Department of
Sustainability and
Environment

Overall fuel hazard assessment guide

4th edition July 2010

Fire and adaptive management

report no. 82

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Overall fuel hazard assessment guide

4th edition July 2010

Fire and adaptive management, report no. 82

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This publication was produced with the support of the Attorney-General's Department of the Australian Government, who part funded this project through the Natural Disaster Resilience Grants Program.

Australian Government
Attorney-General's Department
Emergency Management Australia

Images have been provided by Department of Sustainability and Environment – Victoria, Department of Environment and Heritage – South Australia, Country Fire Service – South Australia, Department of Conservation and Environment – Western Australia and Christian Pearson – Misheye. Katy Friend drew the illustrations.

Cover image: Elaine – Atchison Rd Fire, Victoria, January 2008. Bark Hazard – Extreme, Elevated Fuel Hazard – Moderate, Near-surface Fuel Hazard – Low, Surface Fuel Hazard – Very High. Overall Fuel Hazard – Extreme. Fire burning under FFDI 17 – High.

Published by the Victorian Government Department of Sustainability and Environment
Melbourne, July 2010

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Authorised by the Victorian Government, 8 Nicholson Street, East Melbourne.

Printed by Stream Solutions
Printed on 100% Recycled paper

ISBN 978-1-74242-676-1 (print)
ISBN 978-1-74242-677-8 (online)

For more information contact the DSE Customer Service Centre 136 186

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Contents

1. About this guide

1.1 Purpose

The main purpose of this guide is to allow people to:

- make a rapid, visual assessment of fuel arrangement, and
- gain an understanding of how this will affect the chances of controlling a bushfire.

1.2 Audience

This guide has been principally designed to provide information on fuel arrangement to be used by:

- firefighters to assess the difficulty of controlling a bushfire.

Information on fuel arrangement may also be used by:

- asset owners and managers to assess potential bushfire risks to assets
- land and fire managers to provide a measurable objective and trigger for fuel management in fire management plans
- personnel to identify which key attributes and fuel layers are contributing the most to the hazard
- personnel to plan and conduct planned burns
- personnel to assess the effectiveness of planned burning or mechanical hazard reduction
- fire behaviour analysts to produce fire-spread predictions and community warnings.

Those who use the guide for these other purposes need to be mindful of its limitations and how the results are applied and interpreted.

1.3 What fuel is assessed

This guide is for assessing fine fuels that burn in bushfires. Fine fuels are the fuels that burn in the continuous flaming zone at the fire's edge. They contribute the most to the fire's rate of spread and flame height. Typically, they are dead plant material, such as leaves, grass, bark and twigs thinner than 6mm thick, and live plant material thinner than 3mm thick. Once ignited, these fine fuels generally burn out within two minutes.

This guide focuses on assessing the key structural layers of the fine fuel complex, in particular those of bark, elevated, near-surface and surface fuels.

1.4 How the fuel is assessed

Each fuel layer is assessed simply and visually. Assessing the fuel takes only a few minutes and is based on the premise that the eye is better able to integrate local variations in fuel than systematic measurement. Each fuel layer is assessed in turn and given a hazard rating. Particular emphasis is placed on how the fuel is arranged within each of these layers. The hazard ratings are then combined to produce an Overall Fuel Hazard Rating that ranges from Low to Extreme.

1.5 Why fuel arrangement is more important than fuel load

The image below highlights the effect that changing the arrangement of the fuel can have on fire behaviour. Both fires were ignited at the same time in the same way. Both fires are burning in the same fuel load, approximately two broadsheets of newspaper over a 20cm diameter area. The fuel on the right was laid flat and has little vertical orientation. The fuel on the left was crumpled up, which gave it more vertical orientation and exposed more of the surface to the air. As a result, the fire on the left shows significantly greater flame height and the fuel is consumed much faster.

The simple difference in the arrangement of the fuel significantly affects the resulting fire behaviour. The effect would not be discerned if the fuel assessment was based purely on fuel load. An assessment of fuel hazard takes into account the fuel arrangement. It gives a better indication of potential fire behaviour and suppression difficulty.

1.6 Suppression difficulty is not just about fire behaviour

This guide has been mainly developed to allow people to assess the impact of fuel arrangement on suppression difficulty. An assessment of suppression difficulty (how hard it is to control a bushfire) is not based solely on the anticipated fire behaviour. Many other factors affect the chances of a firefighting operation succeeding, including resources, fire size and terrain.

In order to consider the impact of fuels, the other factors need to be treated as if they are constant. The factors that have been held constant are referred to as the Reference Extended First Attack Conditions. Further detail on these conditions is contained in Appendix 1.

1.7 Basis of the Overall Fuel Hazard classification

A comprehensive explanation of this guide is contained in DSE's *Overall fuel hazard assessment guide: a rationale report – fire and adaptive management report no. 83* (in prep.).

This assessment guide updates and builds on work previously published by Wilson (1992a, 1992b, 1993), McCarthy *et al*. (1998a, 1998b, 1998c, 1999, 2001), the Department of Environment and Heritage (2006) and Gould *et al*. (2007a, 2007b).

Classifying Overall Fuel Hazard is complex, with few available measurements. Therefore, we have relied on the perceptions of experienced fire personnel (e.g. fire behaviour specialists, fire managers and firefighters). The collective experience of these personnel is vast, with a broad geographic base across Australia.

1.8 Need for continual learning and development

Although our knowledge about fuels has many gaps, this guide is based on the best available information and experience. The authors acknowledge that this guide will need to change and improve as more information is obtained.

Observers of firefighting operations can improve future editions of this guide by carefully recording what they see. Observations, comments and feedback can be emailed to fire.monitoring@dse.vic.gov.au.

2. How to use the guide

This guide has been kept concise and should not be considered as a standalone document. To produce reliable and consistent results requires extra knowledge which may be gained through local hands-on training in fuel assessment.

2.1 Application

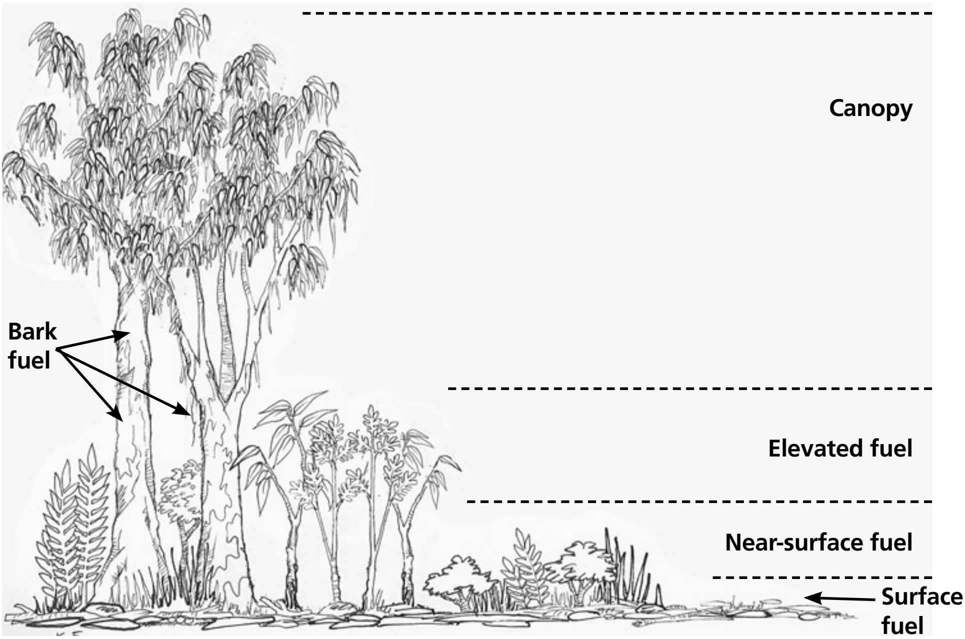
This guide is a tool for rapidly assessing fuel arrangement and its effect on the chances of controlling a bushfire. It may also be used for a range of other fire management purposes, as shown in the table below. Users of this guide should understand the underlying assumptions and limitations before applying it, particularly if applying it for purposes other than the assessment of suppression difficulty.

Application	Methodology
Assess suppression difficulty	Assess the fuels in which the fire may occur or is actually occurring.
Assess fuels for predicting potential risk to assets	Assess the fuels immediately adjacent to the asset as part of an assessment of possible radiant heat loads and defendable space. Assess the fuels further away from the asset; paying particular attention to areas that may generate spotting, such as ridges. Assessments should be focused, particularly in the direction of likely fire attack.
Assess the need for, or success of, fuel management activities	Assess the average fuels across the nominated area by sampling within major vegetation types, slopes and aspects.
Plan and conduct planned burns	Assess the variability in fuels across the nominated area by sampling within major vegetation types, slopes and aspects. Pay particular attention to areas where the burn may escape, such as the tops of gullies, ridge tops and areas adjacent to planned burn boundaries.
Assess fuels for predicting fire behaviour	Assess the fuel values needed as inputs for the appropriate fire behaviour model.

2.2 Fuel layers

Fuel in forests, woodlands and shrublands can be divided into four layers, each based on its position in the vegetation profile (Fig 2.1). This guide focuses on assessing the key structural layers of the fine fuel complex, those of bark, elevated, near-surface and surface fuels.

Figure 2.1 Fuel layers and bark



Use the following descriptions to determine how to separate vegetation into fuel layers.

Layer	Description	Contribution to suppression difficulty
Canopy	• Crowns of the tallest layer of trees. • Under some conditions canopy fuels can play a significant role in fire behaviour and suppression difficulty. Currently, however, these fuels are not assessed as part of Overall Fuel Hazard.	
Bark fuel	• Bark on tree trunks and branches, from ground level to canopy.	Spotting
Elevated fuel	• Fuels are mainly upright in orientation. • Generally most of the plant material is closer to the top of this fuel layer. • Sometimes contains suspended leaves, bark or twigs. • Fuels that have a clear gap between them and the surface fuels. • Can be highly variable in ground coverage. • Low-intensity fire (flame height of less than 0.5m) may pass beneath this layer without consuming much, if any, of it.	Influences the flame height and rate of spread of a fire.
Near-surface fuel	• Live and dead fuels, effectively in touch with the ground, but not lying on it. • Fuel has a mixture of vertical and horizontal orientation. • Bulk of the fuels are closer to the ground than to the top of this layer, or are distributed fairly evenly from the ground up. • Sometimes contains suspended leaves, bark or twigs. • Coverage may range from continuous to having gaps many times the size of the fuel patch. • Low-intensity fire (flame height of less than 0.5m) will consume most or all of this fuel. • Fuel in this layer will always burn when the surface fuel layer burns.	Influences the rate of spread and flame height of a fire.
Surface fuel (litter)	• Leaves, twigs, bark and other fine fuel lying on the ground. • Predominantly horizontal in orientation.	Influences the rate of spread of a fire.

This guide is for assessing fine fuels only. Coarse fuels including logs are not considered. See Section 1.3 for further details.

The descriptions of the fuel layers exclude references to species' names or common vegetation forms, such as shrubs. During a plant's life it may transition back and forth between different layers. For example, juvenile bracken fern can be classified as near-surface fuel before becoming elevated fuel as it matures. Once it dies and collapses it may become near-surface fuel again.

2.3 Assessment based on key attributes of fuel hazard

A fuel hazard rating of Low, Moderate, High, Very High or Extreme is assigned to each fuel layer by assessing it against the key attributes listed below.

Key attribute	
Horizontal continuity of the layer	Determines how readily a piece of burning fuel may ignite the fuel beside it. Identifies which of surface, near-surface or elevated fuels will determine the average flame height.
Vertical continuity of the layer	Determines how readily a piece of burning fuel may ignite the fuel above it.
Amount of dead material in the layer	Determines how much dead material is present to burn and thus help with igniting the live (green) fuels.
Thickness of the fuel pieces	Determines whether the fuel pieces will burn in the flaming front of the fire.
Total weight of fine fuel	Determines the weight of fine fuel contributing to the flaming front of the fire.

The descriptions in the hazard assessment tables do not cover all possible combinations of the key attributes. Users will need to exercise judgement and make an assessment using all key attributes when actual conditions fit between the descriptions.

2.4 Using the descriptions and photographs

This is **not** a photographic guide for assessing fuels. The **descriptions** for each of the key attributes should be used as the basis for determining the fuel hazard rating. Photographs cannot adequately show all of the key attributes that are important in determining fuel hazard. The photographs are provided to illustrate **some** of the key attributes for each fuel hazard rating. They do not represent all possible variations of that particular hazard rating.

2.5 Area of assessment

Within an area of interest fuels are assessed in small patches or plots. The size and number of plots depends on the reason for assessing the fuels. Some applications (such as for input into fire behaviour models) may require a more rigorous and systematic approach to sampling. Other applications (such as assessing fuel hazard during firefighting operations) will necessitate a more rapid informal approach. For whatever purpose the guide is being used it is recommended that the following principles be applied:

- Any assessment of fuels should try to assess the variability in fuels across an area by assessing the fuels at multiple plots.
- The size and number of plots should reflect the level of reliability required of the results.
- For surface, near-surface and elevated fuel layers the result of assessing the plot should reflect the average state of that fuel layer.
- For bark hazard the result of assessing the plot should be based on the trees with the highest rating.
- Always record with the result the name and the version of the guide used.

2.6 Tips for assessing fuel hazard

The process of assessing fuel hazard using this guide is largely subjective. Implementing the following techniques will help to improve accuracy and reliability:

- Identify and agree on examples of the highest rating of fuel hazard for each layer that occur locally. These examples should be used as benchmarks.
- Conduct assessments in pairs of observers and regularly change assessment pairs.
- Assessors should be no more than one hazard rating apart when assessing each layer (e.g. Low or Medium, not Low or High).
- Use different assessors to re-assess completed work and provide feedback.

2.7 Vesta fire behaviour predictions

In dry eucalypt forest with a litter and shrub understorey the *Field guide – fuel assessment and fire behaviour prediction in dry eucalypt forest* (Gould *et al.* 2007b) provides a systematic method for assessing fuel and predicting fire behaviour (rate of spread, flame height, and spotting). The Project Vesta fuel hazard scoring system is similar to the Victorian system developed by Wilson (1992a, 1992b, 1993) and revised by McCarthy *et al*. (1999). The scale that underlies the Vesta fuel hazard scores is directly related to fire behaviour. These scores, along with height measurements of various fuel layers, are needed as inputs into the fire behaviour prediction tables in Gould *et al*. (2007b). Section 9.3 contains a table for translating the fuel hazard rating for each fuel layer into Vesta fuel hazard scores.

2.8 Effect on fire behaviour

Each table for assessing fuel hazard contains information on the effect that the fuel arrangement is likely to have on fire behaviour. This effect is for weather conditions equivalent to a Forest Fire Danger Index (FFDI) of 25 (McArthur 1973). An FFDI of 25 can be achieved in many ways. For the purposes of this guide the specific conditions required to achieve this are:

Temperature: 33°C	Relative Humidity: 25%	Wind Speed: 20km/h
Drought Factor: 10	Slope: 0°	

If weather conditions vary from those listed above the effect on fire behaviour will also vary.

2.9 Fuel assessment data sheet

Appendix 2 contains a sample field data sheet that can be used when assessing fuels.

3. Bark fine fuel

3.1 Identification

Bark fuel is the bark on tree trunks and branches. Bark lying on or near the ground or draped over understorey plants is considered to be surface, near-surface or elevated fuel.

3.2 Identifying bark types

The key attributes for assessing the effect of bark on suppression difficulty are shown below:

Key attribute	Determines	How it is assessed
Ease of ignition	• How readily the bark will ignite. • Whether the fire will burn up the trunk and into the branches of the tree.	Thickness, size and shape of bark pieces.
How bark is attached	• How likely the bark is to break off the tree.	How easily the bark breaks off the tree.
Quantity of combustible bark	• Volume of potential embers that a fire may generate.	Relative quantity of combustible bark.
Size-to-weight ratio of the bark pieces	• How far the wind is likely to carry bark pieces once they break off the tree.	Thickness, size and shape of bark pieces.
Burn out time	• Length of time a piece of bark will stay ignited once it breaks off the tree.	Thickness, size and shape of bark pieces.

Descriptions of trees have been separated into three broad bark types using three of these key attributes – ease of ignition, burn out time and size-to-weight ratio:

1. Fine fibrous barks, including stringybarks
2. Ribbon or candle barks
3. Other bark types, including smooth, platy, papery and coarsely fibrous. The reason for describing these types in some detail is to help observers distinguish them from the above two types.

3.3 Identifying Stringybark and other fine fibrous bark types

Contribution to suppression difficulty	• Bark types that can produce massive quantities of embers and short distance spotting.
Physical description	• Bark is fine fibrous material with easily visible fibres less than 1mm thick covering the whole trunk. • Bark fibres resemble the fine fibres that are twisted together to form natural string. • Old bark is retained on the trunk of the tree for decades, forming a relatively spongy fibrous mass with deep vertical fissures. • Outer bark may weather to a greyish colour, while underlying bark retains its original colour. • Bark may form large strands when peeled off. • Fine, hairlike pieces also break off from the tree when it is rubbed.
Ease of ignition	• Bark is very flammable (can be easily lit with a match when dry). • Fires will readily climb the tree and branches.
How bark is attached	• Young or new bark is held tightly to the trunk. • As bark ages it becomes less tightly held. • Old, long-unburnt bark is held very loosely.
Quantity of combustible bark	• Bark on old, long-unburnt stringybarks can be more than 10cm in depth. During fires it can produce massive quantities of embers.
Size-to-weight ratio	Burning pieces of bark tend to be either: • Very fine lightweight fibres that will be carried for less than 100m. • Small lightweight wads (about the size of a thumb) that will be carried for less than 300m. • Very large wads (bigger than a fist) that fall close to the tree.
Burn out time	• Very fine fibres of bark that will burn out within one minute. • Small wads of bark that will burn out within 2–3 minutes. • Very large wads of bark that will burn for up to 10 minutes.
Hazard accumulation	• Bark hazard can reach Extreme. • Bark hazard increases over time as the thickness and looseness of the old bark increases. • Repeated low intensity fires (<0.5m flame height) may produce a 'black sock' effect on the base of the trunk, but this may have limited effect in reducing the overall quantity of bark and the hazard.

Examples

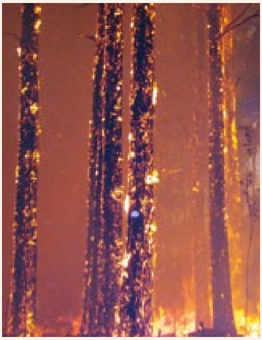


Table 3.1 Assessing the hazard of fine fibrous bark types including stringybarks

Only use this table if at least 10% of the trees in a forest have fine fibrous bark. To achieve a given hazard rating a best fit of both key attributes should be sought. Choices for the hazard rating of fuels that fit across several descriptions may be informed by the effect that different levels of key attributes have on fire behaviour.

Key attributes		Hazard rating	Effect on fire behaviour (at FFDI 25)[1]
How bark is attached	**Quantity of combustible bark**		
This hazard rating cannot occur when only this bark type is present.		Low	
Bark tightly held. Requires substantial effort to break off bark by hand.	Very little combustible bark. Entire trunk almost completely black or charred.	Moderate	Spotting generally does not hinder fire control. Fires will not climb these trees.
Bark is mostly tightly held with a few pieces loosely attached.	Limited amount of combustible bark. 50–90% of trunk charred. Most of the bark is charred, especially on the lower part of the trunk.	High	Infrequent spotting. Fires will climb some of these trees.
Many pieces of bark loosely held. Deep fissures present in bark.	Large amounts of combustible bark. 10–50% of trunk charred. Upper parts of the tree may not be charred at all.	Very High	Substantial spotting. Fires will climb most of these trees.
Outer bark on trees is weakly attached. Light hand pressure will break off large wads of bark. Deep fissures present in bark.	Huge amounts of combustible bark. <10% of trunk charred. Minimal evidence of charring.	Extreme	Quantity of spotting generated makes fire control very difficult or impossible. Fires will climb virtually all these trees.

Assess bark hazard over a plot 20m in radius. Assessing multiple plots will give better results. Trunk is defined as being the part of the tree between the ground and the branches.

See Section 9.3 for application of bark hazard ratings for the Vesta fire behaviour tables.

1 FFDI 25 is a Forest Fire Danger Index of 25 (McArthur 1973). Refer to Section 2.8 for the specific weather conditions used to achieve this FFDI.

Table 3.2 Examples of Stringybarks and other fine fibrous bark hazard

Low	This hazard rating cannot occur when only this bark type is present.		
Moderate			
High			
Very High			
Extreme			

The photos above show some of the variation possible within each bark hazard rating.

3.4 Identifying ribbon or candle bark types

		Example
Effect on suppression difficulty	• Bark types that can produce substantial quantities of spotting at distances greater than 2km. Will also produce short distance spotting.	
Physical description	• Trees characterised by the annual shedding of old bark layers, exposing the smooth new bark underneath. • Bark is shed in the form of long strips or ribbons of bark. • Long strips of bark curl tightly inwards to form a candle-like shape (see image lower right). • Bark strips 50cm or more in length fall off and often drape around the trunk and over branches and surrounding shrubs. • Strips of bark are usually less than 2mm thick. • Bark is shed at various times of the year so that the trunk may have a mottled appearance.	
Ease of ignition	• Bark is moderately flammable (can be lit with a cigarette lighter when dry). • Fires will climb up ribbons of bark.	
How bark is attached	• Bark strips may drape over, or be weakly attached to, the trunk and branches.	
Quantity of combustible bark	• Large quantities of bark can be retained in upper trunk and head of the tree.	
Size-to-weight ratio	• Bark pieces are relatively light for their large size. • Easily transported by strong updrafts – may travel up to 30km downwind.	
Burn out time	• Bark can burn and smoulder within the curled up ribbons for longer than 10 minutes.	
Hazard accumulation	• Bark hazard never exceeds Very High. • Bark hazard tends to increase over the long term as ribbons accumulate on the tree. • A low intensity fire (flame height of less than 0.5m) may not reduce the hazard in this bark type.	

Note: Loose ribbon or candle-like bark that is retained on the trunk near ground level is not included in the assessment of ribbon or candle bark types. It is usually:

- firmly attached to the trunk of the tree
- consumed in place by a surface fire.

This bark is considered in 'Other bark types' and can also be considered as near-surface fuel.

Smooth-bark trees also shed bark as slabs or flakes. These bark types are considered in 'Other bark types'.

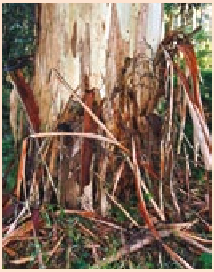


Table 3.3 Assessing the hazard of ribbon or candle bark types

If more than 10% of the trees in a forest are fine fibrous bark trees use Table 3.1 (Assessing the hazard of fine fibrous bark types) to determine the bark hazard for a site.

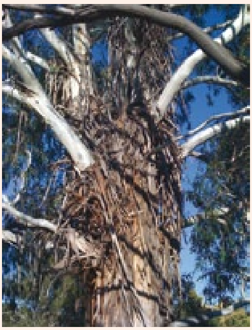
Key attribute Amount of combustible bark	Hazard rating	Effect on fire behaviour (at FFDI 25)[2]
This hazard rating cannot occur when only this bark type is present.	Low	
No long ribbons of bark present. Trunk and branches of trees almost entirely smooth.	Moderate	Spotting generally does not hinder fire control. Fires will not climb these trees.
Long ribbons of bark present on upper trunk (>4m above ground) and in head of trees. Lower trunk mainly smooth.	High	Infrequent spotting. Fires will climb some of these trees.
Long ribbons of bark in the head and upper trunk with: • ribbons hanging down to ground level or, • flammable bark covers trunk.	Very High	Substantial spotting. Fires will climb most of these trees.
This hazard rating cannot occur when only this bark type is present.	Extreme	

Assess bark hazard over a plot 20m in radius. Assessing multiple plots will give better results. Trunk is defined as the part of the tree between the ground and the branches.

See Section 9.3 for application of bark hazard ratings for the Vesta fire behaviour tables.

2 Refer to Section 2.8 for the specific weather conditions used to achieve this FFDI.

Table 3.4 Examples of ribbon or candle bark hazard

Low	This hazard rating cannot occur when only this bark type is present.		
Moderate			
High			
Very High			
Extreme	This hazard rating cannot occur when only this bark type is present.		

3.5 Identifying other bark types

This bark type includes all other bark types not included in the previous two types. As a result, many different tree species are grouped together. This grouping is based on the ease of ignition, burn out time and size-to-weight ratio of the bark, rather than on botanical values. These other bark types can produce limited quantities of short distance spotting.

This bark type group has been divided into several subgroups. These subgroups are described in some detail to help observers distinguish them from the other two main bark types.

3.5.1 Ironbarks and Platy barks

		Example
Physical description	• Trees characterised by layers of old, coarse bark retained on the trunk and branches. • Bark becomes rough, compacted and furrowed with age • Bark feels very abrasive when rubbed by hand. • Bark pieces tend to be more than 2mm thick when they break off. • There may be little or no evidence of charring on the bark following planned burns.	
Hazard accumulation	• Bark hazard never exceeds Moderate.	

3.5.2 Coarsely fibrous barks

Physical description	• Trees characterised by short strand fibrous bark. • Layers of old dead bark are retained on the trunk and branches. • Unlike stringybark trees, the bark on these trees forms only short strands or chunks when peeled off. • Evidence of charring on the bark may last for up to 10 years.	
Hazard accumulation	• Bark hazard never exceeds High. • Bark hazard increases over the long term as the thickness and looseness of the old bark increases.	

3.5.3 Papery barks

Physical description	• Shrubs and trees growing from 2m to 30m tall, often with flaky shedding bark. • Old bark is retained on the trunk and branches and builds up into a thick spongy mass. • Bark layers tend to split allowing sheets of bark to become loose and eventually peel off. • Evidence of charring on the bark may last for up to 10 years.	**Example** 
Hazard accumulation	• Bark hazard never exceeds High. • Bark hazard increases over the long term as the thickness and looseness of the old bark increases.	

3.5.4 Slab bark, smooth bark and small flakes

Physical description	• Trees characterised by the annual shedding of old bark layers, exposing the smooth living bark underneath. • Bark shed is often seasonal and often annual. • Species where the old bark tends to peel into large slabs (<50cm in length) or small flakes when shed. • Most of the bark falls off the tree soon after it is shed. • Some small amounts of bark may be retained on the stem or branches for several months before falling off, leading to a mottled effect. • The mottled effect leads to discontinuous bark fuel up the tree.	**Example** 
Hazard accumulation	• Bark hazard never exceeds Moderate. • Bark hazard tends to be seasonal.	

Table 3.5 Assessing the hazard of other bark types

If more than 10% of the trees in a forest are fine fibrous bark trees use Table 3.1 (Assessing the hazard of fine fibrous bark types) to determine the bark hazard for a site. To achieve a given hazard rating a best fit of both key attributes should be sought. Choices for the hazard rating of fuels that fit across several descriptions may be informed by the effect that different levels of key attributes have on fire behaviour.

Key attributes		Hazard rating	Effect on fire behaviour (at FFDI 25)[3]
How bark is attached	**Quantity of combustible bark**		
No trees present. or Trunk and branches of tree entirely smooth or free from loose bark.		Low	No bark present that could contribute to fire behaviour.
Bark rubs off by hand with firm pressure.	Limited amount of combustible bark.	Moderate	Spotting generally does not hinder fire control. Fires will climb some of these trees.
Light hand pressure will break bark off.	Large amounts of combustible bark.	High	Infrequent spotting. Fires will climb most of these trees.
This hazard rating cannot occur when only this bark type is present.		Very High	
This hazard rating cannot occur when only this bark type is present.		Extreme	

Assess bark hazard over a plot 20m in radius. Assessing multiple plots will give better results. Trunk is defined as the part of the tree between the ground and the branches.

See Section 9.3 for application of bark hazard ratings for the Vesta fire behaviour tables.

3 Refer to Section 2.8 for the specific weather conditions used to achieve this FFDI.

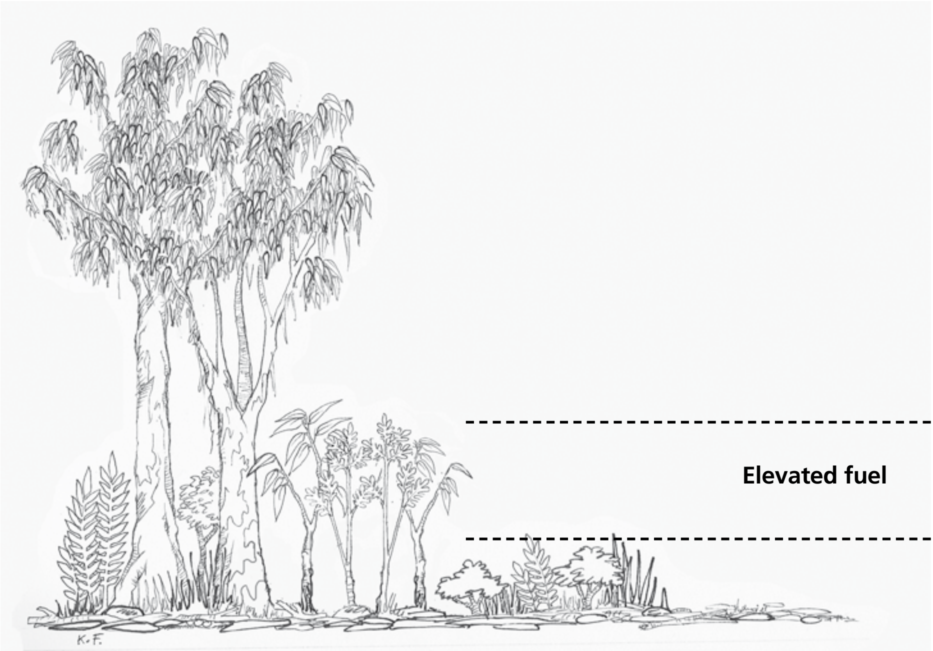
Table 3.6 Examples of other bark types

Low	No trees present. or Trunk and branches of tree entirely smooth or free from loose bark.		
Moderate			
High			
Very High	Does not occur when this is the only bark type present on a site.		
Extreme	Does not occur when this is the only bark type present on a site.		

4. Elevated fine fuel

4.1 Identification

- Fuels are mainly upright in orientation
- Generally most of the plant material is closer to the top of this layer
- Sometimes contains suspended leaves, bark or twigs
- Fuels that have a clear gap between them and the surface fuels
- Elevated fuel can be highly variable in ground coverage
- A low intensity fire (flame height of less than 0.5m) may pass beneath this layer without consuming much, if any, of it.



4.2 Assessment

The elevated fuel hazard is highest when the:

- foliage, twigs and other fuel particles are very fine (maximum thickness 1–2mm)
- proportion of dead material is high
- fuels are arranged with a high level of density and/or horizontal and vertical continuity that promotes the spread of flames
- live foliage has low fuel moisture content.

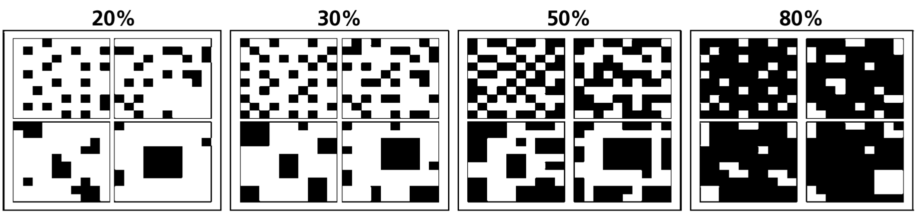
Table 4.1 Assessing elevated fine fuel hazard

To achieve a given hazard rating a best fit of all key attributes should be sought. Choices for the hazard rating of fuels that fit across several descriptions may be informed by the effect that different levels of key attributes have on fire behaviour.

Key attributes					Fuel hazard rating	Effect on fire behaviour (at FFDI 25)[4]
Plant Cover	**% dead**	**Vertical continuity**	**Vegetation density**	**Thickness of fuel pieces**		
<20% or low flammability species	<20%		Easy to walk in any direction without needing to choose a path between shrubs.		Low	Little or no effect.
20–30%	<20%	Most of the fine fuel is at the top of the layer.	Easy to choose a path through but brush against vegetation occasionally.		Moderate	Does not sustain flames readily.
30–50%	<20%	Most of the fine fuel is at the top of the layer.	Moderately easy to choose a path through, but brush against vegetation most of the time.		High	Causes some patchy increases in the flame height and/or rate of spread of a fire.
50–80%	20–30%	Continuous fine fuel from the bottom to the top of the layer.	Need to carefully select path through.	Mostly less than 1–2mm thick.	Very High	Elevated fuels mostly dictate flame height and rate of spread of a fire.
>70%	>30%	Continuous fine fuel from the bottom to the top of the layer.	Very difficult to select a path through. Need to push through vegetation.	Large amounts of fuel <2mm thick.	Extreme	Elevated fuels almost entirely determine the flame height and rate of spread of a fire.

Assessing plant cover

For the purpose of this guide, plant cover is defined as the amount of ground blocked out by that fuel layer if viewed while looking straight down from above. Each plant is considered opaque – any ground within the perimeter of the plant cannot be seen. The following visual guide can be used to assist in assessing plant cover. Each quarter of any one square has the same percent cover.



4 Refer to Section 2.8 for the specific weather conditions used to achieve this FFDI.

Table 4.2 Examples of elevated fine fuel hazard

Low	Elevated fuel absent or virtually absent	
Moderate		
High		
Very High		
Extreme		

Assess elevated hazard over a plot 10m in radius. Assessing multiple plots will give better results.

See Section 9.3 for application of elevated fuel hazard ratings for the Vesta fire behaviour tables. For the Vesta fire behaviour tables the elevated fuel height (m) should be the average of 10 measurements taken along a 300m walk-through. Measure the typical height from ground level.

5. Near-surface fine fuel

5.1 Identification

- Live and dead fuels effectively in touch with the ground but not lying on it
- Fuel has a mixture of vertical and horizontal orientation
- Either the bulk of the fuels is closer to the ground than the top of this layer, or is distributed fairly evenly from the ground up
- Sometimes contains suspended leaves, bark or twigs
- Coverage may range from continuous to having gaps many times the size of the fuel patch
- A low intensity fire (flame height of less than 0.5m) will consume most or all of this fuel
- Fuel in this layer will always burn when the surface fuel layer burns.

5.2 Assessment

The near-surface fuel hazard is highest when the:

- foliage, twigs and other fine fuel particles are very fine (maximum thickness 1–2mm)
- proportion of dead material is high
- fuels are arranged with a high level of density and /or horizontal and vertical continuity, that promotes the spread of flames
- live foliage has low fuel-moisture content.

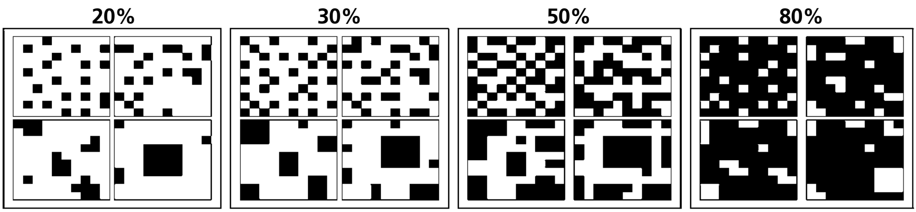
Table 5.1 Assessing near-surface fine fuel hazard

To achieve a given hazard rating a best fit of all key attributes should be sought. Choices for the hazard rating of fuels that fit across several descriptions may be informed by the effect that different levels of key attributes have on fire behaviour.

Key attributes			Fuel hazard rating	Effect on fire behaviour (at FFDI 25)[5]
Plant cover	**% dead**	**Horizontal connectivity**		
<10%	<10%	Near-surface fuel is absent or virtually absent.	Low	Little or no effect.
10–20%	<20%	Gaps many times the size of fuel patches.	Moderate	Occasionally increases flame height.
20–40%	>20%	Gaps between fuel patches are greater than the size of fuel patches. Starting to obscure logs and rocks.	High	Contributes to surface fire spread and causes patchy increase to flame height.
40–60%	>30%	Fuel patches are equal to or larger than the gaps between the fuel patches.	Very High	Contributes significantly to fire spread and flame height. A fire will spread readily in this layer without having to consume the surface layer.
>60%	>50%	Very small gaps between fuel patches. Logs and rocks obscured.	Extreme	Contributes significantly to fire spread and flame height. A fire will spread readily in this layer without having to consume the surface layer.

Assessing plant cover

For the purpose of this guide, plant cover is defined as the amount of ground blocked out by that fuel layer if viewed while looking straight down from above. Each plant is considered opaque – any ground within the perimeter of the plant cannot be seen. The following visual guide can be used to assist in assessing plant cover. Each quarter of any one square has the same percent cover.



5 Refer to Section 2.8 for the specific weather conditions used to achieve this FFDI.

Table 5.2 Examples of near-surface fine fuel hazard

Low	Near-surface fuel is absent or virtually absent	
Moderate		
High		
Very High		
Extreme		

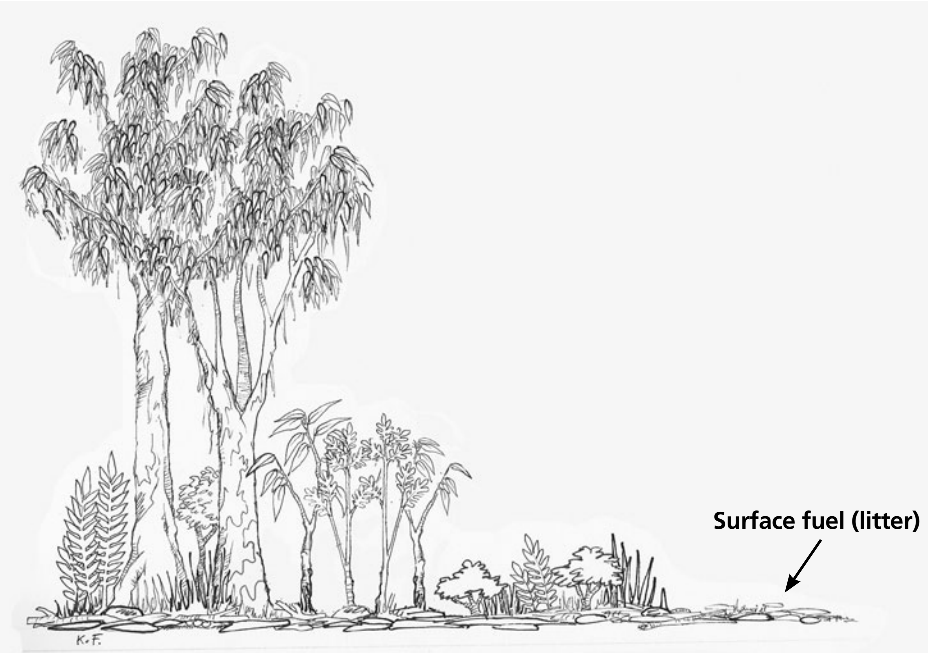
Assess near-surface hazard over a plot 10m in radius. Assessing multiple plots will give better results.

See Section 9.3 for application of near-surface fuel hazard ratings for the Vesta fire behaviour tables. For the Vesta fire behaviour tables the near-surface fuel height (cm) should be the average of 10 measurements taken over a 300m walk through. Measure the typical height from ground level.

6. Surface fine fuel

6.1 Identification

- Leaves, twigs, bark and other fine fuel lying on the ground
- Predominantly horizontal in orientation
- Usually contributes the most to fuel load or quantity
- Includes the partly decomposed fuel (duff) on the soil surface.



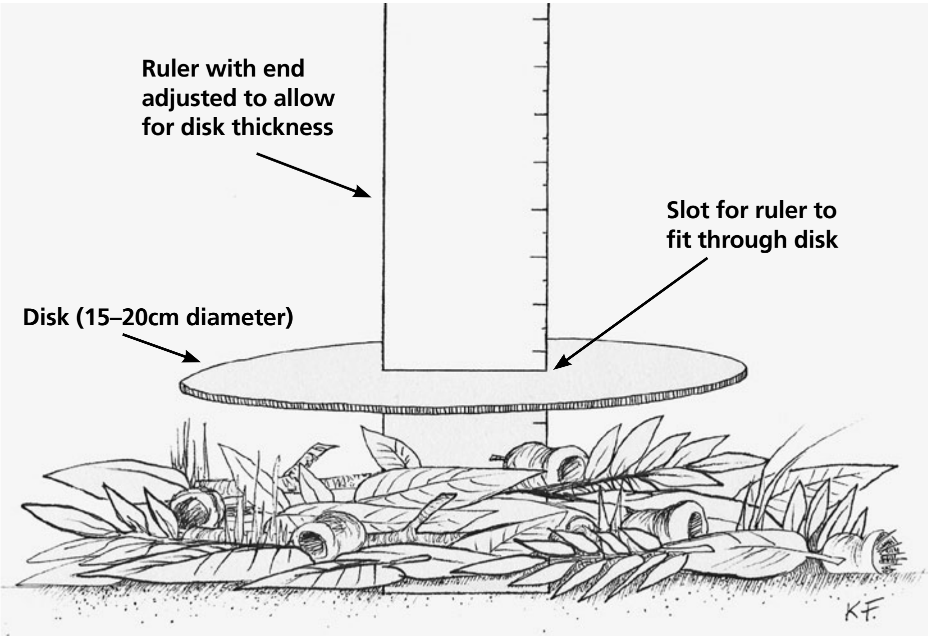
6.2 Assessment

The surface fine fuel hazard is highest when the:

- litter pieces are well connected
- surface litter cover is high, with minimal interruption from rocks, logs or patches of bare soil
- surface litter has substantial depth (greater than 30mm).

6.3 Measurement

Surface litter-bed depth should be measured using a simple depth gauge, as pictured below. This follows the methodology described in McCarthy (2004) and McCarthy *et al*. (1999).



Litter depth should be measured in areas where near-surface fuels do not obscure the litter. Fuel depth is measured using a 15cm circular disk with a ruler through a slot in its centre. To use this gauge, a small gap is made in the litter bed down to mineral soil, then the end of the ruler is placed resting on the mineral soil surface. The disk is pushed down with light pressure until its whole perimeter is in contact with the fuel. Light pressure can be described as 'enough pressure to hold a tennis ball under water'. The ruler is read off level with the top of the disk. Note that the end of the ruler needs to be adjusted to match the thickness of the disk.

Five measurements of litter bed depth should be made at each site. The average of these measurements is one of the attributes that can be used to determine the surface fine fuel hazard.

Table 6.1 Assessing surface fine fuel hazard

To achieve a given hazard rating a best fit of all key attributes should be sought. Choices for the hazard rating of fuels that fit across several descriptions may be informed by the effect that different levels of key attributes have on fire behaviour.

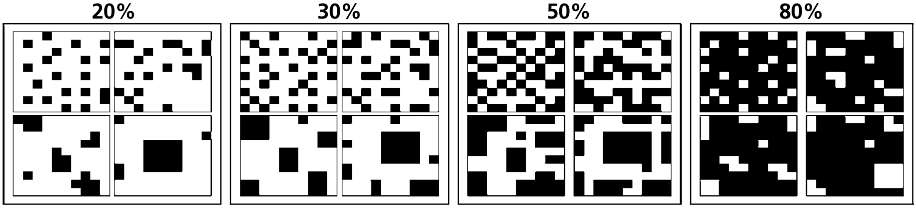
Key attributes			Fuel hazard rating	Effect on fire behaviour (at FFDI 25)[6]
Horizontal connectivity	**Surface litter cover**	**Litter-bed depth**		
Litter poorly interconnected. Large areas of bare soil or rock. More soil than litter. Soil surface readily visible through litter bed.	<60%	Very thin litter layer <10mm	Low	Surface fires will not spread.
Litter well connected. Some areas of bare soil or rock. Soil surface occasionally visible through litter bed.	60–80%	Thin litter layer 10–25mm	Moderate	Litter connected well enough to allow fire spread to overcome bare patches.
Litter well connected. Little bare soil.	80–90%	Established litter with layers of leaves ranging from freshly fallen to decomposing. 20–30mm	High	Surface fires spread easily with a continuous fire edge.
Litter completely connected.	>90%	Thick litter layer 25–45mm	Very High	Surface fires spread easily. Increasing flame depth and residence time.
Litter completely connected.	>95%	Very thick layer of litter >35mm	Extreme	Surface fires spread easily. Increasing flame depth and residence time.

Assess surface hazard over a plot 10m in radius. Assessing multiple plots will give better results. For each plot litter bed depth should be an average of five measurements (McCarthy 2004) or more.

See Section 9.3 for application of surface fuel hazard ratings for the Vesta fire behaviour tables.

The following visual guide can be used to assist in assessing surface litter cover. Each quarter of any one square has the same percent cover.

20% **30%** **50%** **80%**



6 Refer to Section 2.8 for the specific weather conditions used to achieve this FFDI.

Table 6.2 Examples of surface fine fuel hazard

Low		
Moderate		
High		
Very High		
Extreme		

7. Determining the combined surface and near-surface fine fuel hazard rating

Assessments of surface and near-surface fuels must be combined together before an Overall Fuel Hazard rating can be determined. The near-surface fuel rating is used to adjust the surface fine fuel hazard rating, according to Table 7.1.

To determine the effect of near-surface fine fuel hazard:

1. Select the **surface fuel hazard rating** from column ❶
2. Select the **near-surface fuel hazard rating** from column ❷
3. Select the resulting **combined rating** value ❸
4. Use this value to determine the Overall Fuel Hazard rating using the Table 8.1.

Table 7.1 Determining the combined surface and near-surface fine fuel hazard rating

❶ Surface fine fuel hazard rating	❷ Near-surface fine fuel hazard rating				
	Low	Moderate	High	Very High	Extreme
	❸ Combined surface and near-surface fine fuel hazard rating				
Low	L	L	M	H	VH
Moderate	M	M	H	VH	E
High	H	VH	VH	VH	E
Very High	VH	VH	E	E	E
Extreme	E	E	E	E	E

8. Determining Overall Fuel Hazard

Overall Fuel Hazard = (sum of the influences of) Bark Hazard + Elevated Fine Fuel Hazard + Combined Surface and Near-surface Fine Fuel Hazard.

The following table is used to combine the assessed levels of Bark, Elevated and Combined Surface and Near-surface Fuel Hazard to give an Overall Fuel Hazard rating.

To determine the Overall Fuel Hazard rating:

1. Select the row that corresponds to the **Bark Hazard** ①
2. Select the row that corresponds to the **Elevated Fine Fuel Hazard** ②
3. Select the column that corresponds to the assessed level of **Combined Surface and Near-surface Fine Fuel Hazard** ③
4. Identify where these two intersect and this will provide you with the corresponding Overall Fuel Hazard rating.

Table 8.1 Determining the Overall Fuel Hazard rating

① Bark Hazard	② Elevated Fine Fuel Hazard	③ Combined Surface and Near-surface Fine Fuel Hazard *				
		L	M	H	VH	E
Low or Moderate	L	L	M	M	H	H
	M	L	M	M	H	H
	H	L	M	H	VH	VH
	VH	VH	VH	VH	VH	VH
	E	E	E	E	E	E
High	L	L	M	H	H	H
	M	L	M	H	H	H
	H	L	H	H	VH	VH
	VH	VH	VH	VH	VH	E
	E	E	E	E	E	E
Very High or Extreme	L	L	VH	VH	VH	E
	M	M	VH	VH	E	E
	H	M	VH	E	E	E
	VH	E	E	E	E	E
	E	E	E	E	E	E

* Combined Surface and Near-surface Fine Fuel Hazard is a measure of the Surface Fine Fuel Hazard adjusted to account for the level of near-surface fine fuel (see Table 7.1).

9. Interpreting and applying Overall Fuel Hazard

9.1 Chances of extended first attack success

The chances of extended first attack being successful[1] for a fire ignited in these fuels under the reference extended first attack conditions (Appendix 1) is approximately as follows:

Table 9.1 Chances of extended first attack success

GFDI[2]	FFDI[3]	Overall Fuel Hazard rating[4]				
		Low	Moderate	High	Very High	Extreme
0–2	0–5	Green	Green	Green	Green	Yellow
3–7	6–11	Green	Green	Green	Green	Yellow
8–20	12–24	Green	Green	Green	Yellow	Orange
20–49	25–49	Green	Green	Yellow	Orange	Orange
50–74	50–74	Green	Yellow	Orange	Orange	Red
75–99	75–99	Green	Orange	Red	Red	Red
100+	100+	Green	Orange	Red	Red	Red

- Green: Chance of extended first attack success is greater than 95% (almost always succeeds)
- Yellow: Chance of extended first attack success is between 95% and 50% (succeeds most of the time)
- Orange: Chance of extended first attack success is between 49% and 10% (fails most of the time)
- Red: Chance of extended first attack success is less than 10% (almost always fails)

Notes:

1. Extended first attack is deemed successful when a fire is controlled by 0800hrs the day after ignition and at less than 400 hectares.
2. GFDI is the Grass Fire Danger Index at the time of ignition and is assumed to be the highest GFDI expected before 0800hrs the next day.
3. FFDI is the Forest Fire Danger Index at the time of ignition and is assumed to be the highest FFDI expected before 0800hrs the next day.
4. Chance of success is for a fire ignited in fuels with this Overall Fuel Hazard rating.
5. Predicted outcomes will differ if the conditions vary from those listed in the reference extended first attack conditions.
6. Predicted outcomes based on expert opinion and informed by work carried out by Wilson (1992b, 1993), McCarthy *et al*. (1998a, 2001) and Plucinski *et al*. (2007).

9.2 Indicative fuel loads (t/ha)

In the absence of local data obtained by sampling fuel loads destructively the following table of indicative fuel load data from Project Vesta and Victorian studies may be useful. These tonnes per hectare figures may be applied to the Forest Fire Danger Meter Mark V (McArthur 1973) for predicting forward rate of spread and flame height for forest fires.

Table 9.2 Indicative fuel loads (t/ha)

Fuel	Fuel hazard rating				
	Low	Moderate	High	Very High	Extreme
Bark	0	1	2	5	7
Elevated	0–1	1–2	2–3	3–5	5–8
Near-surface	1–2	2–3	3–4	4–6	6–8
Surface	2–4	4–10	8–14	12–20	16–20+

9.3 Determining Vesta fuel hazard scores

The following table translates fuel hazard ratings for each fuel layer into Project Vesta fuel hazard scores. These scores can be used with the fire behaviour prediction tables in publications such as Gould *et al*. (2007b).

To determine the Vesta fuel hazard score:

1. Select the row that corresponds to the fuel hazard rating for required fuel layer ①
2. Select the Vesta fuel hazard score column that corresponds to the same layer ❷
3. Identify where these two intersect and this will provide you with the corresponding Vesta fuel hazard score.

Table 9.3 Determining Vesta fuel hazard scores

	Vesta fuel hazard score ②			
Fuel hazard rating ①	**Surface**	**Near-surface**	**Elevated**	**Bark**
Low	1	1	1	0
Moderate	2	2	2	1
High	3	3	3	2
Very High	3.5	3.5	3.5	3
Extreme	4	4	4	4

Notes:

- Surface and near-surface hazard score and near-surface height (cm) is required for fire spread prediction.
- Rate of spread and elevated fuel height (m) is required for flame height prediction.
- Rate of spread, surface and bark fuel hazard scores are required for prediction of spotting distance.

Acknowledgements

This Fuel Hazard Assessment Guide updates and continues to develop work previously conducted by a number of authors. Andrew Wilson laid the foundations for this guide, with the conceptual framework presented in Research Report No. 31; and the visual guides for assessing the influence of bark and elevated fuels on suppression difficulty in the *Eucalypt Bark Hazard Guide and Elevated Fuel Guide* (Reports 32 and 35, respectively). Greg McCarthy (2004) detailed a method for rapidly assessing surface fine fuels in Research Report No. 44.

These three techniques were brought together in the first three editions of the *Overall Fuel Hazard Guide* (McCarthy, Tolhurst and Chatto, 1998b, 1998c, 1999). A subsequent unpublished edition of the guide, produced by Kevin Tolhurst (2005), provided greater detail on the assessment of near-surface fuels. In 2006, Mike Wouters adapted the guide for South Australian conditions, and incorporated the preliminary results from Project Vesta (CSIRO and Department of Conservation and Environment, Western Australia). Further information and results from the final Project Vesta report (Gould *et al.* 2007a) have also been incorporated.

Thanks to Lachie McCaw (Department of Environment and Conservation, Western Australia), Mike Wouters (Department of Environment and Heritage, South Australia), Jim Gould and Miguel Cruz (CSIRO) for their advice and comments during the production of this guide. Thanks must also go to the many other people across Australia who have provided comments and feedback during the production of the guide.

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Wilson, AAG 1993, *Elevated fuel guide*, research report no. 35, Fire Management Branch, Department of Conservation and Environment, Victoria.

Appendix 1. Reference extended first attack conditions

This guide assesses the impact of fuels in suppressing a fire during extended first attack, using local resources. Several factors affect the success of an extended first attack. Therefore, to consider the impact of fuels alone, the other factors must be treated as if they were constant. Table A1 below adapted from Wilson (1993) summarises reference extended first attack conditions for four fuel types.

Table A1. Revised reference extended first attack conditions

Fuel type	Forest fuels	Grass fuels	Mallee and scrub fuels	Heath fuels
Examples of typical resources (on scene within the designated arrival time)	Small dozer (D4) 1 to 2 small 4WD tankers (400l) 6 firefighters	5 x 4WD heavy tankers (4000l) each with 5 firefighters	Small dozer (D4) or tractor with scrub roller 1 to 2 small 4WD tankers (400l) 6 firefighters	Small dozer (D4) 1 to 2 small 4WD tankers (400l) 6 firefighters
Extended attack resources	Potential additional resources deployed to the fire during extended first attack may include heavy tankers, large plant (dozers, graders or tractors) and fire bombing aircraft.			
Arrival time	Within 60 minutes of detection			
Suppression workload	A single fire			
Topography and terrain	Burning on level ground with good access			
Fuel availability[1]	MDF is 10 or AFF is 1.0	100% grass curing	MDF is 10 or AFF is 1.0	
Wind speed[2]	20km/h	30km/h		20km/h
Fire danger rating system[3]	McArthur FFDI	McArthur GFDI	McArthur FFDI	

Notes:

1. MDF (McArthur Drought Factor) is calculated using the Forest Fire Danger Meter (McArthur 1973) and is a measure of the short-term availability of forest fuels. AFF (Available Fuel Factor) is used in Western Australia to define the proportion of litter fuel available for burning (Sneeuwjagt & Peet 1998).
2. Wind speed is measured at 10m height in the open above ground level.
3. FFDI is the McArthur Forest Fire Danger Index, GFDI is the McArthur Grass Fire Danger Index.

The rationale for the reference first attack conditions is documented in DSE's *Overall fuel hazard assessment guide: a rationale report – fire and adaptive management report no. 83* (in prep).

Appendix 2. Sample fuel assessment field work form

Date Assessed:	Assessors:
Sampling Location:	Veg Type:

Plot Information			
Plot No.			
Zone:			
Easting (GDA94 MGA UTM):			
Northing (GDA94 MGA UTM):			

Canopy (20m radius)			
Canopy Ave Height to Top:	m	m	m
Canopy Ave Height to Base:	m	m	m

Bark fuel (20m radius)			
Stringybark Fuel Hazard:	NP M H VH E	NP M H VH E	NP M H VH E
Ribbon Bark Fuel Hazard:	NP M H VH	NP M H VH	NP M H VH
Other Bark Fuel Hazard:	L M H	L M H	L M H

Note: NP is bark type not present. Use the highest bark hazard rating to determine Overall Fuel Hazard.

Elevated fuel layer (10m radius)			
Elevated % Cover:	%	%	%
Elevated % Dead	%	%	%
Elevated Fuel Ave Height (m)	m	m	m
Elevated Fuel Hazard:	L M H VH E	L M H VH E	L M H VH E

Near-surface fuel layer (10m radius)			
Near-surface % Cover:	%	%	%
Near-surface % Dead	%	%	%
NS Ave Height (cm):	cm	cm	cm
NS Fuel Hazard:	L M H VH E	L M H VH E	L M H VH E

Surface fuel layer (10m radius)			
Surface Litter % Cover:	%	%	%
Ave Litter Depth (mm):	mm	mm	mm
Surface Fuel Hazard	L M H VH E	L M H VH E	L M H VH E

Combined Surface and Near-surface Fine Fuel Hazard calculation (refer Section 7)			
Combined Hazard	L M H VH E	L M H VH E	L M H VH E

Overall Fuel Hazard calculation (refer Section 8)			
Overall Fuel Hazard	L M H VH E	L M H VH E	L M H VH E

Are the plots representative of the average fuels across the sampling location?	Yes	No

If no, explain any significant difference between plots. For example, wet gully runs through the sampling area, no plots were located in this gully.


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