015)) and a fuel load varying from 3-16 t/ha.
The values assume no suppression.

IMPACT RELATED THRESHOLDS AND DESCRIPTIONS

Impact related thresholds and descriptions have been based largely on the work of Kilinc et al (2013), Harris et al (2011) and Blanchi et al (2010).

PROJECT DOCUMENTATION

A comprehensive list of project documentation for the Australian Fire Danger Rating System is available via the AFAC website at: https://www.afac.com.au/initiative/afdrs/afdrs-publications.

SUPPORTING REFERENCES AND FURTHER READING

Blanchi, R., et al. (2010). Meteorological conditions and wildfire-related house loss in Australia. International Journal of Wildland Fire 19(7): 914-926.

Burrows, N.D., Gill, M., Sharples, J. (2018). Development and validation of a model for predicting fire behaviour in spinifex grasslands of arid Australia. International Journal of Wildland Fire 27, 271-279.

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Byram, G. M. (1959). Combustion of forest fuels. Forest Fire: Control and Use. K. P. Davis. New York, McGraw-Hill: 61-89.

Cruz, M. G., et al. (2015). A Guide to Rate of Fire Spread Models for Australian Vegetation. Melbourne, Victoria, CSIRO Land and Water Flagship, Canberra, ACT, and AFAC.

Harris, S., et al. (2011). Establishing a link between the power of fire and community loss: The first steps towards developing a bushfire severity scale. Melbourne, Victoria, Victorian Government Department of Sustainability and Environment.

Kilinc, M., et al. (2013). Project title: A scale for determining the destructive potential of bushfires. Milestone report for the period 2013. Technical Report 1. Monash University, Geography and Environmental Science and University of New South Wales, Canberra.

Noble, I. R., et al. (1980). McArthur's fire-danger meters expressed as equations. Australian Journal of Ecology 5: 201-203.

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Australian Government
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afac

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PARTNER AGENCIES:

A.C.T. RURAL FIRE SERVICE

CFS

EMV EMERGENCY MANAGEMENT VICTORIA

BUSHFIRES NT

NORTHERN TERRITORY GOVERNMENT

QUEENSLAND FIRE AND EMERGENCY SERVICES

GOVERNMENT OF WESTERN AUSTRALIA
Department of Biodiversity, Conservation and Attractions

GOVERNMENT OF WESTERN AUSTRALIA
DFES
Department of Fire & Emergency Services

Tasmanian Government

Tasmania Fire Service

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AUSTRALIAN CAPITAL TERRITORY EMERGENCY SERVICES AGENCY

ACT FIRE & RESCUE

ACT Government
Environment, Planning and Sustainable Development

CFA

RURAL FIRE SERVICE QUEENSLAND

Government of South Australia
South Australian Fire and Emergency Services Commission

Government of South Australia
Department for Environment and Water

VICTORIA State Government
Environment, Land, Water and Planning

WALGA