PUAFIR213

Assist with prescribed burning

LEARNER
RESOURCE

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This learner resource was originally prepared by Ross Runnalls and was reviewed by Tony Blanks. Benjamin Smith (AFAC), Jenise Blaik (Queensland Parks and Wildlife Service) and Wayne Kington (AFAC) refined the learner resource to align to best practice National Guidelines for Prescribed Burning Operations (AFAC 2016a) prepared by Paul de Mar and Dominic Adshead of GHD. Development of the learner resource was guided by Sandra Lunardi and Gary Featherston of AFAC.

The significant input, contributions and review of material by staff from AFAC's member agencies is recognised and highly appreciated. Other valuable contributions, including photographs, were received from other agency staff and their contributions are also appreciated.

Overview

The conduct of a prescribed burn requires a team approach from the time of ignition through to when the fire is made safe and extinguished.

This learning resource will assist you to develop the skills and knowledge required to assist in prescribed burning activities. The participant undertaking this course of study will be required to work as a member of a crew. While there will be some supervision by the Officer-in-Charge, there will be situations where activities will be undertaken without direct supervision.

The learning resource is divided into eight sections, with a structured approach to prescribed burning.

- **Section 1** discusses of the uses of prescribed burning and the associated policy.
- **Section 2** discusses safe work practices when participating in a prescribed burn.
- **Section 3** examines working in a team and participating in team briefings.
- **Section 4** discusses fire behaviour and the factors that should be assessed in describing and predicting it.
- **Section 5** examines personal protective equipment and equipment and media used in igniting a prescribed burn and in patrol, blacking out and suppression of escapes.
- **Section 6** examines preparations for burning and ignition techniques and patterns.
- **Section 7** discusses the monitoring of a burn, the range of hazards that may be encountered and fire suppression techniques which may be required.
- **Section 8** discusses the post-burn activities of burn coverage estimation, blacking out and debriefing.

Suggested activities are included throughout the learning resource, and a series of self-check questions at the end of each section will assist you to monitor your progress and to support the learning process. A comprehensive glossary has also been included to assist in using this resource.

Learning objectives

On completion of this unit, you should be able to:

- describe types of prescribed burns and their application in broad terms
- work as a member of a crew and participate in briefings
- describe fire behaviour and factors that should be assessed in predicting and describing it
- describe and demonstrate the use of the range of equipment and chemicals employed in prescribed burning
- demonstrate and describe the preparation for and techniques used for lighting a prescribed burn

- identify and describe the hazards of firefighting and the range of techniques for fire suppression
- describe and demonstrate the procedures to be followed when blacking out and extinguishing a prescribed burn
- describe the procedure to be followed in debriefing a burning crew on completion of a prescribed burning operation.

The prescribed burning suite of learner resources

This learner resource is part of a family of **three learner resources**, which together cover the five Public Safety Training Package units of competency listed below:

- PUAFIR412 *Conduct simple prescribed burns*
- PUAFIR413 *Develop simple prescribed burn plans*
- PUAFIR511 *Conduct complex prescribed burns*
- PUAFIR513 *Develop complex prescribed burn plans*
- PUAFIR213 *Assist with prescribed burning*.

These five units of competency and their accompanying learner resources are orientated toward the needs of different audiences. Table 1 expresses the relationship between the resources and units along with a description of the typical audience for each.

Table 1: Relationship between the prescribed burning units of competency

Resource	*Simple Prescribed Burns*	*Complex Prescribed Burns*
Units of competency	PUAFIR413 Develop simple prescribed burn plans	PUAFIR513 Develop complex prescribed burn plans
	PUAFIR412 Conduct simple prescribed burns	PUAFIR511 Conduct complex prescribed burns
Typical Audience	Urban and rural fire personnel required to plan and/or supervise the conduct of **low risk, low intensity** prescribed burns.	Land management personnel and *some* rural fire personnel required to plan and/or supervise the conduct of prescribed burn operations **across a range of risk and fire-intensity levels**.

Resource	*Assist With Prescribed Burning*
Unit of competency	PUAFIR213 Assist with prescribed burning
Typical Audience	All personnel required to **assist under supervision** in the conduct of prescribed burns.

Prerequisite units

The units PUAFIR213 *Assist with prescribed burning*, PUAFIR204B *Respond to wildfire* and PUAFIR303B *Suppress wildfire* are the only nationally-specified prerequisite units for the four develop and conduct prescribed burning units. For PUAFIR213 *Assist with prescribed burning*, the only prerequisite is PUAFIR215 *Prevent injury*.

The prerequisite chain for all five prescribed-burning units is illustrated in Figure 1.

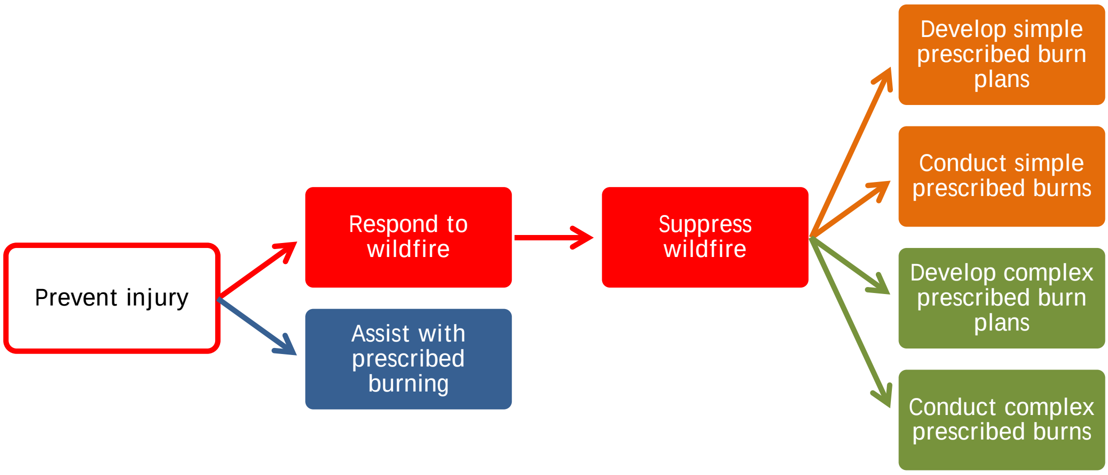


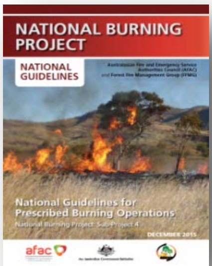
Figure 1: Prescribed burning units and their respective prerequisite units.

Please note that the specification of prerequisite units is intended to ensure the integrity of the qualifications to which they contribute is preserved, and the failure to hold a statements of attainment for any or all prerequisite units does not preclude personnel form receiving training in prescribed burning, nor will it prevent them from finding this manual useful. It will, however, prevent students from being able to receive a statement of attainment should they assessed competent against the performance criteria associated with a particular unit, and will prevent them from performing any role for which a statement of attainment in a prescribed burning unit is mandated until such time as a complete chain prerequisite units has been attained and the relevant prescribed burning unit has been awarded.

The National Burning Project

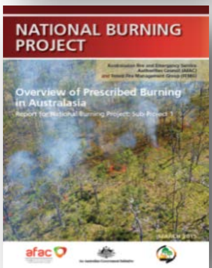
This prescribed burning learner resource form part of the suite of products produced as part of the National Burning Project. The National Burning Project is bringing together inter-related aspects of prescribed burning across Australasia to design guiding frameworks and principles for a more holistic and consistent approach to prescribed burning practices.

Students interested in further learning may be interested in the following products:



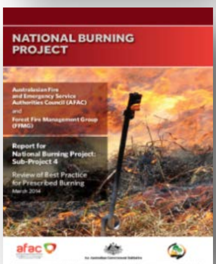
National Guidelines for Prescribed Burning Operations

Through consultation with member agencies, AFAC identified a framework of 17 principles that cover operational planning and implementation phases of prescribed burning. This framework will help align approaches while supporting planners and land managers with an interest in improving prescribed burning. This learner resource has been designed to align to this product.



Overview of Prescribed Burning in Australasia

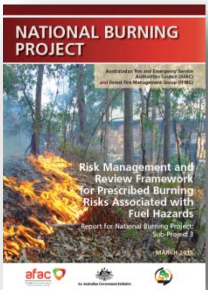
A great resource for students, this report is an introduction and overview of prescribed burning in Australasia, for those interested in the role of fire in the Australasian landscape, the origins of Australasian prescribed burning, its use as a bushfire management tool, its use for biodiversity outcomes, smoke and climate change concerns, and the evidence base that underpins the use of planned fire.

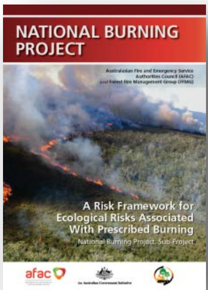


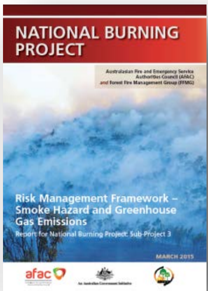
A Review of Best Practice for Prescribed Burning

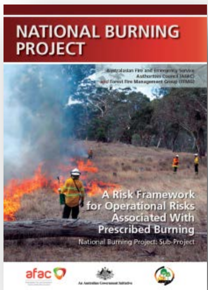
The report provides a detailed account of the prescribed burning practices that are considered to be examples of best practice. The practices north of the Tropic of Capricorn are described separately from those in southern Australia and New Zealand. The report is recommended to fire management practitioners and students of fire ecology.

In addition to the above, there are four risk frameworks available that consider management of risks in relation to fuel hazard, smoke and greenhouse emissions, ecology and operations.









All products are available from **www.afac.com.au/initiative/burning**.

Section

1

Policy for prescribed burning

Section

1

Policy, principles and organisational environment

This section covers the policy, principles and organisational environments that guide prescribed burning.

Prescribed burning is defined as:

> the controlled application of fire under specified environmental conditions to a predetermined area, and at a time, intensity, and rate of spread required to attain planned resource-management objectives (AFAC 2012).

The terms 'prescribed burn' and 'planned burn' are very close in meaning and can be used interchangeably. However, in this learner resource, the term 'prescribed burn' will be used preferentially.

Bushfire (or Wildfire) is defined as:

> an unplanned vegetation fire. A generic term which includes grass fires, forest fires and scrub fires both with and without a suppression objective' (AFAC 2012).

A full list of terms and definitions used in this learner resource are contained in the Glossary at the end of this document.

Principles and purpose of prescribed burning

Prescribed burning may be used for fuel-hazard reduction to reduce the severity and impact of bushfires, to regulate environments that have adapted to the periodic influence of fire, to control introduced species in native bush and grasslands, to encourage grazing opportunities and to regulate and clear land cultivated for timber.

Prescribed burning is undertaken to achieve one or more of the following purposes:

- fuel reduction and/or modification in order to protect life, property and other assets
- habitat maintenance or rehabilitation
- control of weeds or invasive species
- for production outcomes, such as silvicultural or pastoral purposes.

Activity 1.1

Identify the main purpose of prescribed fire for the type of work that you undertake.

Policy considerations

In most jurisdictions in Australia there are both legal obligations to undertake prescribed burning or to control bushfires or bushfire risk on the one hand, and, on the other hand, legal restrictions for how and when prescribed burning can be undertaken.

Legal obligations

Most agencies managing public land have a statutory (legal) obligation to manage the land with respect to:

- **fire protection** issues (protection of life and property)
- **environmental** issues (vegetation and habitat issues).

Also, in most parts of Australia, private property owners and the managers of public land have a statutory requirement to minimise fire hazards on their land.

Meeting fire protection requirements will include, amongst many other things, modification of fuel properties over broad or localised areas to reduce the risk of unplanned bushfires endangering life and property. The well planned and soundly managed use of fire offers one of the few practical tools to achieve such modification.

Management of ecology will also involve consideration of fire. The composition and structure of ecosystems can be altered by the exclusion of fire, or by the planned or unplanned application of fire. Thus the planned application or exclusion of fire can be positive management tools to maintain or deliberately alter ecosystems.

Legal restrictions

Any prescribed burn carries with it some risk that fire behaviour will:

- exceed intended limits, and damage assets or environmental values within the planned area
- escape planned boundaries, and damage assets or environmental values beyond them.

Inevitable by-products of the burn, such as smoke, may also under some circumstances generate a substantial hazard or public nuisance.

To reduce these risks and hazards, some restrictions are commonly placed on the use of prescribed fire at certain times of the year, or under certain environmental conditions.

The laws and regulations governing prescribed burning vary from state to state, and local councils may exercise power to ban burning on certain days within their municipalities. It is important that you make yourself aware of the legislative and regulatory requirements relevant to the location in which a prescribed burn is to occur.

Some states and territories have a general prohibition on prescribed burning when fire danger is particularly high. This may mean that such burning requires specific exemption during the core period of the fire season, when seasonal restrictions on the public's use of fire are in place.

In other jurisdictions, burning may be undertaken at any time of the year, however at some times of the year specific authorisation is required (e.g. in Tasmania a Fire Permit issued under the Fire Service Act 1979). Such a Fire Permit may impose conditions on the burn, including the time of lighting, weather conditions, suppression resources required on site or on standby, and a requirement that all burning material be extinguished before the burnt area is left unattended.

Burning during historically-critical lead ups to periods of high fire danger may also require enhanced safety precautions. For example, in Victoria prescribed burning on public land after 31 October each year requires that:

- all perimeters comprise mineral-earth control lines
- burns are brought out to control lines on the day of lighting
- the maximum possible area of fuels within the control lines must be burnt.

Smoke from prescribed burning can be a hazard due to reduced visibility on public roads, around airfields and airports, or in any other situation in which good visibility is required.

In addition, smoke is a health hazard for susceptible individuals, particularly the very young and the elderly, and people with pulmonary or other respiratory diseases, such as those subject to asthma.

Smoke is increasingly being seen as a public nuisance when atmospheric conditions limit its dispersal, particularly near urban areas, or when major public outdoor events are planned.

Some agencies now have procedures whereby prescribed burning in defined regions is limited or prohibited if atmospheric conditions may lead to significant pollution. Such procedures may rely on daily consultation with other agencies, such as state environment protection authorities.

Activity 1.2

Identify seasonal or other environmental restrictions that may apply to prescribed burning in your area. Contrast these with those restrictions of a similar nature imposed on prescribed burning by another land management agency or fire service in your state or territory (if applicable).

Figure 2: Asset protection burning using low intensity fire (Source: Bushfire CRC)

Authorisations required

The conduct of a prescribed burn is not an operation to be entered into lightly. It is essential that any such burn is managed by suitably skilled personnel with proper authorisation.

Private land

On private lands, any prescribed burn must only be undertaken with the express authority of the landowner or manager. Fire brigades, for example, who may undertake fuel reduction burns on private property, need to ensure that the proper authorisation of the landowner or occupier has been obtained.

Where seasonal fire restrictions are in force, any prescribed burn on private land may proceed only if authorised by the agency managing those restrictions (for example, by issue of a burning permit).

Public land

On public land, each agency responsible for its management normally has specific staff authorised to light or maintain fire on that land. This authority will extend to other employees who, by direction, are involved in prescribed burning operations.

In some circumstances, agency staff may also be required to obtain ‘burning permits’ before undertaking prescribed burning operations on public land.

For all burns, be they on private or public land, a vital part of the authorisation process is a need to notify other interested persons formally of the intention to burn. In most states there are statutory requirements for the formal notification of neighbours within a prescribed period before the commencement of the burn.

Activity 1.3

Identify personnel in your immediate location who are authorised to undertake prescribed burning operations and how such authorisations are obtained.

Are burning permits required to be obtained by personnel in your agency? To whom must applications be made? Are they required all year round or during specific times? If so, when?

Who must receive notifications of intention to burn in your area? What are the requirements which exist in your location, regarding notifications to other persons of the intention to burn?

Section 1 summary

- In most parts of Australia, private property owners and managers of public land have a statutory requirement to ensure fire hazards are minimised on their land. Prescribed burning is one means by which the minimisation of fire hazards can be achieved.
- Prescribed burning is the controlled application of fire under specified environmental conditions to a predetermined area, and at a time, intensity, and rate of spread required to attain planned resource-management objectives.
- Most agencies managing public land have a statutory (legal) obligation to manage the land with respect to fire protection issues (protection of life and property).
- The laws and regulations governing prescribed burning vary between jurisdictions, so it is important that you make yourself aware of the legislative and regulatory requirements relevant to the location in which a prescribed burn is to occur.
- It is essential that any prescribed burn is managed by suitably skilled personnel with proper authorisation:
  - on **private** lands, any prescribed burn must only be undertaken with the express authority of the landowner or manager
  - on **public** land, each agency responsible for its management normally has specific staff authorised to light or maintain fire on that land.
- For all burns, be they on private or public land, a vital part of the authorisation process is a need to formally notify other interested persons of the intention to burn.
- Most organisations have their own procedural doctrine relating to prescribed burning which may consist of standard operating procedures, guidelines, policies and templates. It is important to follow your agency's standards.

Self-assessment questions

1. In relation to fire hazards, what is the general statutory requirement for land owners or managers in most parts of Australia?
2. For what different types of purpose is prescribed burns undertaken?
3. What factors may restrict the use of prescribed burning at particular times of the year?

Figure 3: Ignition while extinguishing the backing fire along a non-mineral earth break (Source: DEWNR, SA)

Section

2

Safe work practices

Section

2

Safe work practices

As a firefighter, your personal safety and that of your crew members should always be foremost in your mind.

In all Australian States and territories there is legislation covering workplace health and safety. While the titles of the legislation may vary, the legislation will always contain a requirement that, so far as is reasonably possible, an employer must ensure that an employee, while at work, is safe from injury and from risks to their health.

To do this, the employer must provide to the extent possible:

- a safe working environment
- safe systems of work
- equipment that is in a safe condition.

In addition, the employer must:

- identify all hazards arising, or that may arise in a workplace
- assess the risk associated with those hazards
- implement appropriate measures to control that risk.

Irrespective of whether you are a paid firefighter, an employee of a land management or similar agency, or a member of a volunteer fire brigade, you are all entitled to the same safety and protection measures in the workplace.

In dealing with risk in the workplace, employers follow a standard series of steps, each of which is intended to reduce the risk of injury occurring:

1. **Eliminate or remove the hazard**. If this is not possible, then
2. **Replace the hazardous procedure** with a safer procedure. If this is not possible,
3. Apply **engineering controls**. For example protection sprays and reflective curtains on tankers are examples of engineering controls. If an engineering control is not possible or appropriate, the employer will next attempt to
4. Apply **administrative controls**. For prescribed burning or firefighting, these are the agency’s standard operating procedures for conducting the operation. All persons on the fireground

must be familiar with and understand the SOPs applying to the activity being undertaken. Finally, if an administrative control is not possible, or appropriate, the employer will rely on

5. **Personal protective equipment**.

Prescribed burning operations and the firefighting which may follow are inherently hazardous activities. While the preferred option would be to remove the hazard from the workplace, in firefighting activities it will not be possible to remove all of the hazards associated with this work.

Consequently reliance falls on safe work practices (safer procedures), engineering and administrative controls, and the use of the appropriate personal protective equipment.

Job safety

Work on the fireground can be dangerous. Safe work practices must be observed at all times, such as making a risk assessment before commencing any task. Your supervisor should identify hazards in a briefing before commencing work, however, you have a responsibility to be alert and aware too, and to communicate your concerns to your workmates, crew members and to your supervisor.

Specific hazards are present when:

- using equipment with cutting edges, for example axes, rakehoes and chain saws
- operating vehicles on steep tracks and trails, or away from formed roads or trails
- working near heavy equipment such as bulldozers
- working with or near aircraft
- working at night.

When working in such situations, you must observe normal safe work practices to minimise the risk of injury to yourself or others. You should:

- apply standard operating practices
- keep a safe distance from other firefighters when using hand tools
- carry tools and equipment in the correct way (see Section 4)
- never get on or off moving vehicles
- step down (don't jump) from equipment or vehicles
- never ride on bulldozers or other equipment not designed for carrying people
- not work immediately in front of or behind a bulldozer
- be alert to rolling and falling materials.

Specific prescribed burn hazards

Hazards that may be encountered at an uncontrolled bushfire or a prescribed burn include heat stress, smoke and fatigue.

Heat stress

Heat stress is a condition where the body's cooling mechanisms are overcome by excessive external and internal heat loads. Firefighters working on the fireground may experience some form of heat stress as a result of:

- radiant heat from flames
- high temperatures normally experienced under summer conditions
- high body temperature caused by strenuous work.

Heat stress can lead to heat exhaustion and, ultimately, to heat stroke which can be a life-threatening condition.

Symptoms of heat exhaustion are:

- cramps
- clammy skin
- feeling faint/light headedness
- dizziness
- headaches
- nausea.

Symptoms of heat stroke (a medical emergency) are:

- dry, hot skin
- disorientation, mental confusion
- staggering and loss of co-ordination
- collapse
- convulsions
- loss of consciousness.

If a person appears to be suffering from heat exhaustion or heat stroke, follow these steps:

- Remove the affected person from further exposure to heat sources
- Loosen the person's clothing to allow for the evaporation of perspiration
- Provide an adequate intake of fluids (small sips of water or weak cordial) at regular intervals.

Severe heat stroke may cause seizures due to the brain being affected by the body's raised core temperature. These seizures will further raise body temperature due to the rapid muscle contractions involved. If seizures occur, the person will die unless immediate cooling is achieved. Where seizures occur:

1. Remove clothing down to the underwear
2. Sponge or spray the casualty with water
3. Fan the casualty to increase the cooling effect
4. Call an ambulance, and get on-site medical assistance while waiting for the ambulance.

If the casualty is unconscious, position them on their side and ensure their airway remains open.

Note: *When heat stroke is suspected, you must act quickly. This can be a life-threatening condition. Seek immediate medical assistance or report immediately to your supervisor.*

How to avoid heat stress

You can minimise heat stress by:

- pre-hydrating yourself prior to commencing firefighting activities
- wearing the correct protective clothing in accordance with your agency's requirements
- avoiding dehydration by drinking plenty of water (at least a litre per hour when working hard in hot conditions)
- sharing heavy workloads
- walking and not running
- working at a comfortable distance from the fire
- taking breaks when appropriate
- avoiding unnecessary exposure to radiant heat.

Maintaining hydration during firefighting activities

Firefighters are particularly susceptible to dehydration during firefighting activities due to:

- high physical activity — high physical activity generates high levels of metabolic heat leading to profuse sweating
- personal protective clothing - the need to wear personal protective clothing to protect against the heat generated by a fire reduces the body's ability to dissipate metabolic heat causing increased sweating in an attempt to increase evaporative cooling
- hot, low-humidity environments — working in hot, low-humidity environments heats the body at a greater rate than in milder weather conditions, resulting in increased sweat production.

Research by the Bushfire CRC (Fire Note 81) has found that the deliberate regular consumption of water and other fluids during shifts, maintained firefighters in a hydrated state and resulted in significantly lower core body temperatures.

Personal protective equipment

On the fireground, personnel use personal protective equipment (PPE) to protect against hazards. PPE includes:

- firefighting helmets
- firefighting boots
- one-piece overalls or two-piece firefighting protective clothing
- protective gloves
- respiratory protection devices.

These items should comply with the relevant Australian or international standards.

PPE is provided for your safety, so you should have it with you when you are deployed to a bushfire or a prescribed burn and wear it at all appropriate times. Besides exposing you to injury, failure to do so will breach the Workplace Health and Safety legislation of your State or Territory, reduce your chance of obtaining compensation if injured, and expose you, your supervisor and your agency to prosecution.

Important points to remember about the features and use of these items are summarised below.

Figure 4: Typical fireline apparel (Source: CFA)

Firefighting helmets

Helmets worn during firefighting and prescribed burning should comply with the Australian — New Zealand Standard (AS/NZ) AS/NZS 1800:1998 'Occupational protective helmets — Selection, care and use' and be marked accordingly.

Figure 5: Examples of wildfire firefighting helmets (Source: PAC Fire Australia)

- A helmet protects you from the danger of material falling from overhead, from radiant heat and windblown embers.
- The neck-flap is an important component of the system protecting your head and neck, so don't remove it.

- A helmet assists by absorbing the impact of any blows. To do this effectively and for your comfort, the harness of your helmet must be correctly adjusted to ensure a firm fit.
- Your helmet must be maintained in good condition and checked regularly for any signs of cracks or damage. A helmet that has suffered any damage or impact should be replaced.
- Some helmets have a limited life-span, e.g. the construction pattern helmets (jockey cap style or full brim) issued by many land management agencies. The date of manufacture is shown by a stamp moulded under the brim. Check your agency's policy on service life duration and replacement.
- To avoid damage to the structure of the helmet, attachments such as earmuffs or visors should be fitted only where intended by the manufacturer and in accordance with the requirements of the relevant standard.
- Your helmet must always be with you. Get into the habit of putting it on as soon as you step out of a vehicle in the bush or onto the fireground. If you develop this habit your helmet will be on your head when you really need it.

Firefighting boots

Boots worn during bush firefighting and prescribed burning should comply with either AS/NZS 2210.1:2010 'Safety, protective and occupational footwear — Guide to selection, care and use' or, AS/NZS 4821:2006 'Protective footwear for firefighters — Requirements and test methods', and have the following basic properties:

- be at least ankle height
- be made of leather or similar (not sneaker style walking boots with 'breathing panels')
- have a protective toecap, and be of lace up or zip close (not elastic sided)
- have a heat resistant sole with good grip.

Many agencies issue boots for their firefighters.

Figure 6: Firefighting boots (Source: PAC Fire Australia)

Protective clothing

Protective clothing issued for use in firefighting or prescribed burning should comply with the provisions of the AS/NZS 4824:2006 **'**Protective clothing for firefighters — Requirements and test methods for protective clothing used for wildland firefighting' and be marked accordingly.

The protective clothing issued by firefighting and land management agencies has been designed specifically for firefighting and includes a two piece trouser and jacket outfit or one-piece overalls. The features and benefits of this protective clothing include:

- full-body-cover protection, including protection of the interface areas such as between sleeve cuff and gloves, thus providing maximum protection from radiant heat
- venting built into overalls to allow air movement and release body heat
- flame resistant fabric, either natural fibre (treated cotton) or synthetic
- retro-reflective and/or fluorescent patches and or stripes, designed to enhance visibility in smoke or at night.

Protective clothing should be worn with the sleeves down to provide maximum protection during a fire.

Whatever you wear beneath your protective clothing should allow you to work comfortably. For your own protection shirts, pants, socks and underwear should contain as little synthetic material as possible. Natural fibres such as wool and cotton provide good resistance to fire.

Nylon and similar synthetics transmit radiant heat more easily, and may melt and adhere to your skin.

Protective gloves

Gloves worn during firefighting and prescribed burning should comply with the Australian Standard 2161.6-2003 ‘Occupational protective gloves — Protective gloves for firefighters’. Laboratory test methods and performance requirements’, be marked accordingly, and have the following basic properties:

- provide protection to the hand
- have good dexterity
- provide protection to the interface between the glove and the end of the sleeve of the jacket or overalls (i.e. have a wide cuff so as not to leave skin exposed at the wrist).

Figure 7: Examples of firefighting gloves (Source: PAC Fire Australia)

Other items of personal protective equipment

You may be issued with the following items for use during firefighting or prescribed burning. If these items are not issued, it is prudent to obtain your own.

Hearing protection

When you are operating any pumps or other noisy equipment, when wearing earmuffs or earplugs, it is vital to be aware of what is going on around you at all times, for example, to hear instructions from other members of the crew.

Any hearing protection devices should comply with the provisions of the AS/NZS 1270:2002 'Acoustics. Hearing protectors' and be marked accordingly.

Eye protection ('smoke goggles')

Any eye protection device should comply with the provisions of the AS/NZS 1337.1:2010/Amdt 1:2012 'Personal eye protection'. Eye and face protectors for occupational applications' and be marked accordingly. Be aware that cheap goggles intended for the home handyman market may melt to your face or even ignite.

Almost all goggles have vents to allow airflow and to reduce internal condensation which interferes with vision. They are of limited value in keeping smoke out of your eyes. They will protect your eyes against larger particles, and will reduce the likelihood of injury by larger objects e.g. sticks.

- Test your goggles to ensure they seal properly on your face.
- If you wear spectacles, ensure that your goggles are large enough and seal over the spectacle arms.
- Make sure the lens is not damaged or scratched in a way that could impede your vision.

Water bottle

During intense firefighting work, the body may need to replace up to one litre of fluid per hour. As well as a personal water bottle, if you are working for long periods, you need access to a continuing supply of drinking water. The water supply can be stowed upon vehicles, collected from clean streams or drawn from a supply carried among your crew.

Your crew kit should include sufficient large water containers to ensure that you have a reserve of three or four litres per person on deployment.

REMEMBER: *Water is* ***essential*** *to prevent dehydration and heat illness. Drink before you get thirsty.*

Personal first-aid kit

- Personal first-aid kits suitable for firefighting situations are widely available.
- The kit should contain material for dealing with simple cuts, blisters, splinters and foreign objects in the eye. More severe injuries can be treated using the items contained in a larger vehicle first-aid kit.
- Your personal first-aid kit should be carried at all times while on the fireline.

Vehicle first-aid kit

- First-aid kits suitable for firefighting situations are supplied for all firefighting vehicles.
- A properly equipped first-aid kit must be with a crew when working away from a vehicle.
- Make sure that your kit is capable of dealing with the types of injuries likely to be encountered in the situation in which you are working.
- First-aid kits need to be kept fully stocked – advise your supervisor of anything used (or faulty or missing) so that it can be replaced.

At least one member of the crew should have knowledge of basic first aid and a current First Aid Certificate.

Routine examination

You should examine each individual item of PPE before and after use. Your personal safety may depend on your PPE functioning correctly.

By examining your PPE and equipment prior to or during the course of cleaning them after the end of each shift, you can ensure they are in good repair or else replaced in good time before you next head out.

Routine examinations of PPE should include checks for:

- physical damage such as rips, tears, cuts, damage to seams and/or other connections non-functional or missing
- physical damage to hardware and other components, e.g. reflective and fluorescent applications
- thermal damage such as charring, burn holes, melting or change in colour
- on-going evaluation of system fit and interfaces, or overlaps and closure systems.

Smoke and personal safety

Smoke is an ever-present irritant at all fires, but prolonged exposure to heavy smoke can be a hazard to firefighters. Smoke irritates eyes and lungs, and it contains toxic materials. Too much smoke can:

- reduce your performance on the fireground
- bring on fatigue more quickly.

Bushfire smoke is a complex mixture of toxic materials and compounds which might be inhaled by persons participating in prescribed burning activities.

Smoke is the airborne by-product of combustion and is made up of visible particles and invisible gases. The visible particles are tar, ash, carbon and unburnt fuel fragments.

The invisible gases include water vapour, Carbon Monoxide (CO), Carbon Dioxide (CO_2), Ozone (O_3) Nitrous Oxide (N_2O) and other organic compounds.

If present at elevated levels, some of these gases can potentially cause short-term health effects (headaches, dizziness, irritation, fatigue, lack of concentration) or long term health effects (cardio-respiratory health effects, reduced lung function, cancer).

Respiratory protection devices (face-masks)

Often referred to as 'respirators', any respiratory protection device (RPD) worn during firefighting and prescribed burning should comply with the Australian/New Zealand Standard **AS/NZS 1715:2009 'Selection, use and maintenance of respiratory protective equipment**' and be marked accordingly. Note: this section does not cover, nor refer to, positive pressure compressed air breathing apparatus (BA) as used in structural firefighting.

Ordinary dust masks, surgical masks, handkerchiefs or bandannas are not effective for filtering out fine particles or gases from bushfire and prescribed burning smoke, and are therefore limited in the protection they can provide.

Most RPDs issued to people engaged in firefighting and prescribed burning are relatively simple filter masks which offer some protection against smoke and ash particles. They do not provide any protection against the gaseous products of combustion. Some agencies issue more sophisticated RPDs which incorporate cartridges containing a material designed to adsorb target compounds from the air breathed by the wearer. Such devices offer some protection against some gasses, the degree of protection and the gasses removed depend on the cartridge(s) fitted to the RPD, and how closely it fits the wearer's face. Such RPDs are often hot and uncomfortable to wear and the filter system makes breathing more difficult, even with exhaust valves.

- No RPD will provide the protection it is designed to give unless it seals firmly on the wearer's face. RPDs intended to protect against particles offer reduced protection if worn over facial stubble or a beard.
- Respiratory-protection devices should be stored, used and maintained in accordance with the manufacturer's instructions. In the case of cartridge RPDs the cartridges should be changed in accordance with the manufacturer's directions, or in accordance with agency instructions.

How to minimise the adverse effects of smoke

- Minimise periods of exposure to smoke and avoid exposure when possible. Use, but don't rely on, any respiratory protection device issued to you. In thick smoke, the air closest to the ground will be the cleanest and easiest to breathe if you can't get away from the smoke zone.
- Take rest breaks in smoke-free areas if possible.

Fatigue

Firefighting can involve strenuous work for extended periods. As well, exposure to radiant heat and smoke for lengthy periods may increase your level of physical stress and the likelihood of fatigue. If you are tired, you are more likely to make mistakes, which can cause accidents and put others at risk.

Symptoms of fatigue include:

- tiredness and lack of energy
- slower reaction times and taking longer to complete tasks
- impaired judgement and inability to make decisions
- inability to concentrate or lapses in attention
- erratic behaviour.

To avoid excessive fatigue:

- pace yourself (that is, conserve energy)

- make the maximum use of your rest breaks
- share heavy workloads around the crew
- ensure that you get adequate meals and maintain your intake of fluids.

It is important that you do not drive when fatigued, particularly on open roads. If you feel tired, tell your supervisor.

Falling trees and tree limbs

Trees weakened by fire are a significant hazard at prescribed burns and wildfires, with falling trees or tree limbs having killed seventeen firefighters during the last 25 years. Bushfire CRC research has indicated that being situationally aware is critical to remaining safe, and that firefighters and burn personnel are most at risk when their attention is drawn elsewhere. You should:

- always wear an approved type of helmet
- actively look around as you move about the burn site so that you can stay away from dangerous limbs overhead
- identify trees with burned out trunks or limbs, which may possibly fall, and bring trees with such trunks and limbs to the attention of your supervisor
- mark dangerous trees in accordance with agency operating procedures
- post a lookout for dangerous trees to warn nearby crews if they start to fall.

Other environmental hazards

Apart from heat, smoke and fatigue related hazards; the burn environment has the potential for injury from many other factors including:

- burns to exposed skin
- sunburn
- falling trees and limbs
- trip hazards
- snake or insect bites
- manual handling injuries
- accidents involving vehicles or machinery operating in restricted visibility.

Activity 2.1

What are the common hazards encountered in a simple prescribed burn in your locality?

Earthmoving equipment

Bulldozers, graders and tractors with blades are frequently used when preparing fire-control lines, vehicle turning bays, or safety zones.

Crews may, therefore, be deployed to work in conjunction with or near earthmoving machinery. Where this is the case, you must be aware of the potential hazards, particularly in the case of bulldozers working in a forest environment.

Beware of:

- dislodged rocks rolling downslope
- trees or limbs falling, or logs being swung around
- the machine itself – do not get too close
- dust from the machine obscuring your view of your surroundings.

Safe work practices around machines include:

- always ensure the operator is aware of your presence
- on slopes, work above rather than below the machine
- in forest situations, keep two tree lengths clear (one tree can fall into another, knocking it over; known as the 'domino effect')
- never work in front of the machine, unless this is for a specified and approved reason.

Figure 8: Bulldozer constructing fire-control line (Source: Bushfire CRC.)

If you need to communicate with the operator of an earthmoving machine:

- use radio if the machine is fitted with one
- do not approach the machine until the operator has clearly acknowledged your presence
- attract the operator's attention by flashing vehicle headlights, waving high visibility material from well behind or to the side of the machine
- step up and step down from the machine – do not jump
- avoid stepping on parts of the machine that could move abruptly – such as, the blade or hydraulic arms.

Never travel on a machine unless you are seated in a properly fitted passenger seat.

Survival in life-threatening situations

When working at a prescribed burn, you must avoid putting yourself at risk. Conditions can alter quickly and can lead to significant changes in the overall fire situation.

Safety zones are areas that have been cleared or are characterised by low fuel hazard in which survival can be assured. It is in your interest to make sure they are adequate, that they can be safely accessed, that the escape routes leading to them are clear and will remain so in the event of a wind change, and that their location is adequately communicated during briefings.

By maintaining situational awareness, many potentially life-threatening situations can be recognised and avoided before there is an actual threat to life. A number of aids or memory prompts can help you put steps in place to identify potentially dangerous situations before you are committed to them.

LACES

Entrapment occurs when the fire behaviour changes and the fire makes a run at the fireline across unburnt fuels to where crews are vulnerable.

When the fire is remote from the crews and there is the risk of entrapment the crews should adopt LACES. LACES is an acronym for the actions required to avoid entrapment.

L	Lookouts	post a competent firefighter at a safe vantage point to observe and report fire behaviour changes
A	Awareness	watch the weather and terrain for triggers for fire behaviour changes
C	Communication	stay in contact with each other and your supervisor
E	Escape routes	have pre-planned escape routes
S	Safety zones	create areas where survival can be assured.

'WATCHOUT' on the fireline

You must remain alert to the overall situation around you when at a burn ('situational awareness'). Observe the fire, and anticipate how it will react with the environment around it (and you). Anticipate what the hazards and threats may be, and think about how you will react to a dangerous situation.

The hazards to look out for can be remembered by using the acronym ‘WATCHOUT’, which stands for:

W	Weather	dominates fire behaviour, so keep informed
A	Actions	must be based on current and expected fire behaviour
T	Try out	at least two safe escape routes,
C	Communications	maintained with your crew, boss and adjoining crews
H	Hazards	to watch for are heavy fine fuels and steep slopes
O	Observe	changes in wind speed and direction, humidity, cloud
U	Understand	your instructions and make sure that you are understood
T	Think	clearly, be alert and act decisively before your situation becomes critical.

Section 2 summary

- Workplace health and safety legislation requires that an employer as far as it is reasonably possible must ensure that an employee, while at work, is safe from injury and from risks to their health.
- Key steps for dealing with risk are to:
  - eliminate or remove the hazard
  - replace the hazardous procedure
  - apply engineering controls
  - apply administrative controls
  - use protective equipment.
- Making a risk assessment before commencing a task and observing safe work practices at all times are key to being a responsible and alert member of a crew.
- Hazards encountered on a fireground vary but some of the more common ones include heat stress, smoke and fatigue.
- Firefighters are particularly susceptible to dehydration during firefighting activities because their work involves:
  - high physical activity
  - wearing personal protective clothing
  - working in hot, low-humidity environments.
- Regular consumption of water and other fluids during a shift enables a firefighter to maintain their level of hydration, which results in lower core body temperatures.
- The effects of smoke can be minimised by correct use of respiratory protection devices and, where possible, minimising smoke exposure.
- Fatigue can be minimized by pacing activities, sharing heavy workloads, taking rest breaks, eating correctly and maintaining intake of fluids.
- When working near bulldozers ensure the operator is aware of your presence.
- Beware of dislodged or rolling material near bulldozers.
- Do not approach an earthmoving machine until the operator has acknowledged your presence.
- 'LACES' is an acronym for the actions required to avoid entrapment.
  - **L**ookouts
  - **A**wareness
  - **C**ommunication
  - **E**scape Routes
  - **S**afety Zones.

- 'WATCHOUT' is an acronym for actions to ensure survival on the fireline:
  - **W**eather
  - **A**ctions
  - **T**ry out
  - **C**ommunications
  - **H**azards
  - **O**bserve
  - **U**nderstand
  - **T**hink.

Self-assessment questions

1. List each of the five steps that should be followed to reduce the risk of injury occurring?
2. List the key hazards encountered at a prescribed burn.
3. What is heat stress?
4. What are the symptoms of heat exhaustion?
5. What is heat stroke?
6. How can you avoid heat stress?
7. When should you examine each individual item of PPE?
8. What should routine examination of PPE check for?
9. How can you minimise the effects of smoke?
10. How can you minimise fatigue?
11. What is a safety zone, and what characteristics should you ensure it has?
12. Explain the difference between 'LACES' and 'WATCHOUT'.

Section

3

Working in a team

Section

3

Working in a team

A workgroup develops into a 'team' when the common purpose of the team is understood by all group members and each member performs their assigned role to the best of their ability to achieve this purpose. While this section refers to a team, the principles covered in this section apply equally to any fireground crew. The term 'team' in this section can therefore be used interchangeably with 'crew'.

People in a fire crew depend on each other and share their skills and experience to achieve outcomes that they could not achieve as individuals.

Successful team performance

The characteristics which typically contribute to successful team performance are:

Size	The size and membership of the team must be appropriate to the task and enable the group to work together comfortably as a unit.
Supportive leadership	A supportive leader who has high personal-performance standards.
Challenging problem(s)	A goal that requires the collective effort and multiple skills of the team.
Shared values	Team objectives and values are understood and accepted by all team members. Team member behaviour is governed by shared team values and attitudes.
Results focused	A focus on results, and commitment to objectives and measurable targets for achieving these results.
Team and individual accountability	Acceptance of both team and individual accountability for performance.
Right mix of skills and knowledge	Team members with the right mix of skills and knowledge required to complete the task.

Role clarity	Clear roles and responsibilities for team members, and team structures and procedures which are linked to team objectives and resources.
Sufficient resources	Resources available for completing team tasks efficiently.
Autonomy	The team has the authority to decide how they will work and how resources will be allocated.
Open communication	There is open communication and information sharing between team members. Issues, difficulties and obstacles to performance are confronted and dealt with openly.
Teambuilding	Efforts are made to develop and maintain a team climate.
Respect	Team members treat each other with respect and trust, support and value each other, and relate well to others outside the team.
Recognition	Formal or informal processes are in place for recognition and reward of individual contributions as well as team successes.
Decision making	Procedures are in place for effective decision making focused on team objectives.
Team learning	• Processes are in place to assist team work, including grievance procedures, conflict resolution and performance feedback. • Time is taken to reflect on progress and learn from outcomes of team activity and team operations and targets are regularly reviewed. • Individual and team development needs are met.

The effectiveness of a work team can be undermined by:

- too many or too few team members making decisions and/or managing the workload
- lack of team leadership
- lack of clarity about team objectives and the roles of individual team members
- inadequate mix of the skills needed for the team to attain its objectives
- poor communication.

Activity 3.1

Consider the most effective work group you have been involved with and identify the main factors which made this group effective.

Consider the least effective work group you have been involved with and identify the main factors which caused this group to be ineffective.

Would you define either of the groups you have described above as a team? Explain why or why not.

Team members

Because of their different skills, personalities and preferred ways of working people contribute to teams in different ways. These differences are essential in a team but they can cause conflict. It is important that you accept and work with these differences to maximise the potential of each team member and benefit the team overall. Each person in a team must be valued for their contribution to the attainment of team goals.

Key responsibilities of team members are to:

- communicate with team leaders and other members
- cooperate with team leaders and other members
- contribute skills and experience towards achieving team tasks
- share in the work and assist and support other members.

A good team player:

- is aware of and accepts individual differences in the team
- contributes and commits to the team goal and sets personal goals which match team goals
- enjoys being part of a team and working with others
- is willing to communicate openly and offers honest, constructive feedback on individual and team progress
- is a good listener
- inspires trust and respect and shows trust and respect
- has skills required by the team
- contributes to reviewing how the team is operating and performing
- asks for support when needed and accepts feedback
- acknowledges the contributions of individual team members
- participates cooperatively in team projects
- respects and acts in accordance with, agreed team standards
- understands that caring for and maintaining the team is as important as the team task
- accepts their share of the workload and meets their deadlines.

Activity 3.2

List what key attributes you would expect of a good team player in a prescribed burning operation?

Following instructions

Communicating effectively and listening carefully is a critical factor in the giving and receiving of instructions. When taking instructions from your team leader, it is your responsibility to listen and then check your understanding of what you have heard by asking questions and repeating back the instructions. If necessary, you should note in writing the key aspects of the instructions you have been given.

Sometimes, having received instructions from a team leader, you may feel you need additional background information before you can do the job and you should seek further clarification before you start the work. If you have concerns about the work assigned or can see what you think is a better way of achieving the desired outcome; you should express your concerns or ideas.

If you disagree with an instruction discuss your concerns with your team leader, stating your opinions calmly and clearly. Try to be constructive in your remarks and explain why you disagree and offer an alternative approach.

If, at the end of the discussion, your team leader still requires you to follow the original instructions, you must do so, provided that no organisational policies or laws, e.g. discrimination or environmental regulations, are contravened.

Reporting

Regular reporting to the team and the team leader on the progress of work is an essential part of being an effective team member. The work plan will be altered according to progress, including whether or not timeframes are being met. Resource issues that may be emerging can also be addressed.

Reporting to the team provides additional opportunity for the involvement of all members. Team members may have useful experience in the task which they can share, other pertinent information, or have a different way of looking at the problem. Points to be considered when reporting to the team leader and/or team include:

- progress on your individual work objectives
- implications of your work progress for the team objective
- any information that may affect the work of another team member
- future resource requirements
- future timeframes and timelines
- any predicted problems in completing work and subsequently the team objective.

Reporting should be succinct and relevant. Ultimately the team and the team leader are only interested in results and issues which may have implications for the team's work overall.

Activity 3.3

Prepare a report for your team leader and team on your current work progress.

Briefing of crews

Briefings are a key component of effective and safe planned burn operations. All personnel to be involved in a prescribed burn must be properly briefed prior to being deployed. The briefing could be a single event with all personnel present, or a series of briefings of different groups of personnel.

Effective briefing requirements

Staff involved in the planned burn must understand what their primary task is, how it fits in with the overall objective(s), and what alternative tasks they may be required to carry out. Briefings need to be visual. This can be achieved with portable blackboards/whiteboards to illustrate features and deployments. Enlarged aerial photographs are very useful for some situations. Maps should be issued to all subordinate task leaders and crew leaders.

Briefings need to be thorough with time allowed to cover all necessary information, to check for understanding and for questions and clarification of any issue.

It may be necessary to take specific personnel to key locations to ensure they understand the 'lay of the land', or walk or drive through the site if the burn area is small enough.

Briefing format

The briefing model commonly known by the acronym SMEACS, represents the key information components of an incident briefing (AIIMS-4, 2013).

- **S** — Situation
- **M** — Mission
- **E** — Execution
- **A** — Administration
- **C** — Communications
- **S** — Safety.

The use of the SMEACS format to structure a briefing enables the person conducting the briefing to ensure that they communicate all relevant information to their team. Further it enables team members to check that all relevant information is communicated to them. Whatever form it takes, each briefing should include the details listed in Table 2.

Table 2: The SMEACS briefing format

S	**Situation** – the current and predicted situation, including: • the burn site and reason(s) for the burn • current and expected weather • at-risk values to be protected • a summary of resources deployed.
M	**Mission** – the statement of the specific objectives set for the burn.
E	**Execution** – how the mission will be accomplished; that is: • strategies and tactics in the form of lighting sequencing, patterns and timings • constraints • task and resource allocation • access around the burn site • immediate tasks after briefing • contingency plans.
A	**Administration** – Logistics for the operation including: • key support locations and roles • burn staging area • catering • supply • ground/medical support.
C	**Command and Communications** – Burn Management Structure including: • sectorisation • reporting relationships and times • the communications plan • contact numbers, radio channels.
S	**Safety** – Identification of known or likely hazards including: • weather • 'watch-out' situations • safety equipment required and protective clothing standards • welfare, hydration and first aid.

Remember, each individual may hear the same information but perceive quite different things; clarify that the message heard is indeed what was intended.

If you are listening to a briefing and anything is unclear, note the topic and ask for clarification before the briefing in concluded. Opportunity to ask questions should always follow a briefing.

If no questions are asked, it is good practice for the person conducting the briefing to ask 'open' questions (i.e. questions that require more than a simple 'yes' or 'no' response) of the briefing recipients to check that they have heard and understood the information delivered in the briefing.

Section 3 summary

- A team is a small number of people with complementary skills who are committed to a common purpose, performance goals, and an approach for which they hold themselves mutually accountable.
- A workgroup develops into a 'team' when the common purpose of the team is understood by all members and each member plays their assigned role to the best of their ability to achieve this purpose. People in a team depend on each other and share their skills and experience to achieve outcomes that they could not achieve as individuals. The combined capability of the team is the key benefit for both individual team members and the organization.
- In an effective team, you would observe:
  - individual and mutual accountability
  - specific team purpose
  - an outcome that all team members have contributed to
  - open-ended discussion and active problem-solving meetings
  - performance being measured by assessing the team's work
  - members who discuss, make decisions and work together.
- To successfully undertake tasks, team members must understand organizational policies and procedures particularly those which are relevant to their work.
- Team members must be prepared to request and accept assistance from other team members.
- Regular reporting on work is essential. Team members need to give information about the progress of work and any other relevant information to the team leader and other team members.
- All personnel must be briefed prior to being deployed at a burn.
- Briefings should be delivered using a standard format, and include details of burn objectives, lighting patterns, contingency arrangements, tasks, chain of command, communications procedures, hazards, and any specific safety issues, including safe areas and escape routes.
- Briefings should use visual aids (use whiteboards, maps, aerial photographs, etc.).
- Briefings should be thorough, and allocated sufficient time. The person conducting the briefing should always check that the people being briefed have heard and understood the briefing.
- If you are being briefed and don't understand something ask for an explanation. If you don't understand there are probably other people standing beside you who don't understand either.

Self-assessment questions

1. What is a team?
2. List five characteristics of teams.
3. What sort of things would you observe in an effective team?
4. What should you do if you disagree with an instruction from a burn supervisor?
5. What kinds of information does a team leader need in a report from a team member?
6. What key details should be covered in crew briefings prior to a prescribed burn?
7. What is it important to check for at the end of every briefing?

Section

4

Fire behaviour and prescribed burning

Section 4

Fire behaviour and prescribed burning

Fire behaviour influences

Fire behaviour determines whether any prescribed burn achieves its objective. Fire behaviour is governed by fuel, weather and topographic factors, and by the lighting pattern used in igniting the fire.

This section covers fire behaviour for prescribed burning in terms of:

- the general distinction between low and high-intensity burns
- the important factors that determine fire behaviour
- available and appropriate ignition techniques and patterns.

Fire behaviour and fire intensity

The term 'fire behaviour' refers to the manner in which fire reacts to variations in fuel, weather and topography. Key aspects of fire behaviour include fire intensity, flame height, rate of spread and spotting.

Fire intensity is defined as the rate of heat output per length of fire edge, in units of kilowatts per metre (kW/m). It is a function of the amount of fuel burnt in the flame front of the fire, the calorific value (heat yield) of that fuel, and the rate of spread of the fire.

Any factor that influences available fuel load, or rate of spread of a fire, will influence fire intensity. Because the concept of fire intensity contains a numerical description of fire behaviour characteristics, it can be used to predict our ability to suppress a fire.

Fire intensity is also a good indicator of other aspects of fire behaviour, such as flame height and length and can be used to predict rates of spread, the likelihood of spotting in certain fuels, as well as its likely effects on vegetation and fuel, such as scorch height.

Flame height refers to the average maximum extension of flames at the leading edge of a fire front (occasional flashes that rise above the general level of flames are not considered). Flame height should not be confused with flame length. The flame height will be less than the flame length if flames are tilted due to wind or slope (see Figure 9).

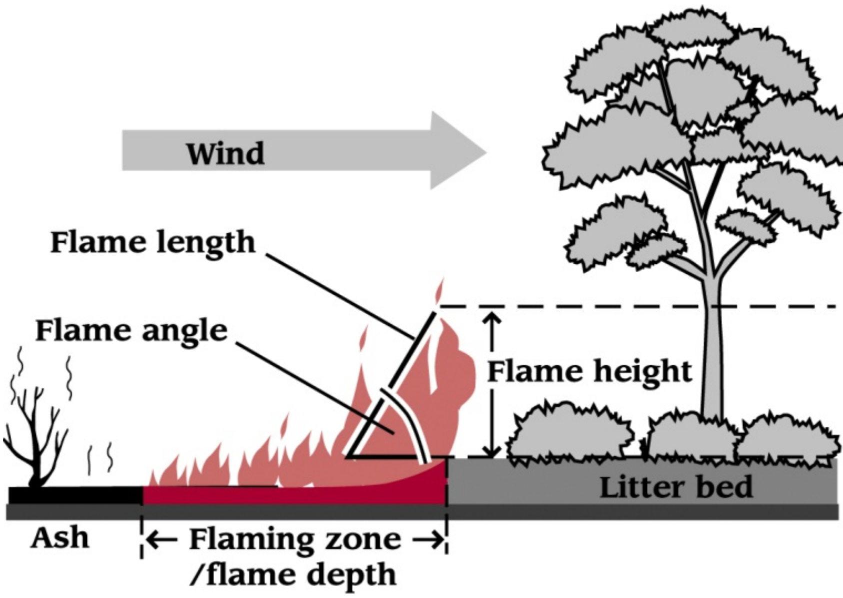


Figure 9: Features of a moving head fire (Source: DPAW, WA)

Rate of spread is another effect influenced by fire intensity. It describes the speed with which a head fire moves in a horizontal direction across the landscape. Figure 10 summarises the different parts characteristic of spot fires and lines of fire respectively, as well as indicating the proportion of ground burnt by each.

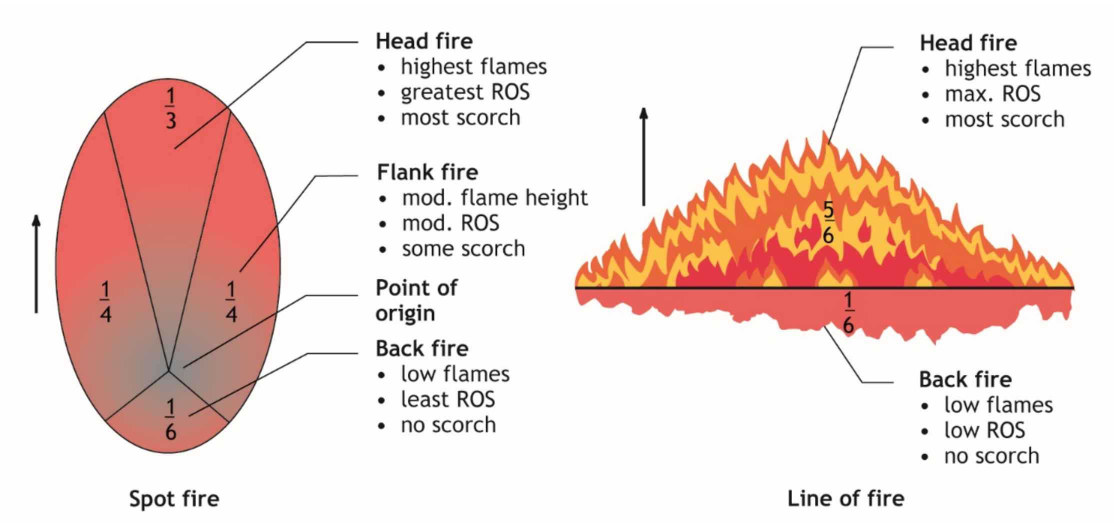


Figure 10: Parts of a fire and relative proportions burnt by each part

Spotting is a type of fire behaviour that occurs when a fire produces sparks or embers that are carried by the wind and start new fires beyond the zone of direct ignition by the main fire. Spotting becomes more likely as fire intensity increases and the associated increase in convection carries embers aloft.

Because the concept of fire intensity is central to describing and prediction fire behaviour, prescribed burning is often broadly classified into high-intensity or low-intensity burning.

Low-intensity burns

Low-intensity burns are normally desirable where the objective is to consume some portion of surface litter and lower shrub and bark fuels, with minimum burning of, or damage to (scorch) middle and over-storey vegetation.

Such burns are appropriate for hazard reduction (fire protection) programs, and to achieve some ecological objectives where only lower level fuels and vegetation need to be modified. They are characterised by:

- low flame height (typically less than 1.5 metres)
- slow rates of spread (less than 100m/hr)
- intensities less than 500 kW/m.

A consequence of any fire in forest or shrubland fuels is scorch, where leaves above the flame zone are turned brown by convected heat from the fire passing below. The scorch height of a fire is a function of:

- the amount of fine fuel burnt
- the air temperature
- the moisture stress in living vegetation (reflecting seasonal soil dryness).

Scorch can be closely related to flame height. In southern Australia the upper margin of the scorch zone varies with the seasons. The scorch height may be seven times higher than the flame height in spring, and up to 16 times higher in autumn.

In tropical Australia the situation is complicated by vigorous growth of tropical grasses during the wet season, which then cure (die off) and may then be knocked down by dry season winds.

Scorch is an undesirable consequence of low-intensity prescribed burning. Scorched leaves fall to the ground in the six weeks or so after the burn, creating a new and possibly quite heavy surface fuel layer. Scorch can be minimised by careful management of flame height.

High-intensity burns

High-intensity burns are appropriate where the objectives of the burn include:

- consuming the greatest possible quantity of the available fuel
- causing significant soil heating
- killing as many plants as possible of some target species, e.g. weed control or control of shrub and scrub species in rangeland pasture
- regenerating vegetation species that may be dying out in the area, e.g. Acacia (hard seeds stored in the soil), Banksia, Hakea and Eucalyptus species (seed stored on the tree in a cone or capsule, released by fire)
- creating an ash seed bed and reduce competition from other species: post-harvest silvicultural burns in wet eucalypt forest.

Such burns are characterised by:

- tall flames (greater than 2 metres)
- rapid rates of spread, if allowed by the lighting pattern and nature of fuels
- intensities greater than 1000 kW/m. Some classifications describe fires of greater than 7000 kW/m as ‘very high intensity’.

Fire behaviour factors

Fire behaviour during prescribed burns is primarily influenced by fuel characteristics, weather and topography.

Additional factors that will influence the behaviour of any prescribed fire are the ignition pattern and technique used to light the burn.

Fuel characteristics

The characteristics of fuel include its type, quantity, moisture content, arrangement and distribution across a site. Each of these characteristics will contribute to overall fire behaviour.

Fuel type

Vegetation type is usually used to describe fuel type. Differences in fuel type may mean differences in general arrangement and bark and fuel size characteristics. This will influence flame heights and rates of spread and hence fire intensities.

The major types for which fire behaviour characteristics are known and predictions can be made include:

1. dry eucalypt forest
2. sub-tropical eucalypt plantation
3. logging slash
4. southern pasture grassland
5. northern grassland, including sparse grassland or grassland in association with open forest or woodland
6. buttongrass moorland
7. semi-arid mallee/heathland
8. coastal heathland
9. spinifex grassland.

Fuel quantity

Weight, in tonnes per ha is used to describe fuel quantity. It is used in many fire spread models to predict fire intensity and rate of spread. Various methods are available to ascertain fuel quantity from visual estimation guides to fuel sampling surveys requiring precise measurements.

Available fuel quantity is that proportion of total fuel quantity that is available to burn. The available fuel will fluctuate during the day as fuel moisture changes in response to changes in the relative humidity of the atmosphere. Since relative humidity fluctuates in response to temperature (but with a lag time), on fine days, the available fuel will generally be at its lowest just after sunrise, and at its greatest in the late afternoon.

Fuel moisture content

Fuel moisture content (FMC) is the proportion of free and absorbed water in the fuel expressed as a percentage of the oven-dry weight of the fuel (%ODW).

FMC is fundamental to determining whether fuels burn, and if so, how rapidly (and intensely). The distribution of moisture in fuel beds also determines the proportion of fuel available to burn. A good knowledge of FMC is essential to predict likely fire behaviour, and related things such as smoke properties and difficulty of fire control. Figure 11 shows the relationship between fuel moisture content and rate of spread under varying wind speeds, with other factors assumed constant. The dramatic increase in rate of spread when fuel moisture falls below 8% illustrates the importance of monitoring this parameter.

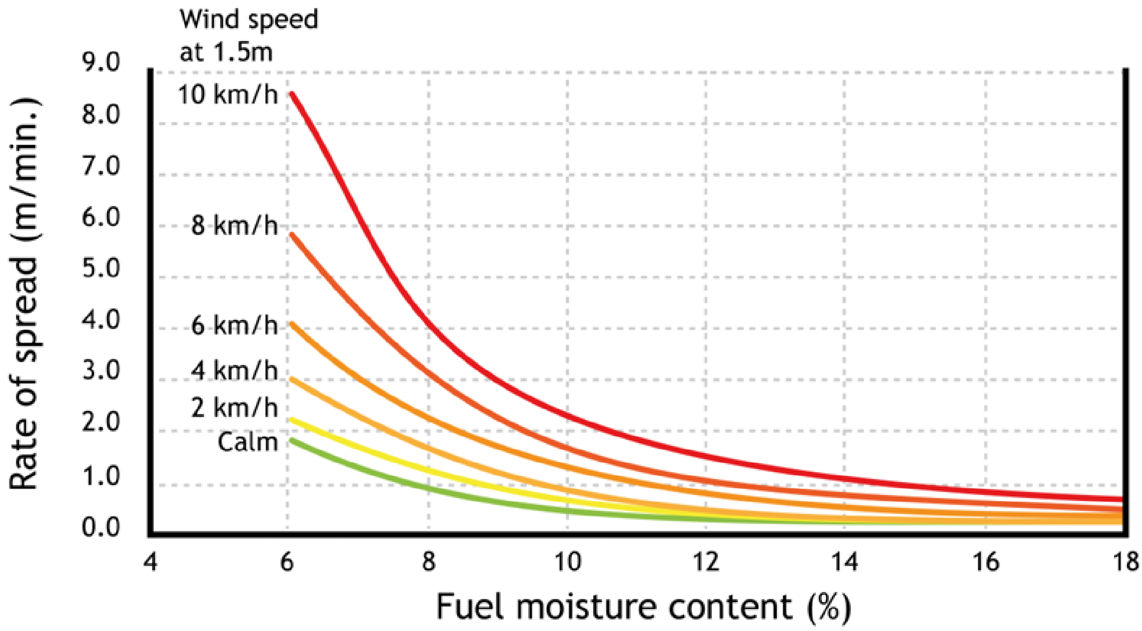


Figure 11: Relationship between FMC and forward rate of spread in open forest (Tolhurst and Cheney, 1999)

Prescribed limits on fine fuel moisture content will depend on the nature of fire behaviour desired (as dictated by the burn objective), and other site factors such as the typical fuel arrangement. Table 3 provides descriptions of indicative fire behaviour for a range of moisture contents in surface fine fuels, the fine fuels in the upper 10 mm of the litter bed. If a high proportion of fuel is elevated it will be drier than surface fuels and will burn more readily. Fuel moisture and therefore fire intensity will vary significantly across a burn area with aspect and slope due to the sun angle of intercept to fuel, being of concern on steeper north facing aspects.

FMC can be measured or monitored in a variety of ways in different jurisdictions including: predictions from temperature and RH, in-field moisture meters, fuel analogues such as hazard sticks or hazard bags, by oven-drying fuel samples, or estimates from a burning leaf test (see Figure 12).

The burning leaf test provides a simple and quick estimate of FMC from the angle at which a cured eucalypt leaf from the litter layer burns. The angle to which a burning leaf is tilted so that combustion is just sustained will depend largely on the leaf’s moisture content.

Table 3: A guide to fuel moisture content and fire behaviour in eucalypt forests

Surface moisture content (% ODW)	Indicative fire behaviour in eucalypt fuels
<4	Litter extremely dry. Potential for extreme fire behaviour with intense short-distance spotting and crown fire at moderate wind speeds.
4–6	Litter very dry. Very rapid ignition from small smouldering firebrands. Fire behaviour could be severe, spotting likely, possible crown fire under strong winds.
6–9	Litter dry. Conditions may not be suitable for fuel reduction burning. Fuel very easy to ignite, spotting initiated by large smouldering firebrands. High intensity fire may develop under strong winds.
9–13	Litter is reasonably dry. Eucalypt litter easy to ignite. Burning readily sustained. Fuel reduction may be carried out in light fuels under very mild weather conditions. Limited spotting from large flaming firebrands.
13–16	Litter just moist. Eucalypt litter moderately easy to ignite. Burning is sustained. A suitable range for fuel reduction when other conditions, particularly wind, are suitable. Spotting unlikely.
16–22	Litter is damp. Eucalypt litter is difficult to ignite. Burning difficult to sustain. Low intensity burning could be patchy. No spotting.
22–28	Litter is wet. Fuel very difficult to ignite. Burning very difficult to sustain.

Fuel arrangement

Flame height, intensity and rate of spread are influenced by vertical arrangement of fuel. Well aerated elevated fuels will promote taller flames, higher intensities and more rapid rates of spread.

Fuel distribution

The degree of uniformity of fuel load moisture content and arrangement affects fire intensity and rate of spread. Patchy (discontinuous) fuels (e.g. mallee, central Australian spinifex) in which areas of fuel are separated by bare earth or patches carrying little or no fuels may be may require that special consideration be given to lighting patterns if they are to burn at all. Fires in such fuels are often referred to as 'go—no go' fires, because they do not propagate from one fuel patch to the next until a critical minimum wind speed is reached.

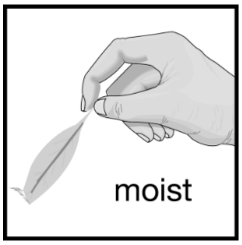
Fuel hazard is rating system that summarises the contribution that fuel type, fuel quantity and fuel arrangement make to fire behaviour. It is common to use field guides that assist in the visual assessment of fuel hazard presented by surface fuels, near surface fuels, elevated fuels and bark hazard.

The *Overall fuel hazard assessment guide* (Hines *et al.*, 2010) has been adopted by a number of fire and land management agencies for fuel assessment in forest fuel types. This guide provides an overall fuel hazard rating as its main output.

Leaf burns if held straight down or does not burn at all

All fuels too wet if this leaf is in the area to be burnt.

OK if only in wet area not to be burnt.



Leaf burns if angled downwards

Fine fuels from this leaf's position will only burn if on a slope or in the wind.

OK if the leaf was from the bottom of the litter in the burn area, or from a wet area not to be burnt.

Leaf burns if level

Fine fuels from this leaf's position will burn, but very slowly unless helped by wind, slope and fuel continuity.

Leaf can be angled upwards and still burns

Fine fuels from this leaf position are dry enough to burn.

OK if this leaf is from the top of the litter, risky if from the bottom.

Leaf burns if held straight up

All fine fuels are very dry and flammable. Fire will spot if windy.

DON'T BURN.

Figure 12: The burning leaf test

Assessing fuels

To enable use of the McArthur Forest Fire Danger Meter mk.V — which uses fuel loads rather than fuel hazard for predictions of forward rate of spread, flame height and potential spotting distance — the guide includes Table 4, which can be used to estimate equivalent fuel loads for given fuel hazard ratings for various fuel components in foothill forests in southern Australia. Fuel hazard scores for each fuel component (surface fuel, near surface fuel, elevated fuel and bark fuels are converted to equivalent tonnes per hectare in order to estimate fuel load.

Table 4: Equivalent fuel loads (tonnes/ha) for given fuel hazard ratings

Fuel component	Fuel hazard rating				(Hines *et al.* 2010, p.36)
	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+

An overall value of fuel load can be estimated at any location where a subjective appraisal of fuel hazard by component has been made.

For example, where a site carries a ‘High’ bark hazard, a ‘High’ surface fuel hazard and a ‘Very High’ elevated fuel hazard, the overall fuel load may be:

2 + 11 + 4 = 17 tonnes/ha.

This total could then be used, for example, with the McArthur Forest Fire Danger Meter mk.V for predictions of forward rate of spread, flame height and potential spotting.

Topographical conditions

Three key topographical influences on fire behaviour are slope, aspect and elevation.

Slope

Slope will influence a fire’s rate of spread, and hence intensity. The radiant heat and combustion gases produced by a fire advancing up a slope pre-heat the fuels ahead of the flame front. A fire backing down a slope does this only to a very limited extent. The differences in rate of spread in the two situations become greater and greater as the slopes become steeper. In addition steep slopes are often more exposed to wind. In prescribed burning, we may be able to use downslope spread (that is, a backing fire) as a factor to make the burn more controllable.

Aspect

Aspect will influence fuel type, available fuel quantity and fuel moisture content. Different aspects are also likely to have different wind conditions. In prescribed burning operations you must expect significant differences in fire behaviour on different aspects.

Elevation

Big differences in elevation will have similar influences on fuel characteristics as differences in aspect. At higher elevations conditions are generally cooler and wetter than at lower elevations and consequently available fuels will have higher moisture contents.

Weather conditions

Important weather elements often prescribed for burning are temperature, relative humidity, wind, atmospheric stability and drought index. These will influence the proportion of fuels available to burn, rate of fire spread, and fire intensity.

Air temperature will affect the temperature of exposed fuel elements on and above the litter bed surface. The higher their temperature, the drier they will be, and the more easily they will be preheated to their ignition temperature.

Relative humidity affects the moisture content of dead fine fuels through the processes of adsorption and desorption. Fuel moisture content is a critical factor in determining if fuels will burn, and how rapidly (and intensely) they will burn.

For a given air mass, temperature and relative humidity are inversely related, and will exhibit a diurnal cycle as represented in Figure 13. Dew point temperature (the temperature at which an air mass will be saturated) is a useful indicator of changing air mass characteristics. The lower the dew point is relative to air temperature, the lower the relative humidity and the faster dead fine fuels will dry out.

Diurnal trends in temperature and relative humidity are generally monitored to determine whether conditions on the day of proposed burning will stay within prescription.

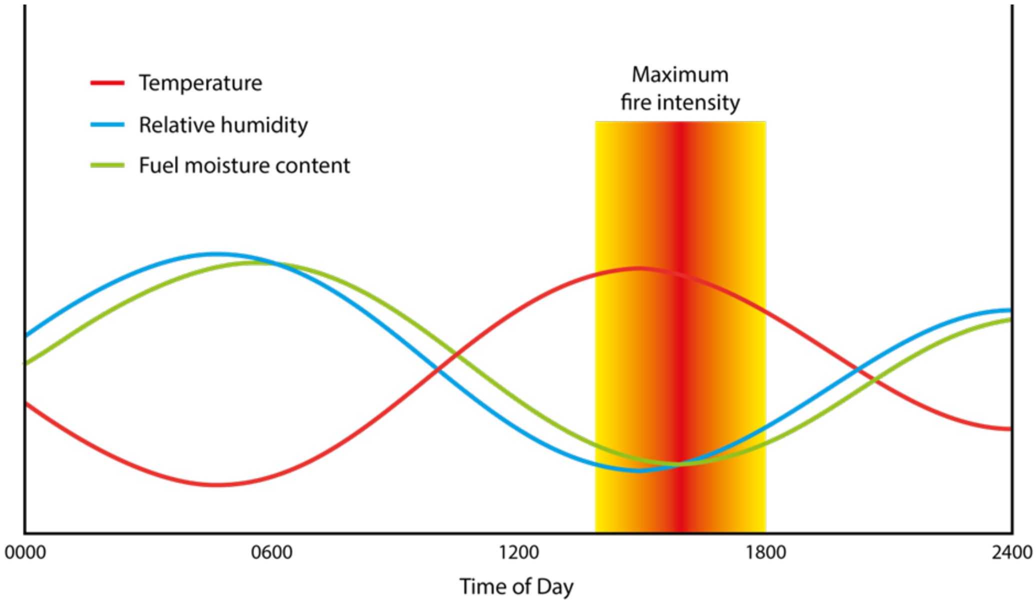


Figure 13: Variations to relative humidity and temperature throughout the day.
(Note how the period of maximum fire intensity coincides with lowest fuel moisture content and occurs after the temperature begins to fall.)

Wind

Wind is always a critical factor in fire spread and hence fire intensity. In most prescribed burning situations, low wind speeds are desirable to ensure that fire behaviour is manageable. Wind direction may also be an important factor because of the geographic orientation of the burning unit, and/or the desired lighting pattern.

Most prescribed burning guides stipulate a maximum wind speed of 15 km/h at 10 m above-ground in the open, although in some specialised fuel situations, such as mallee or desert heaths, wind speeds up to 25 km/h may be acceptable or desirable.

The corresponding wind speeds near the surface in forests will depend on the nature of the vegetation, but will be generally less than half the open wind speed. The relationship for well-stocked forests can be estimated from Table 5 (modified from the Beaufort wind scale).

Table 5: Beaufort wind scale for land areas, plus a (non-standard) guide (on right) to estimating wind speed in well-stocked forests

Beaufort scale	Description	Wind speed at 10m above ground in the open (km/h)	Specifications for estimating speed over land	Wind speed at 1.5m in the forest (km/h)
0	Calm	<1	Calm; smoke rises vertically	<1
1	Light air	1–5	Direction of wind shown by smoke drift but not by wind vanes; slender branchlets and twigs of trees move gently.	1.3–2.0
2	Light breeze	6–11	Wind felt on face, leaves rustle; ordinary vanes moved by wind; trees of pole size in the open sway gently; tops of trees in dense stands intermittently sway gently.	2.2–3.0
3	Gentle breeze	12–19	Leaves and small twigs in constant motion; wind extends light flag; trees of pole size in the open sway very noticeably; tops of trees in dense stands sway.	3.2–4.4
4	Moderate breeze	20–28	Raises dust and loose paper; small branches moved	
5	Fresh breeze	29–38	Small trees in leaf begin to sway; crested wavelets form on inland waters	
6	Strong breeze	38–49	Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty	
7	Near gale	50–61	Whole trees in motion; inconvenience felt when walking against the wind	
8	Gale	62–74	Twigs break off trees; generally impedes progress.	
9	Strong gale	75–88	Slight structural damage (chimney pots and slates removed)	
10	Storm	89–102	Seldom experienced inland; trees uprooted; considerable structural damage	
11	Violent storm	103–117	Very rarely experienced; accompanied by widespread damage	
12	Hurricane	118 plus	Devastation	

***Note:** While use of the Beaufort scale to estimate wind speed can give useful information, it is still quite subjective. Use a good quality anemometer wherever possible. Remember to average the strength of gusts and lulls over several minutes, when measuring wind speed with an anemometer. Modern electronic handheld anemometers such as the 'Kestrel' can do this automatically.*

If you are asked to measure wind speed during a prescribed burn remember that the Bureau of Meteorology forecasts wind speeds in the open at a height of 10 m above an unobstructed smooth ground surface. The fire behaviour models used in Australia all use the 10 m wind speed, not the surface wind speed.

This is why it is important to become familiar with the use of the Beaufort scale to estimate wind speeds in bush and forest. It can be used in situations where an anemometer would be useless because there is insufficient clear space.

Stable atmosphere

Atmospheric stability affects convection and directly impacts on fire behaviour.

Most low-intensity prescribed burning will be undertaken in stable atmospheric conditions. These more likely be associated with predictable wind conditions, and will limit the development of strong convection. However, stable atmospheric conditions hinder the rapid dispersion of smoke.

Visual indicators of a stable atmosphere are slow moving cirrus clouds, poor visibility, steady light winds, or still conditions.

Unstable atmospheric conditions promote strong convection, which in turn generates strong indraught winds at ground level, leading to increased fire intensity. Visual indicators of atmospheric instability are: cumulus clouds which change shape rapidly, good visibility, gusty winds.

Drought Index

Drought Index, as measured by the Keetch-Byram Drought Index (KBDI) or the Soil Dryness Index (SDI), is a measure of the dryness of the soil profile. Each index maintains a daily calculation of soil moisture balance from inputs of rainfall, and losses from evapotranspiration.

Drought indices are indicators of the seasonal dryness of living vegetation, deep litter beds and coarse fuels. At high drought indices, fire intensities will be higher (because of higher overall fuel availability) and effects on vegetation (such as scorch height) will be more severe.

The KBDI has a scale of 0 to 200, where 0 represents saturated soils and 200 the maximum possible dryness.

At high drought indices, burning intensities and scorch height will be higher, reflecting higher available fuel loads, and greater moisture stresses in living vegetation. As a general rule:

- for good planned burning conditions a KBDI < 100 (preferably < 80) will ensure good soil moisture and vegetation recovery.
- for periods where weather conditions are deteriorating (such as the lead up to the fire season) and more cautious approach is advised and a KBDI < 30 is recommended.

Fire Danger Index

McArthur's Forest Fire Danger Index (FFDI) broadly summarises fuel and weather influences on fire behaviour. A maximum FFDI is commonly specified for prescribed burns because it provides an indication of the anticipated level of difficulty of fire control in the specified weather and fuel moisture conditions.

Satisfactory low-intensity prescribed burning can be conducted at FFDIs of less than five. As a general rule, an FFDI of 10 represents the upper limit for low-intensity prescribed burning in forests. However this would be associated with fire behaviour at the upper end of the acceptable range, and normally would be acceptable only in tall forest (for example, with canopy height > 40 m). In desert heaths or mallee vegetation, prescribed burning at FDIs up to 20 may be acceptable.

Figure 14 shows an area that has been subject to a prescribed burn carried out under very mild conditions. The near-surface litter has been too damp for fires to spread and only the elevated fuels have been burnt, ideal for the removal of scattered logging debris in a dry forest selective harvesting operation. The smooth-barked gums have been a significant factor in keeping fire on the ground and reducing scorching.

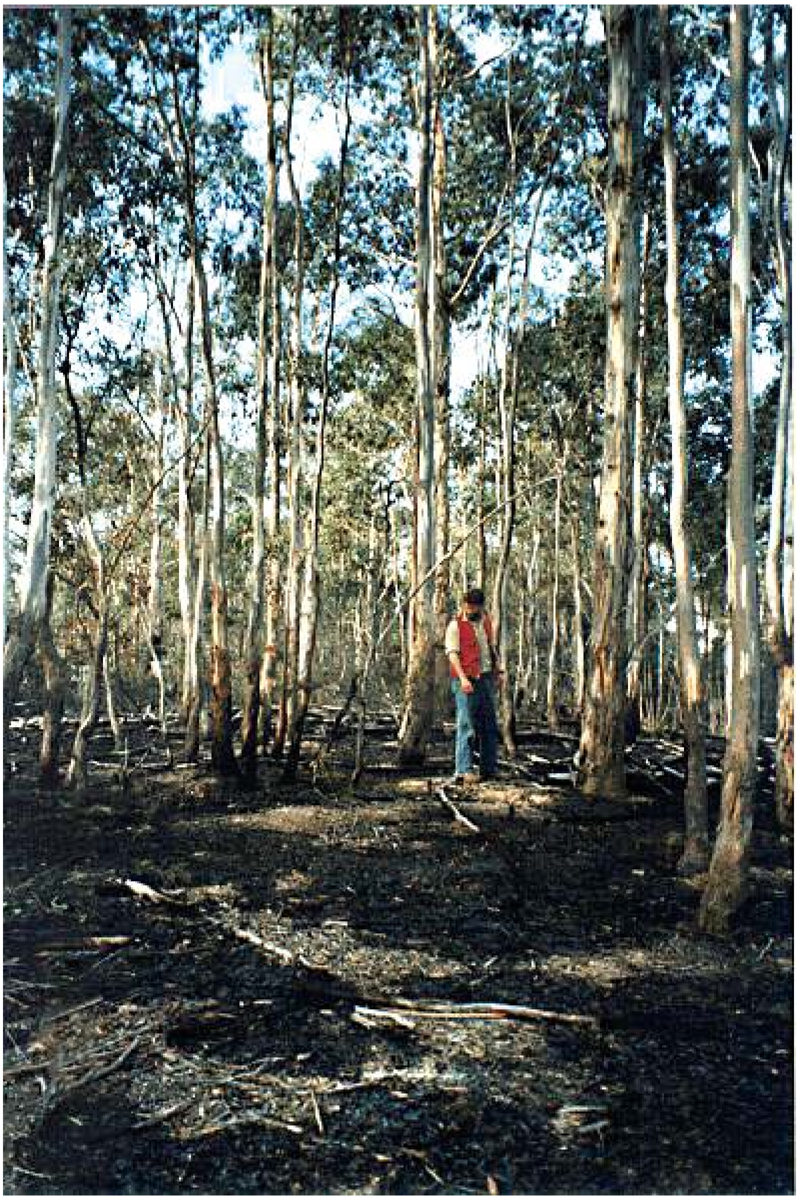


Figure 14: An area cleared through prescribed burning under very mild conditions

Activity 4.1

Identify the fuel and weather characteristics critical for low- and high-intensity prescribed burning in your locality.

Section 4 summary

- Any prescribed burn objective will be closely related to fire intensity.
- Low-intensity burns are required to consume surface litter fuels, and lower shrub and bark fuels.
- High-intensity burns are required to consume maximum fuel loads and cause maximum soil heating.
- Fire behaviour in prescribed burns will be influenced by fuel, weather and topography, and ignition pattern and technique.
- Differences in fuel type mean differences in general arrangement and bark and fuel size characteristics. Together with fuel load, fuel hazard and fuel moisture content they influence flame heights and rates of spread and hence fire intensities.
- Slope, aspect and elevation influence fuel type, available fuel quantity and fuel moisture content, and therefore rate of spread and fire intensity.
- Temperature, relative humidity, wind, atmospheric stability and drought index influence either proportion of fuels available to burn, or rate of fire spread, and thus fire intensity.
- McArthur's Forest Fire Danger Index (FFDI) summarizes fuel and weather influences on fire behaviour with an indication of the anticipated level of difficulty of fire control for the prevailing weather and fuel moisture conditions.

Self-assessment questions

1. What are the maximum values for flame height, rate of spread and intensity generally considered appropriate for low-intensity prescribed burns?
2. What are the greatest influences on scorch height?
3. Under what circumstances are high-intensity burns appropriate?
4. What factor in addition to fuel, weather and topography will influence the fire behaviour of prescribed burns?
5. What is an appropriate range of fuel moisture content for most low-intensity prescribed burning?
6. For low-intensity burning, what are desirable maximum values of the KBDI or the SDI, and of the Fire Danger Index?

Section

5

Equipment for prescribed burning

Section
5

Equipment for prescribed burning

In addition to your PPE the equipment and chemicals you may use in prescribed burning activities include:

- hand tools
- knapsack
- ignition devices
- hoses and small gear
- water supplies and hydrants
- pumps and pumping operations
- light and heavy tankers
- wetting agents, foam, gelling agents and fire retardant
- earthmoving equipment.

Hand tools

Some simple common hand tools can be extremely effective in firefighting operations.

The most common hand tools used on the fire ground are the axe, the rakehoe (combined heavy rake and hoe) and various types of slashers. The Pulaski hand tool (combined axe and hoe) may also be used specific situations.

Axe

The axe is used for many activities in prescribed burning including:

- felling small trees
- removing branches
- cleaning bark from trees
- splitting logs and stumps.

All axes must have secure handles because an axe head flying off a handle can cause serious injury.

An axe will be most effective and safest when it is sharp. Axes will become blunt after coming in contact with soil or rocks whilst cutting logs or stumps. Once an axe has been used in this manner, it should be correctly re-sharpened to make sure it is ready for use.

Use an axe head cover to protect the axe head when not in use, and to protect yourself and other personnel from injury.

Rakehoe (McLeod tool)

A conventional rakehoe as shown in (Figure 15) is equipped with:

- one pronged edge for raking
- one sharpened edge for cutting, chipping and scraping down to mineral earth.

Figure 15: A rakehoe and close-up of the head (image courtesy of BRT Fire and Rescue Supplies)

The rakehoe is used for:

- raking and scraping away surface fuels to create fire-control lines (see Figure 14)
- raking litter and vegetation into the burnt area
- scraping bark from tree trunks
- raking out hot coals from logs and stumps.

There is a wide range of single and multiple use tools modelled on the basic rakehoe and offering additional features. The Gorgiou tool shown in Figure 16 is one example of such a tool.

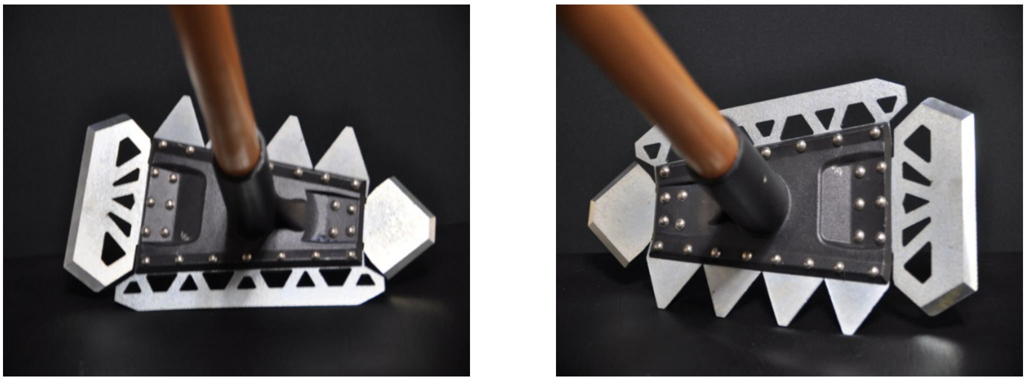


Figure 16: A Gorgiu tool — a tool with a combination raking, trenching and scraping head (image courtesy of BRT Fire and Rescue Supplies)

Figure 17: Construction of a handline

Slashing tools

Two types of slashing tools (Figure 18) are commonly used: slashers and fern hooks. These are used in shrub and scrub fuels for:

- the initial clearing of scrub by a crew cutting a fire break or fire-control line
- clearing a large area for the safe siting of a tanker and crew
- clearing a helicopter landing zone.

Note: *When slashing scrub, try to avoid leaving sharp-cut stumps near the fireline where they may present a trip or fall hazard.*

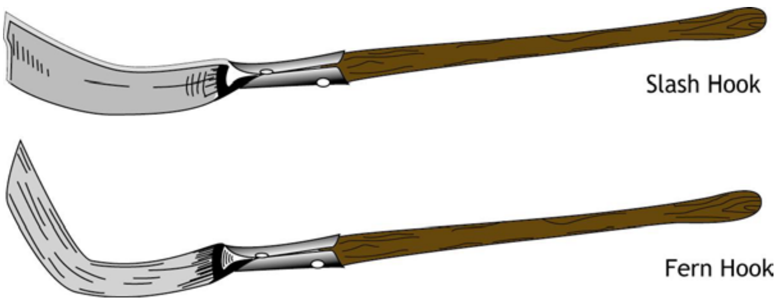


Figure 18: Slashing tools

Pulaski tool

The Pulaski tool is a combination of a hoe and an axe fitted to a straight handle (see Figure 19). It is used mainly:

- in rocky terrain where there is a lot of tussock type grass
- for splitting open and raking out logs or stumps.

There are two basic types of Pulaski, those in which the horn or hoe is forged in one piece with the axe head (very strong) and those in which the horn or hoe is a separate piece which has been welded to the axe head. If you are using a welded Pulaski it is very easy to break the weld if the tool is used roughly to chop and dig rather than to chip and scrape.

Take care when using a Pulaski, there is always one cutting edge which is not in use, but is unguarded.

Figure 19: Pulaski tool

The chipping edge is sharpened like a rakehoe, while the cutting edge is sharpened like an axe.

Maintenance of hand tools

Maintenance of hand tools involves checking the condition and security of the handle and sharpening cutting edges.

Your agency may have a Standard Operating Procedure for hand tool maintenance and sharpening.

If not, when you sharpen any hand tool, you should:

- where possible, secure blades in a vice, for easier and safer sharpening
- use a file or sharpening stone. A power grinder or linish grinder may be faster, but you can easily soften the steel in the tool as a result of the heat generated by grinding. Power grinding is acceptable only if you repeatedly cool the cutting edge with water, or preferably, soluble oil
- angle sharpening strokes away from the cutting edge. If you file towards the cutting edge you may be injured if the file slips
- never use a file without the correct handle.

Wooden handles should be checked for gouges and splinters, lightly smoothed with sandpaper and oiled with linseed oil.

Carrying hand tools

When carrying hand tools, you must:

- ensure cutting edges are properly guarded at all possible times
- carry the tool close to your body with the handle parallel to the ground, do not carry them over your shoulder. If you swing a tool around, it may strike another person, or if you fall, it may cause you serious injury
- carry tools on the downhill side when walking on steep side slopes. This way, if your feet slip out from under you, you will fall onto the hill and not on top of the tool.

Knapsacks

A knapsack is a portable water tank fitted with shoulder straps for carrying on the back (see Figure 20) and a hand-operated pump which can deliver water either in a jet or spray. The tank may be rigid or flexible and hold between 16 and 20 litres of water.

The tank of most modern rigid knapsacks is made of polythene, and very robust. Flexible tank knapsacks are generally used in applications where space saving is more important than cost, e.g. by helicopter transported remote area firefighters.

On the fireground, you can use a knapsack to:

- make a direct attack on a low-intensity flank fire
- support hand crew who are constructing a fire-control line close to the fire edge
- assist in blacking out operations.

The pump has a nozzle which can be adjusted to give either a straight jet for long distance work or a fantail spray for close work. The fantail method uses water more economically and effectively when a firefighter is working close to a fire.

Figure 20: Flexible Knapsack spray pump (image courtesy of BRT Fire and Rescue Supplies)

Before and after use check the knapsack as follows:

- sealing ring is present in the screw cap (these are easily lost, resulting in leakage)
- flexible hose is in good condition with secure connections to the tank and the pump
- pump trombone and the spray adjustment move easily. If the pump is made of brass, lubricate the 'O' rings and moving parts with petroleum jelly (Vaseline). If the pump and nozzle is plastic, check the manufacturer's recommended maintenance procedure.

Ignition devices

To ignite a prescribed burn, a range of ignition devices can be used, including matches, drip torch, hand-held or vehicle-mounted flame throwers and hand-held incendiary launchers. In large-scale operations, aerial ignition machines using incendiary capsules or helitorches dropping gelled petrol may be used. The most commonly used of these devices are described here.

Wind and water proof matches

Features of wind proof/water proof matches are:

- cheap, easy to carry
- allow good control of ignition density (they can be rationed to crews to prevent over-lighting)
- only suit fuels which are relatively dry and will ignite easily.

For safety reasons, personnel should carry boxes of matches in a light shoulder bag, rather than in the pockets of clothing. In the unlikely event of a loose match igniting in the bag (and igniting other boxes of matches) the bag can be instantly thrown clear.

Driptorch (firelighter)

The driptorch is used for lighting backburns and for burning out fuels in a parallel attack. A driptorch is a container holding a fuel mixture which runs, drop by drop, out of a nozzle over a lighted wick, dripping burning liquid onto the fuel to be ignited (see Figure 21).

If using a driptorch follow your crew-leader's instructions closely. Common mistakes are:

- opening the fuel tap too far and using more fuel than is needed to do the job
- taking too long lighting each spot and wasting fuel
- lighting spots too close together, which increases the intensity of the subsequent fire
- walking from spot to spot with the torch hanging down rather than held upright. This both wastes fuel and creates a line of fire, which will also increase the intensity, and the rate of spread of the subsequent fire.

A driptorch is made up of a:

Tank	an alloy cylinder consisting of a handle, filler cap and air vent.
Wand	a section of brass tube, about a metre in length and containing a coiled section to prevent flashback from the lighted tip to the tank.
Burner	made up of a nozzle and an ignition wick.

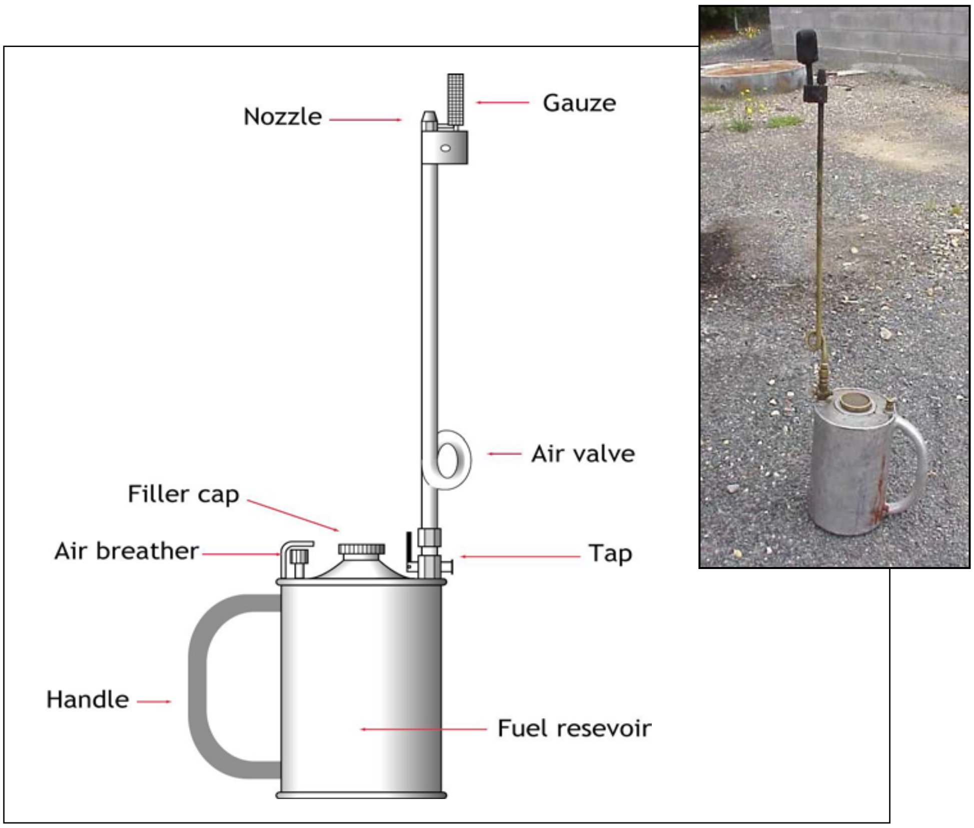


Figure 21: Drip torch

Important points when using a driptorch:

- Check the preferred fuel mix. Some agencies use kerosene, others use blends of diesel fuel and petrol, ranging from 2 parts diesel fuel to 1 part petrol, through to 4 parts diesel to 1 part petrol.
- Mixtures containing too much petrol flare excessively on the driptorch wick, and do not drip well, nor burn long enough to ignite the target vegetation. Mixtures high in diesel drip well but may be hard to light at the wick.
- Stand away from any sources of ignition, unscrew the filler cap and fill the tank with the preferred fuel. Avoid spilling the mixture.
- Replace the filler cap and check that its neoprene ‘o’ ring is in place and sealed correctly. Move away from the filling point and wipe off any spilt fuel before lighting.
- Loosen the air vent screw and tilt the driptorch so that the wand is pointing to the ground.
- Let fuel drip from the nozzle onto the wick.
- Ignite the wick with a match or lighter. If the fuel is kerosene or a mix rich in diesel, it may be easier to drip some fuel onto a grass tussock, light the tussock and fuel with a match, and to then light the driptorch from that.
- The burning fuel on the wick will serve as a pilot flame. As fresh fuel drips onto the wick, that fuel will catch alight and fall to the ground and onto the vegetation to be lit. The flow of the driptorch fuel is controlled by the air vent screw. On some types, there is also a tap at the base of the wand.
- When finished, tilt the torch upright to stop the flow of fuel.
- When the lighting is completed, close the fuel tap and air vent screw, and extinguish the pilot flame with a sharp puff of breath.
- Do not drive the burner into loose soil to extinguish the flame as this will block the nozzle and may damage the burner.

Flamethrowers

Two types of flamethrowers are in common use:

- a backpack type of about 20 litres (kerosene type fuels), connected to a hand wand incorporating a hand pump
- a vehicle mounted type of up to 120 litre capacity (diesel/petrol blend fuels), with fuel being electrically pumped to a hand wand, with electrical ignition.

Backpack flamethrowers are appropriate where fuels are difficult to light or are discontinuous.

Vehicle mounted flamethrowers (Figure 22) are appropriate where:

- trackside lighting is required over long distances (for example, ridge top burning in remote areas)
- fuels are difficult to light or are discontinuous.

Because of the nature of the flame produced, care must be taken not to use any sort of flame thrower near other personnel.

Figure 22: Vehicle mounted flamethrower (Source: DPAW, WA)

Propelled incendiaries

Incendiaries are usually fired from hand-held devices which should only be undertaken by licenced operators.

They are useful where ignition is required:

- on steep slopes difficult to traverse on foot
- in dense vegetation where access on foot may be difficult.

Aerial ignition devices

Aerial ignition devices may be used to light very large areas. Capsule dropping machines operated by specially trained staff, are most commonly used in heathland, grassland, grassy woodland and open forest. Helitorches, which drop gelled petrol are usually used for high-intensity burning after forest harvesting operations, but may be used in circumstances where the area to be burnt contains elevated fuels with little or no surface fuel. An example is old closed canopy heath communities.

Hoses and small gear

Agencies within Australia use different types of hoses and accessories to deliver water.

The following water delivery equipment may be used on the fireground:

- hoses
- couplings
- adaptors
- breechings
- branches and nozzles.

Hoses

The types of fire hose you may use on the fireground are:

- hard suction hose
- soft and hard delivery hose.

You should be able to identify the types of hose your agency uses at an incident. If possible match the hose to the task.

Suction hose

A suction hose conveys water to a pump when taking water from a tank, dam or river (a process called draughting). Draughting is the action required to pump water when a pump is situated in a position higher than the water supply. A suction hose is reinforced to withstand external pressure so that it will maintain its shape and not collapse when the pump is draughting water (see Figure 23).

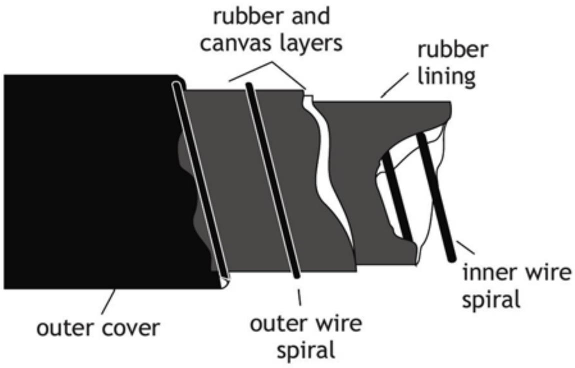


Figure 23: Suction hose.

When working with a suction hose, you must be careful not to puncture it. A hole in the hose or leaking coupling seals will make it useless as the pump will not be able to maintain sufficient vacuum in the hose to draw up the water from the supply. A suction strainer (Figure 24) must be connected to the end of the suction hose to prevent solid objects from entering the pump. Most strainers incorporate a foot-valve to prevent water running back from the pump.

Figure 24: Suction strainer attached to a hose and rope (left) and the same suction strainer fitted with a suction strainer basket (right). (Images courtesy of CFA.)

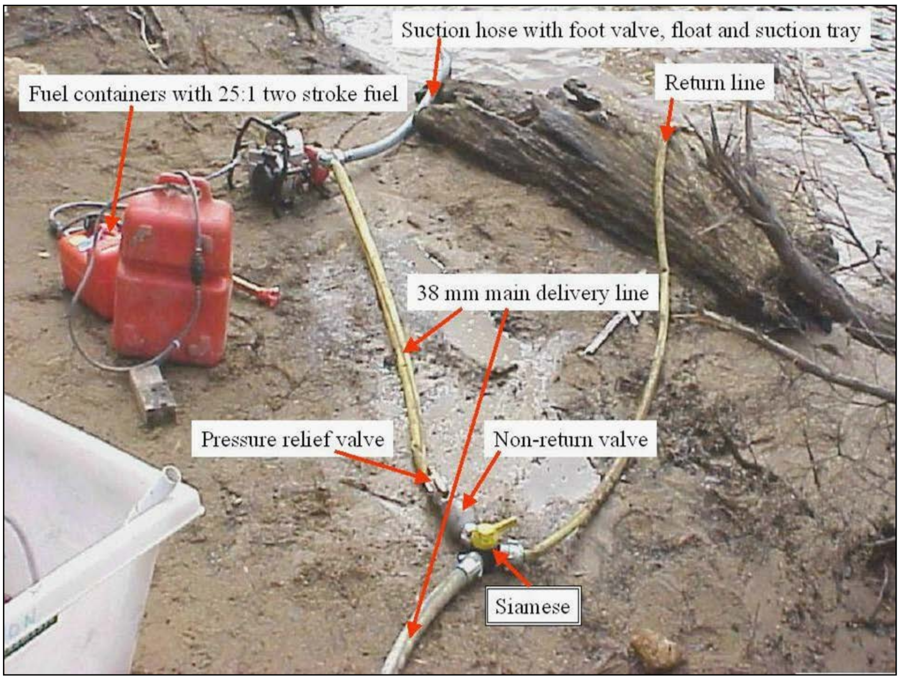


Figure 25: High pressure pump set-up

Delivery hose

Delivery hose is used for conveying water from pumps or hydrants to the fire. It is designed to withstand internal pressure. This hose can also be used as a supply line, that is, from a hydrant to a pump. There are four main types of delivery hose (Figure 26):

- **Layflat woven percolating** – mainly used in forest firefighting. In the manufacturing process the liner is needle-punched to create a large number of tiny perforations. These allow water to seep through the hose jacket to give some protection from hot embers.
- **Layflat woven non-percolating** – the lining is not needle-punched during manufacture and so the hose does not weep so the outer jacket remains dry. Intended for structural firefighting, extreme care must be taken when using this hose in bushfire fighting.
- **Layflat extruded** – where the outer jacket is encapsulated between the inner lining and outer coating. This hose is non-percolating, very resistant to heat and abrasion but very heavy in comparison to woven hose. Extruded hose is relatively low maintenance and does not need to be dried between uses.
- **Rubber/synthetic** – mostly used on manual or automated hose reels. This hose is quite heavy for its length and diameter.

Layflat hose can be rolled or flaked to occupy a very small space.

Figure 26: Types of delivery hose: From left — percolating or non-percolating, extruded and rubber/synthetic on a hose reel

Hose sizes

The size of delivery hose is based on its internal diameter. In prescribed burning operations, two broad categories of hose size are used: small (up to 38 mm) and medium (from 38 mm to 64 mm).

- Rubber hose reel hose is usually 19 mm to 25 mm in diameter. You don't have to unroll all the hose from the hose reel to get water and so can use it:
  - when it is necessary to take a line of hose quickly to a fire using the available water supply on the tanker
  - for rapid deployment and delivery of water
  - when rapid retrieval of hose is important
  - when only a short run of hose is needed.
- Layflat hose of 38 mm is commonly used to deliver water for extended distances from tankers, but is very difficult to move once filled with water. Think of this as a "water main" delivering water to a location.
- Layflat hose of 25 mm, and sometimes 19mm is often used along fire edges because it is lighter and easier to move than 38mm hose. It is also easier and cheaper to replace if it is damaged or burnt.
- Layflat hose of 64 to 75 mm diameter is commonly used to deliver water from quick fill pumps, or hydrants, to tankers or storage tanks.

Choice of hose diameter will depend on the quantity of water needed (and available), and the distance the water is to be moved. The further the water has to travel the larger the hose which should be used. When the water is only to be moved a short distance, ease of handling of the hose may be more important.

Hose classes

Three classes of woven layflat hose are available, Class L, Class M and Class H, classified according to the maximum operating pressure for which they are designed (see Table 6).

The following table shows the intended working pressure, the test pressure and the minimum pressure which the hose should contain before bursting for the three classes. Note that this is for new hose, as the hose ages in store or is knocked about in use the working pressure will reduce a little, but the burst pressure is likely to be greatly reduced.

Table 6: Pressure specifications for delivery layflat fire hose classes*

Hose class	Working pressure kPa	Proof test pressure kPa	Burst pressure (minimum) kPa
Class L	1000	1500	2500
Class M	1400	2100	3500
Class H	2100	3150	5250
*From Australian Standard AS2792-1992 Fire Hose — Delivery layflat.			

If you are helping to set up a hose lay, and find a mixture of hose classes to work with the rule is to always use the best condition highest class lengths of hose closest to the pump, as this is where the greatest pressures will occur, and so there is the greatest chance of bursting a hose. Hose in the poorest condition should go at the far end of the lay, closest to the branch, because this is where the pressure, and the problems caused by a burst hose will usually be least.

If you are using permeable or weeping hose it is important to match the hose to the pump if at all possible: Class L hose with low pressure pumps and Class H hose with high pressure pumps. The rate at which a hose is designed to weep water depends on the class of the hose and the pressure it is containing.

Hose care and maintenance

Hoses require specific care and maintenance for long life. However, the procedures used will vary from agency to agency. Familiarise yourself with the procedures required by your agency.

Couplings

Couplings are fittings used for connecting two lengths of hose together or joining hose to a pump or hydrant outlet. The types of couplings used by fire and land management agencies within Australia and New Zealand fall into 3 basic types are:

- screw or threaded
- Storz
- quarter turn hermaphrodite, sometimes called forestry, or Wajax couplings after the first manufacturer.

Screw or threaded couplings

Screw or threaded couplings are able to be used on all types of hose lines, including delivery and suction, to connect hose lengths. Hoses to be connected need to be positioned so that the male coupling of one hose can be connected to the female coupling of the next hose.

These couplings are generally made of brass, are heavy, and inclined to catch on obstructions when used in the bush.

Storz couplings

Storz couplings can be used on both delivery and suction hoses (see Figure 24). The couplings fitted to each end of a length of hose are identical. Either end of the hose can go to the pump, unlike screw or threaded couplings.

Quarter-turn hermaphrodite

These couplings are made of light alloy and are similar in concept to Storz couplings but the lugs are external to the coupling face for easy cleaning in dusty or muddy conditions. They are suitable for delivery hose only, and are most commonly used in rural firefighting operations. These couplings should not be over tightened — hand tight is sufficient.

Care and maintenance of couplings

You should treat couplings with care because damage may cause air leaks in suction hose or water leaks in delivery hose. Damaged to the thread of a screw coupling may render the hose-length unusable until the thread can be repaired.

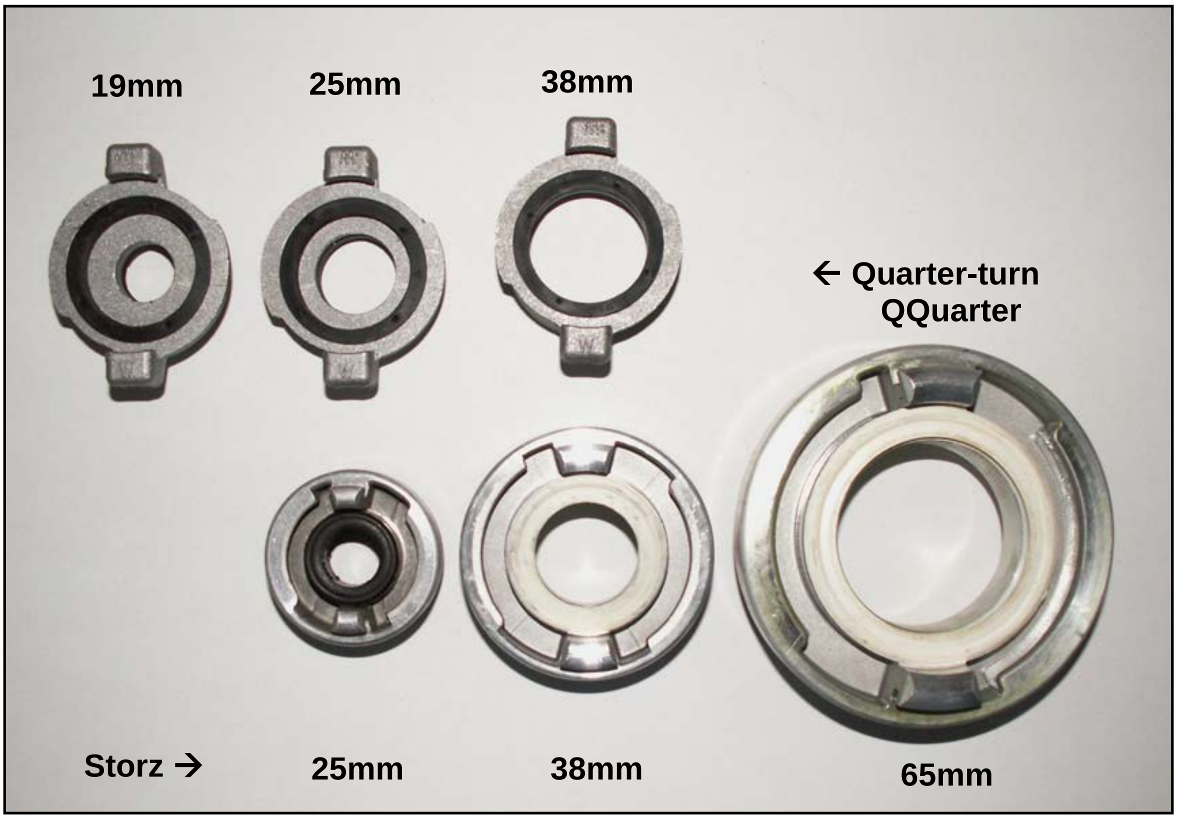


Figure 24: Storz and quarter-turn couplings showing relative sizes

When working with couplings, you should:

- never drop or drag them along the ground
- not use a hose-key or hose spanner to tighten them at the joints unless essential, and then use the correct size tool. Never use a tool to tighten quarter-turn hermaphrodite couplings.
- inspect seals and washers for wear and replace as necessary
- not treat them with lubricants.

Couplings must be regularly inspected to ensure that they are in operational condition. The procedures used for their cleaning and testing vary from agency to agency. Apply the procedures required by your agency.

Adaptors

These are fittings used to couple different sized hoses, hoses of the same size with different threads, different types of couplings, or to connect the male to male, or female to female parts of the same type of coupling (see Figure 28).

Breechings (siamese)

'Breeching' is a name commonly used by fire services, whereas the term commonly used by land management agencies is 'siamese' (see Figure 29).

A breeching may be used to divide or unite streams of water:

- dividing breeching – dividing one line of hose into two
- collecting breeching – uniting two lines of hose into one.

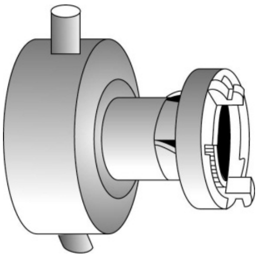


Figure 28: A typical adaptor

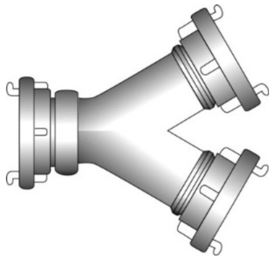


Figure 29: A typical breeching

Branches and nozzles

The terms branch and nozzle are often used interchangeably and quite loosely. The definitions are:

A **branch** is a tapered pipe, fitted to the end of a hose line, which increases the velocity of the water or foam solution travelling through the hose, and forms an effective firefighting jet or spray.

A **nozzle** is a fitting that is used with a branch to control the size, pattern and/or velocity of water or extinguishing medium being discharged. A separate nozzle may be fitted to the end of a branch, or the branch and nozzle may be a combined unit. Find out the terms used in the agency or brigade you work with and use those.

In prescribed burning operations you will most commonly use lightweight, single piece multi-pattern nozzles, which connect directly to the end of the hose (Figure 30). These offer great flexibility in use but rarely have the range of a traditional branch and nozzle combination. One place where a branch and nozzle combination is useful is for directing a stream of water high, into the top of a standing hollow tree, or to attack burning elevated fuel, e.g. bark in the fork of a tree branch.

Branches and nozzles come in various types and sizes. They provide you with a range of options for delivering water at a fireground. It is important to select the branch and nozzle most suited to a particular task.

Many branches are fitted with controls to allow you to control the flow of water and the stream pattern.

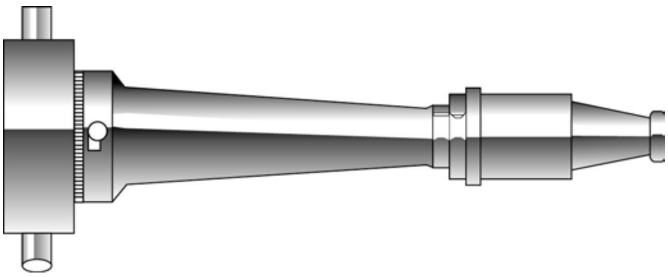


Figure 30: Standard branch and nozzle

Types of branches and nozzles

The branches and nozzles most commonly found may be divided into two main types:

Standard branch	This is used to increase the velocity of a jet of water. It does not have variable or shut-off controls. This is the branch shown in Figure 30.
Variable control branch (or nozzle)	May have options such as: – shut-off control – water volume control – jet and spray selector – independent control of jet and spray – variable spray patterns from a jet to a fog pattern – fog.

Some types of branches may be operated to supply a fog water curtain and a jet at the same time. Most variable branches are capable of being shut-off at the branch and some have a pistol grip that makes them easier to operate.

Using a branch

When using a branch, it is essential that you hold it correctly. This will reduce fatigue, prevent accidents and ensure efficient and effective firefighting. Pumps working on too high a pressure will always make branch handling difficult. If you are unsure about what to do, see your supervisor.

Water streams

You can extinguish fire by applying water using various techniques such as jet stream, spray pattern and fog pattern.

Jet stream

A jet stream is an unbroken stream of water projected from a nozzle. It is designed to give maximum throw (see Figure 31). The principal purpose of a jet stream is to achieve a long reach, either horizontal or vertical, penetrate the flames and attack the seat of the fire.

When using a jet, you should direct the stream onto the seat of the fire and move the jet across all burning material to achieve maximum cooling. The jet can also be used to break up the burning material.

The **advantages** of a jet (depending on the nozzle size selected and pressure used) are:

- longer reach than sprays (so is useful for dealing with burning trees)
- provides greater penetration than sprays
- least affected by wind
- less affected by radiant heat.

The **disadvantages** of a jet are:

- jet reaction (the rearward force) is increased with high pressure and firefighters may tire quickly
- may cause significant disturbance which damages potential evidence at the point of fire origin
- capable of conducting electricity
- high water use
- may push hot coals across a fire-control line
- doesn't provide any heat protection to operators.

Figure 31: Jet stream (photo courtesy of QFES)

Spray pattern

The spray nozzle or variable control branch breaks the water stream into small droplets (see Figure 32). These small droplets have a much larger total surface area than a jet. A given volume of water in a spray will absorb more heat than the same volume of water in a jet.

Figure 32: Spray pattern (photo courtesy of QFES)

The **advantages** of a spray pattern are:

- can be configured to provide a curtain of water for firefighter protection
- increases the rate at which water is converted to steam, removing more heat from the surrounding fire
- covers a large area and is therefore more economical in its use of water.

The **disadvantages** of a spray pattern are:

- shorter reach and less penetration capability than a jet stream
- doesn't effectively cool hot spots or objects unless it is applied directly on to them.

Fog pattern

A fog pattern is an extremely fine spray of particles of water forming a mist pattern (see Figure 33).

Figure 33: Fog pattern (photo courtesy of QFES)

The **advantages** of a fog pattern are:

- covers a larger surface area than water spray or jet stream
- absorbs heat rapidly within a contained area
- enhances the rate at which water is converted to steam, removing more heat than a spray pattern
- minimizes damage to property
- maximizes effective use of water
- can be configured to provide protection to firefighters.

The **disadvantages** of a fog pattern are:

- has a shorter reach than a jet stream
- will not cool hot objects unless it is applied directly on to them
- affected by wind
- can impede visibility.

Water supplies and hydrants

Water is commonly used in controlling, blacking out and extinguishing prescribed burns. If it is not readily available then you will need to use dry fire control techniques.

Sources of water

Water for firefighting can be obtained from:

- **Reticulated** supplies: water mains or pipes which deliver water to consumers for domestic and industrial purposes. To enable water for firefighting to be obtained from mains, fittings called hydrants are attached to mains at various points.
- **Static** supplies: these are bodies of water such as dams, rivers, lakes, tanks, reservoirs or private swimming pools. When using water from a static supply, firefighters must draught water using firefighting pumps and suction hoses.

In some rural areas covered by your agency, water may be drawn from a reticulated or static supply elsewhere and transported to the incident in water tankers. You should identify the reticulated and static water supplies available in the vicinity of the area to be burnt.

Legislation

The taking of water from reticulated and static supplies is controlled by State and Local Authority legislation, and Fire Authority Acts. If assisting with a prescribed burning operation you will be told what you are permitted to do when accessing water supplies.

Hydrants

Hydrants are devices that allow you to connect a hose or a standpipe to a water main. Hydrants may be above ground or below-ground. A standpipe is a portable piece of equipment used to extend the outlet of a below-ground hydrant to above ground level.

Hydrants are situated at regular intervals along mains. You can use hydrants to:

- supply water to a fire tanker
- supply water to a branch via a hose for attacking a fire.

Types of hydrants

Hydrant types and patterns vary across Australia and New Zealand. You should familiarise yourself with the hydrants in your local area.

Hydrants can be classified as being either above ground or below ground.

Above-ground hydrants

Above-ground hydrants (see Figure 34) have a screw valve to control the flow of water. In most instances, you will need to use a hydrant key or spanner.

Note: *It is also important to be aware that in some remote areas, large water tanks with hydrant fittings and valves may be available. These outlets are gravity fed and are not pressurised. They enable you to obtain water during firefighting operations – principally for refilling tankers.*

Figure 34: Types of above-ground hydrants

Below-ground hydrants

Below-ground hydrants (Figure 35) are used in conjunction with a standpipe:

Figure 35: A typical below-ground hydrant with standpipe fitted

Hydrant indicators

Water supply authorities, councils and fire authorities provide markers to indicate the locations of hydrants. These markers are designed to be seen easily by firefighters, in day or night conditions. The marking systems used vary considerably.

The preferred methods of marking are blue retro-reflective markers on the road surface or on an adjacent post or pole.

A standpipe is a portable piece of equipment used to raise the outlet of a below-ground hydrant to above-ground level (see Figure 36). Once you have done this, you can connect a hose to the standpipe outlet. When you use a standpipe, be aware that:

- because the hydrant is below-ground, it may be full of dirt and debris
- dangerous wildlife may hide under a hydrant cover
- syringes may be concealed under a hydrant cover.

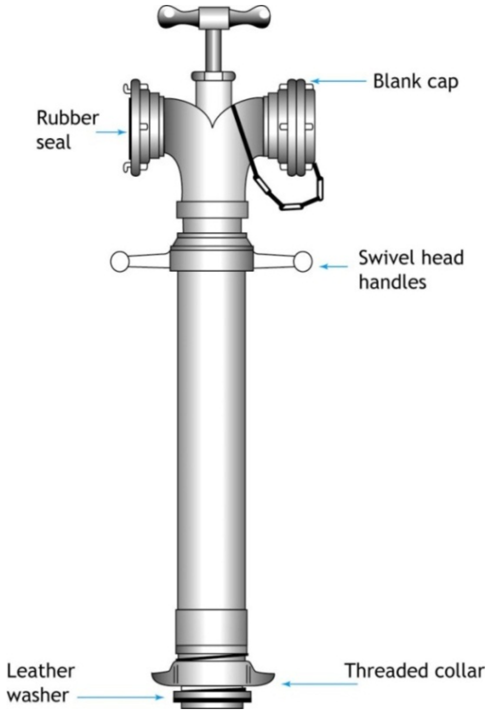


Figure 36: A standpipe

Operating hydrants

When operating a hydrant, you should:

- flush the hydrant to remove debris before connecting a hose
- open and close the valve slowly to prevent water hammer and damage to the main or hose especially if the hose is connected directly to the branch (this also prevents potential injury to firefighters)
- don't attempt to set or remove a standpipe from a hydrant until you have been shown how to do so by a competent person.

Ancillary hydrant equipment

When operating a hydrant, there are two useful pieces of equipment available in addition to the standpipe. They are the hydrant key and the hydrant bar.

The **hydrant key** is used for:

- lifting and removing the cover plate
- loosening dirt and rubble underneath a hydrant cover plate
- turning the hydrant on or off.

A **hydrant bar** is used for:

- lifting and removing the hydrant cover plate
- loosening dirt and rubble underneath the cover plate.

Pumps and pumping operations

After firefighters have located a source of water for fire operations, the water needs to be fed into a pump to enable the pressure and flow to be controlled.

Types of pumps

Pumps used by fire agencies may be divided into two broad categories:

- centrifugal pumps
- priming pumps.

Centrifugal pumps

The most common type of pumps used on fire appliances in Australia are centrifugal pumps. These pumps are designed to pump water only; they do not pump air. For this reason, a separate priming device must be fitted to get the water into the pump so that it can begin pumping.

Centrifugal pumps:

- have only one moving part and are simple to maintain. This makes it very unlikely that the pump will break down when in use.
- single stage centrifugal pumps can be run while delivery lines are closed for a short time without damage or danger

In general multi-stage high pressure centrifugal pumps cannot be run without some water flowing through the pump. These pumps should be set up with a gated siamese (breeching piece with valves so that water can be returned to the supply source: tanker, stream, or static water body).

Most, if not all, fire tankers use centrifugal pumps. Each agency has its own training methods and requirements for pump operation. You should make yourself aware of the pumps and operating procedures used by your agency.

Priming pumps

The function of a priming pump is to remove air to allow water to flow into the centrifugal pump (to commence draughting). This is called priming the pump.

There are various types of priming pumps. These include:

- positive displacement pumps e.g. rotary pump (see Figure 37)
- diaphragm pumps — usually found on small slip-on bushfire fighting units (see Figure 38)
- ejectors.

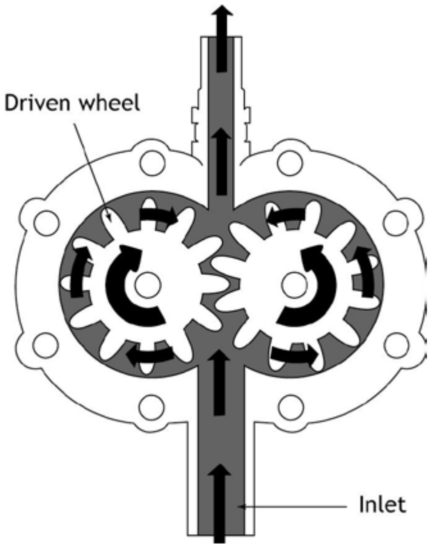


Figure 37: Positive displacement rotary pump

Figure 38: Typical diaphragm pump

Pump operation

Regardless of the pump type or the source of supply, there are some common points that must be considered when pumping water:

- pressure and flow should be carefully controlled and any changes should be gradual. Sudden changes in pressure and flow alter jet reaction (force) at the branch, making it difficult to hold and placing the branch operator at risk
- all pumps should be operated in accordance with your agency's procedures.

Pumping from a tanker

Pumping from a tanker is the most common operation undertaken during fire operations. It is the simplest pumping operation and involves:

- checking that the correct valves are open, particularly the tank supply valve
- monitoring the rate at which water is being used from the tank
- adding wetting agent or foam concentrate if required

Draughting from a static supply (water body)

Draughting (pumping) from a static water supply enables water to be delivered for firefighting when there is no reticulated supply available.

When draughting, the pump should be sited as close to the water surface as possible while remaining safely on solid ground. The greater the height of lift from the water surface to the eye of the pump impeller, the more the output of the pump is reduced.

When draughting, you should be aware that:

- mud, weed or other foreign bodies can clog the suction strainer
- the water needs to be sufficiently deep to draught. If too shallow, a whirlpool will form above the strainer, air will be drawn into the suction hose and the pump will lose its prime. In an emergency this can be prevented by placing a solid object such as a garbage bin lid, over the strainer so that it can only draw water from the sides, and not down from the surface
- if draughting from a tidal water source, the water level can rise and fall. As the tide ebbs, it may expose the suction hose and draughting will cease.

Pumping from a reticulated water supply (water mains or pipes)

When pumping water supplied from a hydrant, use the largest size hose available between the hydrant and the pump to minimise pressure loss due to friction. Always try to locate your pump as close as practical to the hydrant. If it is necessary to set the pump at some distance from the hydrant, consider twinning the supply lines (using two hose lines with breechings) to minimise friction losses.

If using a hydrant that requires the insertion of a standpipe, follow the procedures outlined in the previous section. In addition, the pump operator should:

- ensure that the hydrant or standpipe is opened and closed slowly to avoid water hammer
- constantly monitor the pump gauges to ensure that inlet pressure does not fall to zero

Water relay

Water relay involves spacing a number of pumps at regular intervals along a route between the water source and the point where water is needed. A water relay is used when the water supply is distant from the fireground, and overcomes the effect of friction (where very long hose lines are required) and/or gravity (where water has to be pumped uphill). It involves connecting lines of hose from one pump to another to where the water is required.

Tankers

Firefighting tankers (see Figures 39 and 40) can be purpose-built vehicles, tray type vehicles fitted with a slip-on unit of tank, pump and hose, or temporary units mounted on a variety of vehicles such as tray trucks or tippers.

If you are deployed to work with a tanker, it is vital that you are familiar with all the equipment features you may have to operate. Many tankers and slip-on units are now fitted with foam induction systems that give the choice of plain water or a foam solution that is usually aerated to create foam by a special branch. You may be required to use the controls on such vehicles to achieve the foam or water output required.

Figure 39: Some types of large and small tankers.

If working with a tanker, ensure that water levels are monitored according to agency procedures so that you do not run out of water when you most need it. Some agencies specify minimum levels of water that must be retained in tanks for the operation of the appliance's crew protection system in an emergency. Be sure you are familiar with your agency's crew protection procedures, and the operation of the tanker's self-protection system.

Tankers (and slip-on units) are often required to operate in difficult, steep terrain. Be aware that water movement in tanks can reduce the vehicle's stability on side slopes. These vehicles should only be driven by accredited, approved drivers.

Figure 40: A typical heavy tanker (photo courtesy of Forestry Tasmania).

Conserving water

When working on a fireground, activities should be carefully planned to avoid wasting water. You should:

- use an appropriate hose and always select the smallest nozzle that will do the job effectively
- shut off the nozzle when water is no longer required
- use a jet stream for initial knockdown but then change to spray so that water covers the greatest possible area (or combination of a jet and a back-up spray)
- direct water at the point where it will have the maximum effect, that is, at the base of the burning fuel and not at the flames
- where appropriate, use additives such as foam or wetting agents to make the water more effective.

Wetting agents

These are chemicals that reduce the surface tension of water causing it to spread across a surface more easily and so cover a greater area. The use of a wetting agent will mean more economical use of water.

Figure 41 shows a leaf sprayed with water and the same leaf sprayed with a similar volume of water to which a wetting agent has been added.

Caution: some wetting agents can be corrosive. Thoroughly clean all pumps, knapsacks and sprays with clean water after using any wetting agent, and replenish with fresh water, follow the manufacturer's specifications and agency SOPs.

Note: *Never drink from firefighting water tanks. You have no idea where the water came from, or what has been added (e.g. detergent foam or gel concentrate).*

Figure 41: The effect of a wetting agent

Foam

Foam is a frothy liquid produced by aerating a mixture of water and concentrated detergent, which enables fires to be put out more efficiently.

Foam extinguishes fire by:

- preventing radiant heat from flames reaching adjacent fuel surfaces which have been blanketed with foam
- isolating the fuel from the oxygen in the air
- cooling the fuel due to the water content of the foam
- clinging to fuels for longer than plain water, allowing greater water penetration and reducing waste through run off
- lowering the surface tension of water, allowing it to penetrate fuels more easily.

The foam used in bushfire fighting and prescribed burning is called 'Class A' and is especially formulated for use on Class A type fires, which are those burning in natural fuels such as grass, forest litter or wood. Class A foam can be applied to a fire through a spray nozzle or a special foam-making nozzle, or it can be spread by aircraft. Foam is visible when applied, allowing firefighters to avoid under- or over-application.

The strength of the solution can be varied, from 3% concentrate when used with an aerating nozzle to produce a foam bubble blanket, down to 0.5%, at which concentration the foam concentrate acts as a wetting agent, increasing the penetration of the fuel particles by the applied water.

Precautions

When using foam concentrate, it is important to follow your agency's SOPs. Drums of this concentrate should be handled very carefully. The lids or caps should remain properly sealed to prevent spillage or splashing.

Foam concentrate is a powerful detergent which can remove skin oils. Wear gloves, eye protection and long sleeves when handling containers of foam concentrate. Wash splashed concentrate off of your clothes and skin immediately. Wash your hands and face with clean water after using foam concentrate or foam solution.

Foam either as concentrate or in diluted form is a strong surfactant and must not be allowed to flow into still or moving bodies of water. In high enough concentrations foam solution kills fish, by preventing their gills working, and amphibians (frogs, toads, etc.) by disrupting the water management properties of their skin.

Note: *When using foam, if at all possible, use a dedicated quick-fill pump to fill tankers, rather than draughting water using the tanker pump. This reduces the risk of foam solution running back through the pump into the water source.*

Applying foam

Foam should be applied to a fire as gently as possible, ensuring uniform coverage. It can be applied on scrub or trunks of stringy bark trees near the edge of a fire-control line just before lighting a backburn. The maximum projection of the stream should be used, letting the foam do the work. Foam is also particularly effective in blacking out work (see Figure 42).

Figure 42: Foam applied to ensure uniform coverage during mop-up (Photo courtesy of Bushfire CRC)

Fire retardants

A retardant is any firefighting substance applied on, or ahead of, the flame front of a fire in order to reduce its rate of spread or intensity, rather than to directly suppress combustion in the flaming zone. Fire retardants can be broadly categorised as short-term and long-term.

Short-term retardants

Short-term retardants rely almost entirely on their ability to retain moisture, thereby cooling the fire and keeping fuels ahead of the fire too moist to burn. Once the water evaporates the retardant action ends.

Class A foam can be used both as an extinguishing agent (as discussed above) and as a short-term retardant. In fact, it is probably the most common short-term retardant used in Australia. When used as a retardant, Class A foams may be effective for 20 to 40 minutes depending on the foam concentration and weather conditions.

Long-term retardants

In the context of bushfires, long-term retardants are chemicals (usually ammonium salts) which are mixed with water to form a thick liquid. This mixture not only coats the fuel, therefore acting as a physical barrier, the chemical also retards the combustion process. Long-term retardant mixtures are effective after the water has evaporated from them, and may continue to retard combustion for more than 24 hours.

Long-term retardants can be applied by tanker-type equipment, but are more commonly used in aerial fire-bombing operations, particularly to slow the spread of fires in remote areas while ground crews travel to them.

Equipment recovery and storage

At the end of firefighting operations there may be a considerable confusion of stores and equipment spread around the fireground and nearby. It is essential in the interests of efficiency and environmental care that such stores and equipment are recovered, stored and maintained as appropriate.

Recovery

Equipment and stores that may be deployed around the fireground include pumps and hose, fuel drums, hand tools. When no longer needed for fire suppression operations, it is essential that they be recovered from the field. Items such as hoses may have to be rolled in a temporary fashion to be transported to a suitable location for cleaning and storage.

Ensure fuel drums are properly sealed before loading on vehicles or trailers. Seek assistance to load heavy drums, using appropriate lifting equipment and techniques.

Storage and maintenance

All equipment and stores recovered from the fireground must be stored properly in accordance with agency procedures.

Equipment recovered from the fireground will almost always need some form of cleaning and maintenance prior to storage. Hoses should be cleaned and dried following agency procedures. Mechanical equipment should be checked to ensure it is in good working order. Some items require specialised lubrication prior to storage – make sure correct procedures are followed.

Firefighting appliances should be re-stowed with levels of supplies and equipment as per your agency’s standard stowage procedures for the particular vehicle involved. Water and fuel tanks should be refilled and all devices should be checked for proper operation. Any damage or items for maintenance or repair should be attended to or reported, as appropriate, in accordance with your agency’s normal procedures.

All litter from firefighting operations must be removed from the fireground and disposed of correctly.

Section 5 summary

- The types of hand tools used in firefighting include:
  - axes
  - rakehoes (McLeod tool)
  - slashing hooks
  - Pulaski tool (combined hoe and axe).
- Axes, rakehoes, slashing hooks and Pulaski tools require ongoing care and maintenance. Their blades must be sharpened carefully as blunt blades can be particularly dangerous.
- Hand tools must be carried carefully to avoid injury to the carrier or fellow firefighters.
- A knapsack consists of a backpack reservoir and a hand-operated pump connected by a length of tubing. It is used by firefighters in mop-up activities and can be used in attacking low-intensity fires.
- Prescribed burns can be ignited with matches, driptorches, flame throwers, incendiary projectiles, electrical circuits, aerial incendiaries or aerial driptorches.
- There are two main types of hoses: suction hose and delivery hose.
- There are four types of delivery hose: percolating, non-percolating, extruded, and rubber.
- Couplings are fittings used to connect two lengths of hose together, or to connect any piece of equipment to a length of hose.
- Adaptors are fittings used to couple different size hoses, hoses of the same size with different threads, or different types of couplings.
- A breeching is a device used for uniting or dividing hose lines.
- A branch is fitted at the end of a delivery hose to allow water or other extinguishing mediums travelling through the hose to form an effective firefighting jet or spray. It is used to control and direct water at a fire.
- A nozzle is a fitting that is used with a branch to control the size, pattern and/or velocity of water or extinguishing medium being discharged. A separate nozzle may be fitted to the end of a branch, or the branch and nozzle may be a combined unit.
- Three types of water streams are:
  - a jet stream
  - a spray pattern
  - a fog pattern.
- A reticulated supply is water fed from catchments to service reservoirs. The water is then delivered through a network of mains (pipes) to consumers.
- A static supply is a body of water, for example a dam, river or lake.
- Legislation controls the use of water from reticulated supplies.
- Hydrants are fitted to water mains.
- Hydrants can be located above or below-ground.
- Ancillary hydrant equipment includes hydrant keys, bars and standpipes.
- Pumps may be divided into three groups: centrifugal, displacement, and ejector.

- Pressure and flow from a pump, should be carefully controlled.
- Any necessary adjustments to pressure and flow should be gradual.
- Delivery gauges register outlet pressures in a pump.
- Compound gauges register inlet pressures in a pump.
- Pumping can be undertaken from:
  - a static water supply
  - a reticulated water supply
  - a tank supply.
- A hose lay involves checking that all excess hose taken to a fire is laid out in 'S' bends.
- Always monitor water levels in tankers.
- Water movement can reduce stability in tankers on side slopes.
- A tanker should support bulldozers used in direct attack.
- A wetting agent is a chemical which reduces the surface tension of water causing it to spread out and cover a wider area.
- Foam is a frothy liquid produced by aerating a mixture of water and concentrated detergent; a blanketing and cooling agent used for extinguishing fires.
- Class A foam is used on natural fuels such as grass, forest litter and wood.
- A fire retardant is a firefighting substance designed to retard combustion. It is applied on or ahead of a fire's flame front to reduce the fire's rate of spread or intensity.
- Fire retardants may be categorized as:
  - short term
  - long term.
- Long-term retardants are usually ammonium salts mixed with water.
- Recover equipment, stores and litter from around the fireground.
- Clean, maintain and store equipment as per your agency's SOPs.
- Restow, restock and replenish firefighting vehicles upon return from a fire.

Self-assessment questions

1. What are the main uses of an axe during burn operations?
2. What are the main uses of a rakehoe during burn operations?
3. What are some advantages of using fuses (matches) to light prescribed burns?
4. What are some disadvantages of using drip torches to light prescribed burns?
5. What fuel does a driptorch use?
6. Under what circumstances may the use of vehicle-mounted flamethrowers be appropriate?
7. What are the advantages of aerial ignition for prescribed burning?
8. Name the two main types of fire hose, and describe when they are used.
9. Name four different types of delivery hose.
10. What is the function of a hose coupling?
11. Name the three main types of hose couplings.
12. What is the function of an adaptor?
13. What is the difference between a branch and a nozzle?
14. What is a reticulated water supply?
15. What is a static supply?
16. Where are hydrants situated?
17. What is a standpipe?
18. What is the most common type of pump used on fire appliances?
19. What are wetting agents?
20. What is foam?
21. When is Class A foam used?
22. What does a fire retardant do?

Activity 5.1

Perform the following activities under supervision:

1. Demonstrate the appropriate method for carrying and sharpening hand tools.
2. Demonstrate the use of a rakehoe, knapsack pump and hand tools used by your agency.
3. Demonstrate the use and maintenance of the knapsacks used by your agency.
4. Demonstrate the use and maintenance of a driptorch.
5. Identify the branches, nozzles and hose fittings used by your agency and participate in activities involving the operation, and care and maintenance of each.
6. Participate in activities using a range of branches and nozzles used by your agency.
7. Practise running out hose reels and delivery hoses, branch and nozzle operation, and setting up a suction hose.
8. Extinguish a small (contained) fire by spraying water at the flames, then at the burning fuel. Satisfy yourself that the base of the flames is the correct point of aim.
9. Carry out maintenance procedures on the fire hose used by your agency, to your agency's SOPs.
10. Identify the types of hydrant that exist in your local area.
11. If possible, sketch or take photographs of each type of hydrant, and the indicators used to show their location.
12. Give a brief description of each hydrant and demonstrate how each is operated.
13. Outline relevant legislation for accessing water supplies for firefighting purposes in your area.
14. Operate the different firefighting pumps your agency uses:
    - Pump from a reticulated water supply.
    - Pump from a tanker.
15. Set up and operate an open circuit relay pumping operation.

Section

6

Prescribed burn ignition

Section
6

Prescribed-burn ignition

Pre-burn checks

Before ignition the person responsible for the conduct of the prescribed burn will check that everything is ready.

Prior to day of ignition (lead-up weeks and days)

- Burn plan drafted, endorsed and approved
- Perimeter controls planned and prepared
- Assets removed or protected
- Ignition technique and pattern planned
- Resources planned and committed, particularly specialist resources
- Contingencies planned (escapes, fall-backs, optional lighting patterns)
- Traffic management planned (where required)
- Early notifications made
- Weather and fuel being monitored, trends established.

Day before ignition

- Inspect that control lines suitable
- Secure relevant authorisation to ignite
- Confirm resource availability
- Obtain best available weather forecast
- Undertake test burn, if applicable
- Refine briefing script.

Day of the burn

- Entire approved burn plan available
- Authorisations confirmed
- On-the-day notifications completed
- Latest weather forecast available
- On-site fuel, weather assessed
- Ignition pattern confirmed
- Finalise briefing script
- Assemble and brief burn personnel
- Undertake test burn, if applicable.

Decide to burn

- Are site conditions within the burn prescription?
- Are prescribed resources available?
- Is test burn behaviour within prescription?

Ignition techniques

As described in the Equipment section a variety of ignition tools are available for prescribed burning. A range of ignition techniques are also available and the most appropriate technique will depend on:

- the size of the proposed burn
- the nature of the fuels
- topographic constraints (especially slope)
- the desired fire behaviour
- other constraints such as limited access.

Ignition patterns

Ignition patterns can have a big influence on fire behaviour by affecting:

- rate of spread
- total burn out time
- incidence of junction zones, and thus
- flame height and fire intensity.

Common ignition patterns

There are several common ignition patterns that can be varied to suit local conditions and the desired intensity of the subsequent fire. These are illustrated in Figure 43 and include:

- backing fire ignition, where all fuels are burnt by fire backing into the wind, or downslope (or both). Usually results in a low-intensity fire.
- strip ignition, where lines of fire are successively lit from the upslope or downwind perimeter, across the slope or at right angles to the prevailing wind. A variation on backing fire ignition. The intensity of the resulting fire will depend on the interaction of slope, wind direction and the distance between the strips.
- chevron (flank fire) ignition, where lines of fire are lit into the wind or downslope, resulting in the majority of the area being burnt by back fire. Another variation on backing fire ignition.
- spot or grid ignition, where fires from separate ignition points spread substantially before influencing one another. The overall fire intensity will be influenced significantly by the spacing of the spots.
- convection (centre fire) ignition, where fire is established first in the centre of the burning unit. Strong convection draws subsequent concentric lines of ignition towards the centre. Used to generate a high-intensity fire and most commonly in forest industry silvicultural prescribed burning.

Low-intensity burns

For low-intensity burns the level of fire behaviour (flame height, fire intensity) is critical to the burn's objective. Careful control of the ignition pattern is vital.

The lighting pattern chosen should allow all available fuels to burn out in the forecast burning period, with fire behaviour consistent with the burn's objective(s).

The fire behaviour of any prescribed burning operation will be largely determined by:

- prevailing fuel and weather conditions, and topography
- the area burnt by head fire, flank and back fire
- the area affected by junction zones.

The last two factors are determined by the choice between spot ignition and line ignition and the spacing of spot ignition points.

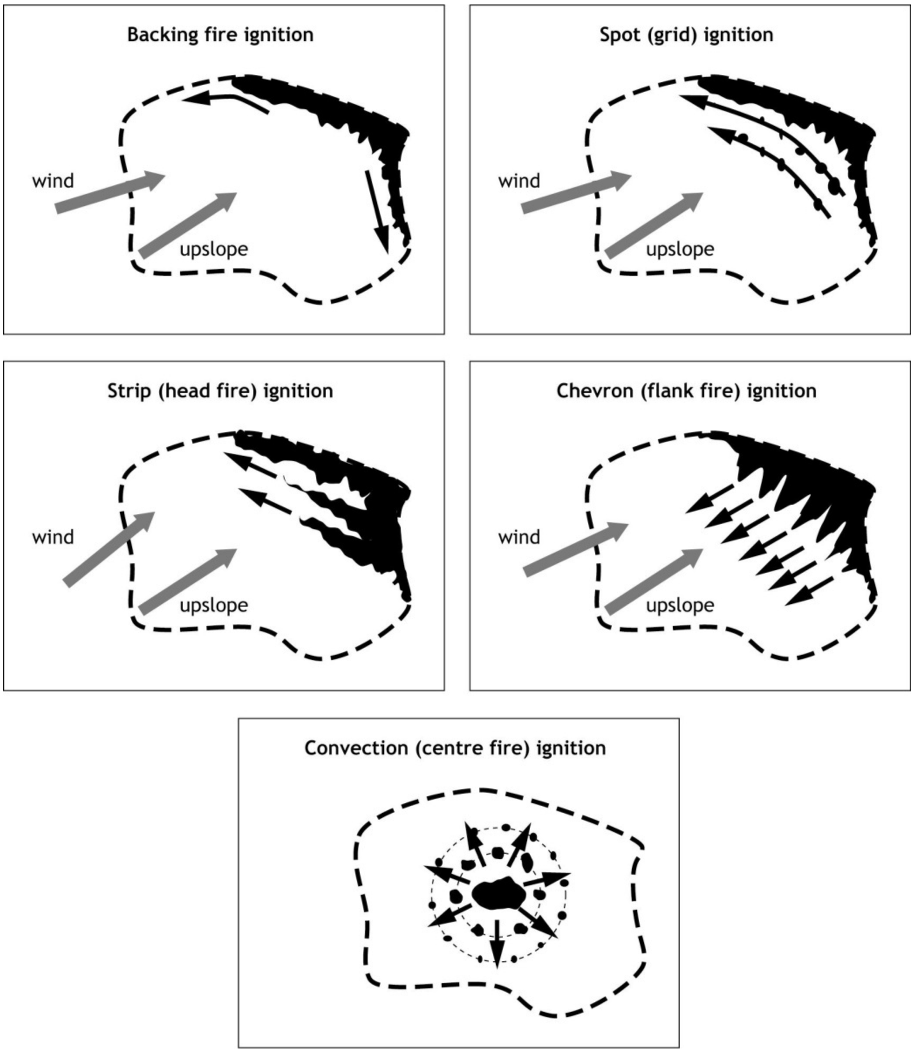


Figure 43: Common ignition patterns

Spot ignition versus line ignition

Figure 44 shows that a fire spreading from a single ignition point will burn approximately a third of the area with head fire, and two thirds with flank and back fire. By contrast, approximately five-sixths of the area burnt by a fire spreading from a line of ignition will be burnt by head fire, and one sixth by backfire.

Rate of fire spread for a given set of conditions is related to the width of the headfire. Under the conditions prescribed for low-intensity burning, fires spreading from individual spots will remain narrow and should not reach their potential rate of spread before the end of the burning period. Conversely fires spreading from extended lines of ignition may reach their potential rate of spread very quickly.

Similarly, wherever separate fires are lit in close proximity, some junction zone effect will occur as they burn together. Where it is essential that fire intensity be minimised, spot fire ignition is preferable to line ignition, unless the lines are lit such that the bulk of the planned area will be burnt by the back fire (that is, a **backing fire** lit close to an upslope or downwind control line).

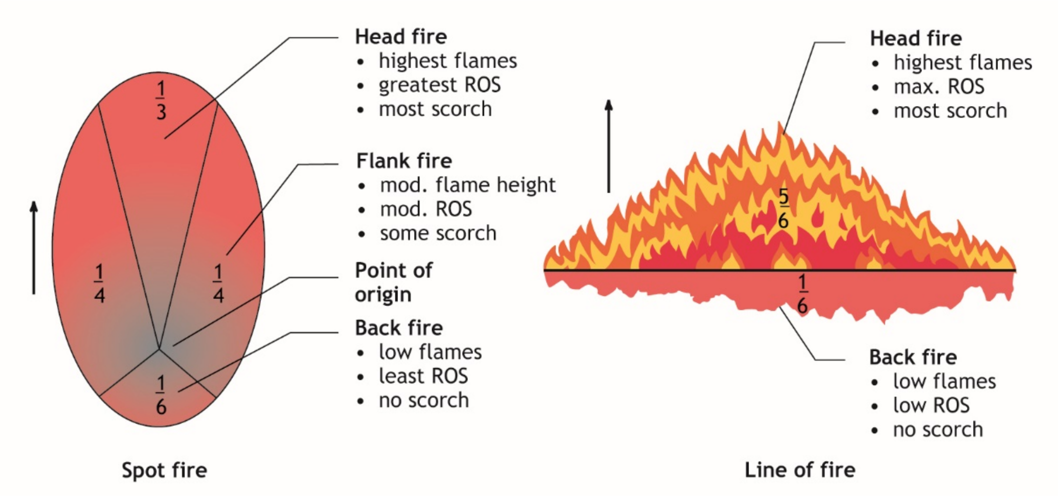


Figure 44: Spot fire versus line of fire

Use of grid ignition pattern

Where possible a grid system of spot fires should be used. Lighting should be done along the leeward or upslope boundary first. When this boundary is burning satisfactorily against the wind or downslope, further spots may then be lit in parallel strips running at right angles to the prevailing wind-direction or along the contour, if the slope is significant (Figure 45).

For hand lighting operations the crew of lighters should move in a slanted formation through the area, with the lighter on the downwind or upslope line leading the staggered crew. This ensures that each lighter is not endangered by fire from the next lighter upwind or downslope. Good communication between lighters (preferably with line of sight and voice contact) is essential to maintain this formation and ensure safety of individual lighters.

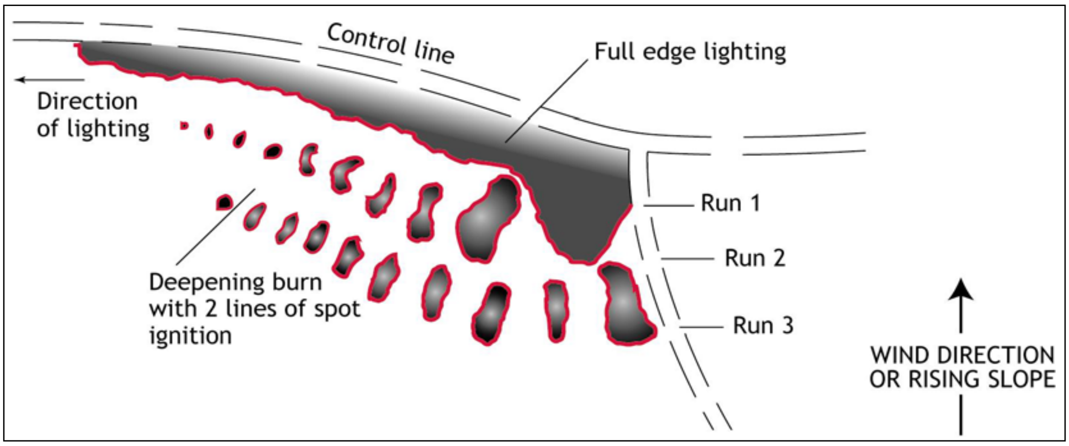


Figure 45: Lighting pattern for low-intensity ground ignition by crew on foot

Estimating spacing

The distance between lighting strips can be estimated as follows:

- predict the forward rate of spread (FROS) based on observations of a test fire in typical fuels, and on data from any tables or meters available
- estimate how much effective burning time is left. Allow for lag times and the fact that fires will burn more intensely as they draw together.

For example, if estimated FROS = 30 metres/hour and available burning time is three hours, then lighting strips should be about 100 metres apart. Successive strips are set upwind or downslope.

Individual spots along each strip should be at intervals of about half the strip width. This is because flank fire spread rates will be less than half the head fire spread rates.

Adjust pattern if necessary

Rates of spread of individual fires should be continually monitored. Distance between strips/spots is altered as required to give each fire maximum travel before it joins another (see Figures 46 and 46). Be flexible and prepared to alter plans to suit changing conditions.

It is better to space spot fires too far apart than too close together. Too close a lighting pattern will cause a big increase in junction zone effect, with a much higher overall fire intensity and effects such as scorch. If fires are obviously not going to meet in the available burning time, further ignition of unburnt patches should be considered if possible.

In many circumstances it will be necessary to burn out the whole perimeter and achieve a blacked out control line

Figure 46: Well-spaced fire rings on moorland subjected to a low-intensity prescribed burn

Figure 47: Spaced spot fires on moorland to achieve a low-intensity prescribed burn

High-intensity burns

For high-intensity burns, ignition patterns may need to be somewhat different.

To achieve the necessary high-intensity fire behaviour in standing forest or heathlands, ignition patterns may need to allow individual spots or lines of fire to ‘run’ downwind or upslope (see Figure 48). Such burns will have a higher risk of escape, and fuels on the down wind or upslope boundary may have to be burned first at lower intensities to provide a buffer.

The fuels remaining following timber harvesting are an example of debris type (slash) fuels, comprising mainly leaves and branches of the heads of trees. Harvested areas are often called coupes. Ignition patterns for slash fuels will involve either strip lighting or convection lighting.

Figure 48: High-intensity spot ignition in moorland (note the close proximity of ignition points)

High-intensity strip lighting of slash fuels

Strip lighting (Figure 49) is used where slopes are greater than about 10^o or wind strengths exceed about 15 km/h at the surface of the area to be burned.

A narrow strip of fuels along the vulnerable (upslope, downwind) edge is lit first. When these fuels are burned sufficiently to provide a safe buffer, further strips are lit progressively downslope (or up wind). Strips may be allowed to widen once a safe buffer has been established. The width of the strips will depend on:

- wind speed
- slope
- distribution and arrangement of fuel.

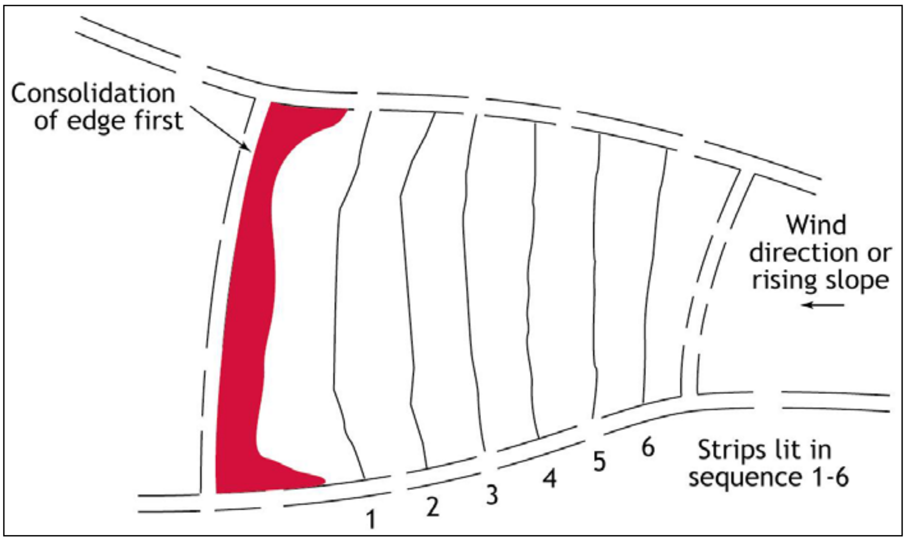


Figure 49: Strip lighting for high-intensity burns

High-intensity central ignition of slash fuels

Central ignition (Figures 50 and 51) is used to deliberately create an initial strong convection column from burning fuels in the centre of the area, which will create indraughts around the entire perimeter of the area to be burnt. Once the central fire is well established and burning strongly successive concentric lines of fire are lit, the lighting being completed with a line of fire around the perimeter of the burn area. The indraught winds contain the lines of fire and propel them towards the central convection column.

The successful undertaking of central ignition high-intensity burns relies on:

- establishment of a strong central convection column
- resulting strong indraught winds
- a difference in moisture content between the fuels to be burnt, and the vegetation surrounding the burn area. Ideally fuels to be burnt should be between 10% and 14% moisture content, while the dead fuels in the surrounding vegetation should have a moisture content of no less than 16%.

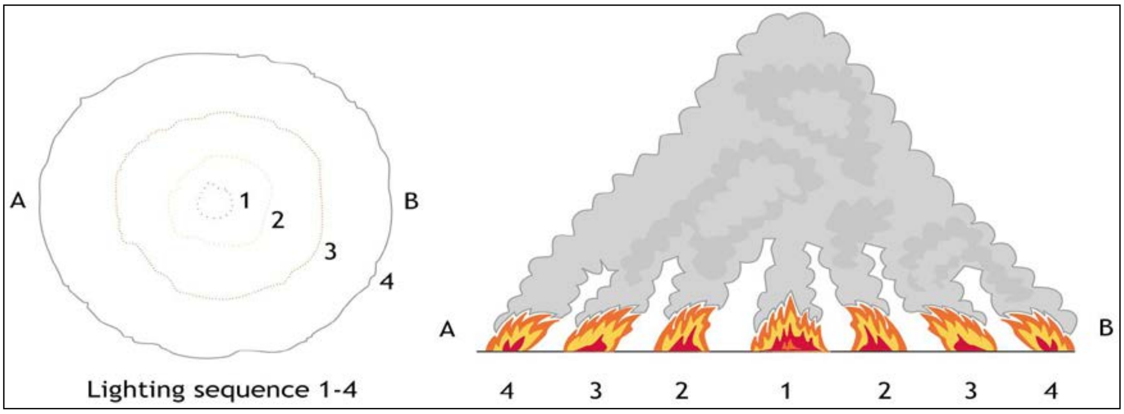


Figure 50: Central ignition for high-intensity burns

Central ignition has advantages in terms of:

- crew safety (high-intensity fire is drawn inwards from the perimeter)
- good visibility for the lighting personnel (smoke is drawn to centre of area)
- control (indraughts minimise risk of escapes over perimeter control lines).

Figure 51: Convection ignition showing indraught effect

Constraints on convection lighting

Unless the burn supervisor and the burning crew have extensive experience in central ignition high-intensity burning in steep topography, central ignition lighting should not be attempted where:

- slopes exceed 10 degrees
- wind speeds exceed 15 km/h.

Steeper slopes or stronger winds may overcome the convection indraught effect and allow the column to move towards the upslope or downwind edge.

Timing is important. Once the central convection column is established, successive lighting must follow promptly before the indraught influence starts to weaken. However if perimeter lighting is commenced too early, it may draw the central fire towards it, possibly causing mass spotting over control lines.

Beware of erratic fire behaviour as the fire intensity diminishes and the central convection column collapses. At this time the indraught winds will rapidly decrease in strength and fire whirls may develop above fuels remaining unburnt at this time.

Activity 6.1

What is an appropriate ignition pattern for a low-intensity burn and a high-intensity burn in fuels typical for your locality?

Section 6 summary

- A number of checks are required in relation to plans, perimeter controls, asset protection, weather and fuel monitoring and notifications, in the weeks and days leading up to a burn, on the day before ignition, and on the day of the burn before a decision is made to ignite
- The most appropriate ignition technique will depend on:
  - — the size of the proposed burn
  - — the nature of the fuels
  - — topographic constraints (especially slope)
  - — the desired fire behaviour
  - — other constraints such as limited access.
- Ignition patterns can include:
  - — backing fire ignition
  - — spot (or grid) ignition
  - — strip ignition
  - — chevron (flank fire) ignition
  - — convection (centre fire) ignition.
- Low-intensity prescribed burns are best lit with a grid system of spot fires, starting on the downwind/upslope boundary.
- Spacing is based on estimated ROS and available burning time.
- High-intensity burns may be ignited by strip lighting or convection lighting.
- Use strip lighting, rather than convection lighting for high intensity burns where slopes are greater than 10°, and/or wind is greater than 15 km/h.

Self-assessment questions

1. What checks should be carried out on the day of a burn before ignition?
2. What characteristics of a burn determine the most appropriate burn technique?
3. Generally, what proportion of the area burnt by a fire spreading from a single ignition point is burnt by the head fire?
4. Why is a spot ignition pattern generally preferred to strip (or line) ignition where fire intensity must be kept low?
5. How is spacing for spot ignition determined?
6. What slope and/or wind conditions make convection ignition risky in slash fuels?
7. What are the major advantages of convection ignition for high-intensity slash burns?

Section

7

Prescribed burn monitoring and control

Section

7

Prescribed burn monitoring and control

Monitoring of conditions

The success of a prescribed burn depends to a large extent on:

- the quality of fuel appraisal information
- the adequacy of prescribed limits on fuel and weather parameters
- how closely conditions on the day match those forecast or expected and those prescribed.

What and when to monitor

Once a burn has been ignited, actual site conditions should be monitored at regular intervals throughout the burning period to ensure that weather conditions remain within expected limits. Site conditions to be monitored and recorded include

- fuel moisture content
- temperature
- relative humidity
- wind speed and direction

along with fire behaviour parameters such as

- flame height
- rate of spread and spotting characteristics.

If relevant, fire behaviour parameters should be recorded for different parts of the burn perimeter (for example, head fire versus flank or back fire behaviour). This will allow anticipation of significant weather-induced changes to fire behaviour.

The monitoring and recording function is a vital component of safety management at the burn and should be carried out by appropriately skilled personnel.

Proformas for recording

Most agencies have a standard template to record forecast and actual conditions.

If conditions change

If, during the course of a burn, conditions change and move outside the prescribed limits, a decision will need to be made by the officer in charge whether to:

- terminate the burn at some intermediate boundary
- or alter the lighting pattern to minimise the effect of the changed, now unsuitable, conditions.

It is essential to constantly assess the information gathered by monitoring personnel.

Activity 7.1

Demonstrate how you would monitor site conditions at a simple prescribed burn in your locality including leading up to and during the burn.

Patrolling a burn

After a burn has been ignited, its perimeter must be constantly monitored by patrolling burn personnel. This needs to be done before, in conjunction with and following, mopping-up work. If you are required to assist in patrolling a burn, you must look out for:

- burning material within the fire area which could breach the fire-control line (especially overhead in trees)
- spot fires beyond the fire-control line
- weak spots in the fire-control line where further work is required
- overhead limbs in trees which may fall and endanger you or other staff.

Follow these precautions if you are patrolling in a vehicle:

- when travelling in smoke or dust, reduce speed, switch on lights and occasionally sound the horn
- do not block access or escape routes.

When travelling along fire breaks, take note of the nearest turning areas and safety zones, and be aware of other vehicles, and of firefighters on foot.

Bush firefighting techniques

There are three ways to attack an open fire:

- smothering the fire to cut off its oxygen supply
- cooling the fire to reduce its temperature
- starving the fire of fuel by removing the flammable material from the path of the fire.

Cutting off the oxygen supply

This may be the quickest and most efficient form of attack with small fires (see Figure 52). However, cutting off the oxygen supply of a large fire in the open is usually too difficult.

Firefighters can use the following methods to cut off the oxygen supply to a small fire:

- stamping out the flames along the edge of a fire-control line
- shovelling soil onto a fire – in most cases this will help to put the flames out, but **embers may continue to burn slowly**
- laying foam on burning fuels.

Figure 52: Cutting off a fire's oxygen supply.

Reducing the temperature

Reducing the temperature is a very effective way to stop a wide range of fires. When water is added to a fire:

- the water absorbs a lot of the heat energy, and removes it as the water evaporates
- it cools the fuel below its ignition temperature.

The main purpose of using water when fighting fires is to cool the fuel to the point where combustion stops. Water must be directed initially to the base of the flames, where combustion is occurring, as shown in Figure 53. Adding water to unburnt fuel increases its moisture content. This delays the heating process as the moisture must be expelled before the ignition temperature is reached.

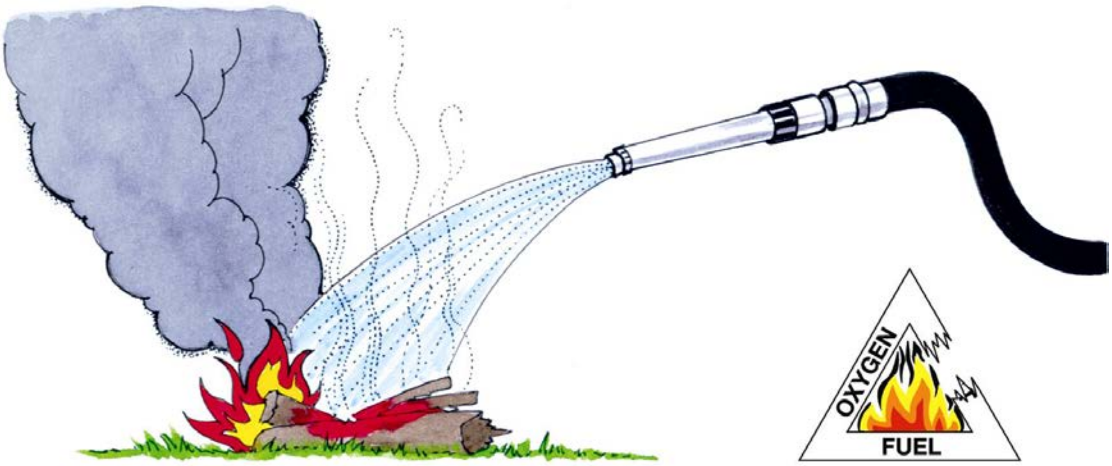


Figure 53: Reducing the temperature of the fire.

Removing the fuel

Removing the fuel may be an effective way of stopping a fire (see Figure 58) and may prevent large fires occurring. Dry firefighting is the term used to describe firefighting techniques that do not involve water. The suppression of fire without the use of water is normally achieved through the removal of fuel.

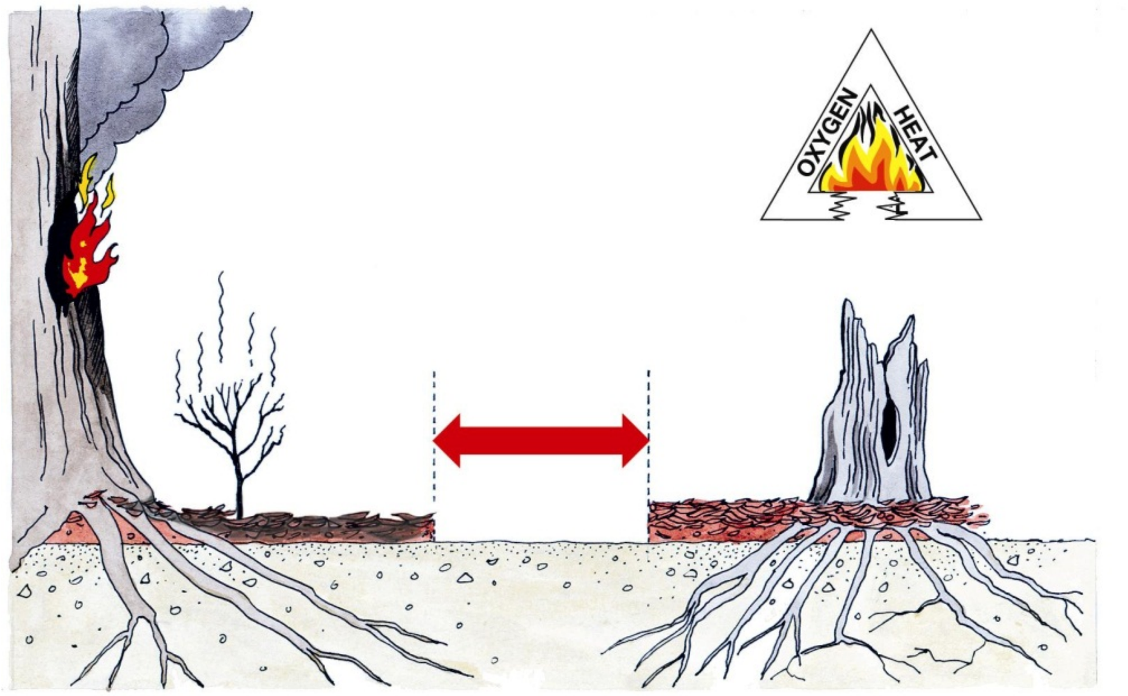


Figure 58: Removing the fuel.

Dry firefighting techniques

- Using handtools to break up fuel and remove it from the heat of a low to moderate intensity fire.
- Using handtools to remove fuels and create a bare earth break as an edge for backburning to control a moderate intensity fire.
- Using machinery, such as bulldozers, in order to make a wide break or to clear a large area to stop a large fire or to provide an edge for a large backburn.
- Backburning, or removing fuels by burning from the path of a wildfire.

Combination of techniques

- In many instances, it is a combination of methods of attack on a wildfire that brings about extinguishment. For example, the main effect of water is to cool the fire. However, the production of steam has a minor secondary effect. It helps smother the fire by keeping out the oxygen. Also, where water is used to extinguish a flame front, a fire-control line bare of fuels may also be constructed to minimise the possibility of the fire re-igniting and spreading.

Fire-control lines

A fire-control line is a man-made or natural fuel-free path (see Figure 54). It is used to prevent the spread of fire. When constructing fire-control lines, the term mineral earth is sometimes used. This term refers to ground where all vegetation cover has been removed and only rocks and soil are exposed (see Figure 55). The mineral earth should be exposed for the length and width of the fire-control line. The width of a fire-control line may vary from one to ten metres or more, depending on the anticipated fire intensity. Temporary fire-control lines can also be established by laying foam or retardant. A fire-control line can be constructed by using:

- handtools (e.g. axes, slashers, rakehoes)
- bulldozers
- other machinery, such as graders or farm tractors with a blade.

Any fire-control line must be commenced at an **anchor point**. This is an existing area of low fuel (e.g. a road or track, rocky area, substantial stream, already extinguished fire edge) that will prevent the fire burning around the end of the constructed fire-control line. The anchor point should also provide a safety zone for firefighters in the event of a significant increase in fire intensity.

Note: *Always tie fire-control lines into suitable anchor points.*

Figure 55: The track above acts as an effective fire-control line (Source: Bushfire CRC)

How to make a fire-control line using handtools

There are two preferred methods for constructing fire-control lines using a team of firefighters equipped with handtools:

- the step-up method
- the one-lick method.

These two methods are preferred because they both allow firefighters to retain their order within the line of personnel working on the fire break, and so avoid the risks associated with firefighters walking past and around each other while handtools are being swung.

Note: *Fire-control lines constructed with handtools are often called 'handlines' or 'rakehoe trails'.*

Step-up method

The **step-up** method is usually used for constructing a fire-control line when crew size is no more than 10 or 12 firefighters.

This method involves firefighters in a crew working in a line on individual sections of the fire-control line (see Figure 56). Crew members:

- stand approximately three metres apart (distance depends on fuel type and terrain)
- clear their individual section of the fire-control line down to mineral earth, raking the fuel away from the fire.

When a member of the team reaches the end of a section up to where the next crew member commenced, he or she calls out, 'Step-up'. This signal is repeated all along the line and then:

- all workers in front of the person who called, 'Step-up' move on one place to the next incomplete section, while maintaining their order in the line
- workers behind the person who first called, 'Step-up', continue until their section is completed and then call, 'Step-up'.

This way the group moves along at a steady rate, and no-one overtakes the person in front. The last member of the crew checks that the fire-control line is cleared to the required standard. The crew leader usually works at the head of the team, selecting the route for the fire-control line. If the fire is nearby, the completed line must be patrolled as it is extended.

Figure 56: The step-up method of fire-control line construction.

One-lick method

A method for a team of firefighters to construct a fire break in which each firefighter removes part of the vegetation as they move along. In the one-lick method, each person removes a portion of the fuel by raking it away from the fire as they move along the line. This continues until the mineral earth is exposed and a fire-control line is established. This method may suit situations where larger crews (say more than 12 firefighters) can be deployed as a unit (see Figure 57).

In both the step-up and one-lick methods of fire-control line construction, the last member of the team must be responsible for ensuring the line is completed to the necessary standard.

Figure 57: The one lick method of fire-control line construction.

Features of fire-control lines

- Always start a fire-control line at a suitable anchor point.
- Make the most of natural fire breaks, such as:
  - exposed rock shelves
  - open ground
  - creek beds
  - animal tracks
  - old logging trails.
- Keep the fire-control line as straight as possible. This will provide firefighters with a clear view and will enable them to move along the fire-control line easily.
- Keep each stretch of the control line as straight as possible, but avoid sharp bends by using multiple short segments angled slightly off each other. Fires can often spot over at thesesharp bends. Where there is a corner, the control line must be widened since the fire's intensity may increase when it burns into a corner.
- Avoid heavy concentrations of fuel, as the fire's intensity will increase in such areas.
- Cut saplings and small trees at ground level to minimise the potential for the sharp stumps to cause accidents.
- Keep the fire-control lines clear of dead trees or stumps, since these can have extended burn-out times. Rake around these if it is not possible to avoid them.
- Avoid areas of stringy-bark trees with long unburnt bark, or rake around them to prevent short-distance spotting.
- Be sure that the fuel is removed down to mineral earth.
- Look up to make sure that the fire cannot cross the trail through upper-storey vegetation.

- Before you commence work, make sure you know where the nearest safety zone is, and your escape route to it.

Bushfire suppression strategies

If a prescribed burn escapes the perimeter control lines, then conventional fire suppression techniques must be promptly implemented, depending on the fire behaviour and topography encountered. These fire suppression strategies fall broadly into two categories:

- offensive strategies, where the fire can safely and effectively be attacked or extinguished
- defensive strategies, where the fire is too remote or too intense to be safely or effectively attacked or extinguished.

Offensive strategies usually include:

- direct attack
- indirect attack.

The strategies that are used at an incident will depend on the location of the fire and the intensity with which its different parts burn.

Offensive strategies

Direct attack

A direct attack is used mainly on low-intensity fires that can be easily and safely reached by firefighters. Firefighters work directly on the edge of the fire (see Figures 58). This edge then becomes the established fire-control line.

In forest fuels, firefighters use hand tools or mechanical equipment such as bulldozers to clear a strip of exposed earth (called a mineral earth fire-control line) along the fire’s perimeter. Firefighters may also use water, foam and fire retardants to extinguish a fire, before building a mineral earth fire-control line.

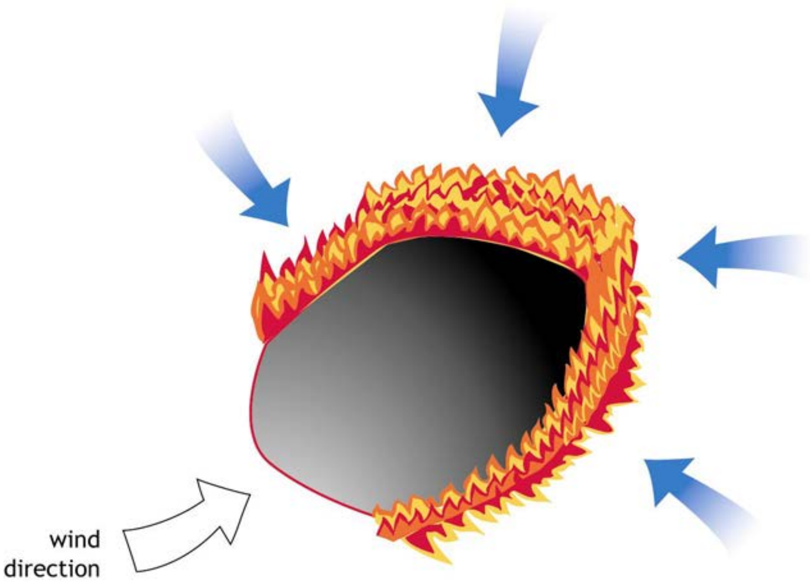


Figure 58: A direct attack on a fire

In grassland situations, water is commonly used to extinguish the burning edge of the fire (see Figure 59). A mineral earth fire-control line may not be required.

To make a direct attack you can use:

- water contained in knapsacks or tankers, or in hoselines from a static water source
- bulldozers and other earthmoving equipment
- hand tools such as axes, rakehoes (McLeod tools), slashers and/or chainsaws.

For safety, a direct attack on grass fires using tankers, knapsacks or hose lines is usually conducted from burnt ground.

Figure 59: Firefighters undertaking a direct attack on the head of a grassfire from a tanker situated on burnt ground.

The advantages of a **direct attack** are:

- less area is burnt
- in dry firefighting techniques, the fuel is removed from the immediate path of the fire, providing for the earliest possible control
- parts of the fire edge that may have gone out may be quickly incorporated into the fire line.

The **disadvantages** of a direct attack are:

- firefighters working at the fire's edge can be exposed to heat and smoke
- an irregular fire-control line has to be constructed in a short time (if the perimeter of the fire is irregular)
- fences and natural barriers may present obstacles
- patrolling the constructed fire-control line can be difficult, due to its irregular shape and course through the terrain.

Note: *In a direct attack, firefighters must always have a safety zone nearby which they can access via an escape route. The best safe area is on burnt ground.*

Head attack and flank attack

In the previous section the different parts of a bushfire's perimeter, such as the head, flanks and rear were discussed. The terms '**head attack'** and '**flank attack'** describe techniques for suppressing a bushfire.

A head attack involves directly 'knocking down' the head of the fire, that is to say directly extinguishing the flaming edge of the fire, usually with water (see Figure 60). This type of attack is possible only for low-intensity, slow moving fires, where it is safe for firefighters to get close enough to attack the burning edge.

A head attack minimises the area burnt, but involves a higher degree of risk than a flank attack. In particular firefighters will be working in the smoke from the fire, with limited visibility. Appropriate safety procedures must be in place and escape routes and/or safety zones, available, checked and the arrangements for their use understood by all participants in the firefighting operation.

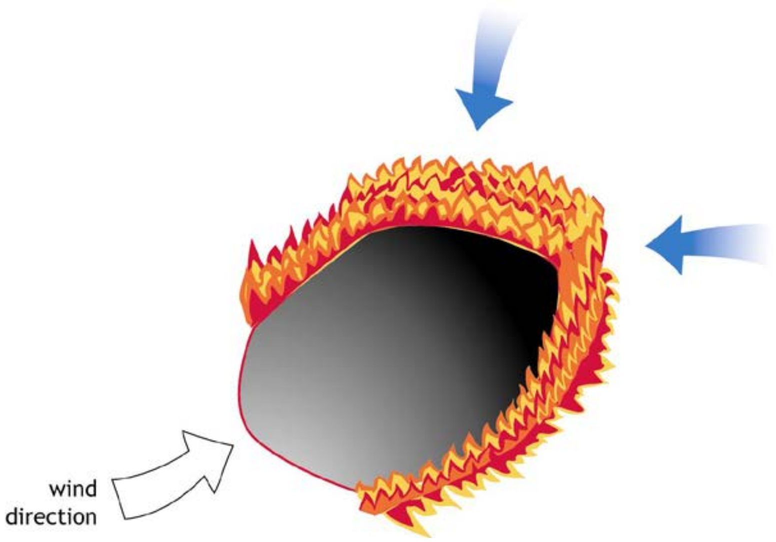


Figure 60: A head attack on a bushfire

By contrast, a flank attack (Figure 61) involves approaching the fire from the rear and working along the flanks towards the head of the fire in an attempt to 'pinch' it out. This is the most common technique used in a first attack.

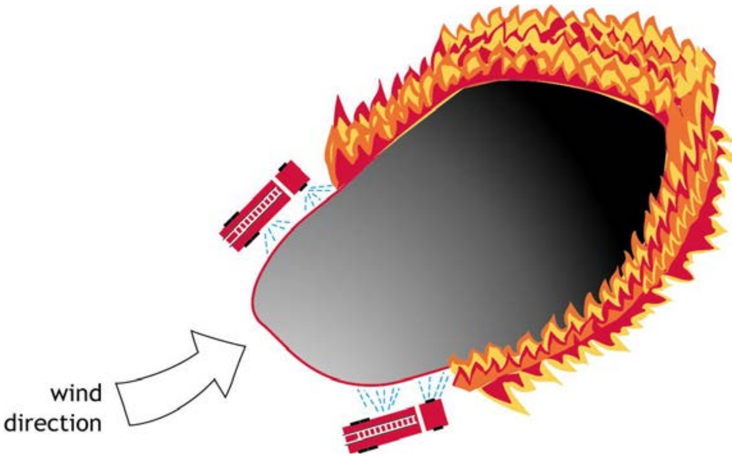


Figure 61: A flank attack on a bushfire

Parallel attack

This technique is used for low to medium intensity fires. It involves the construction of a fire-control line parallel to the fire, or just a short distance away from the fire's edge, and the burning out of intervening fuels as fireline construction proceeds (see Figure 62).

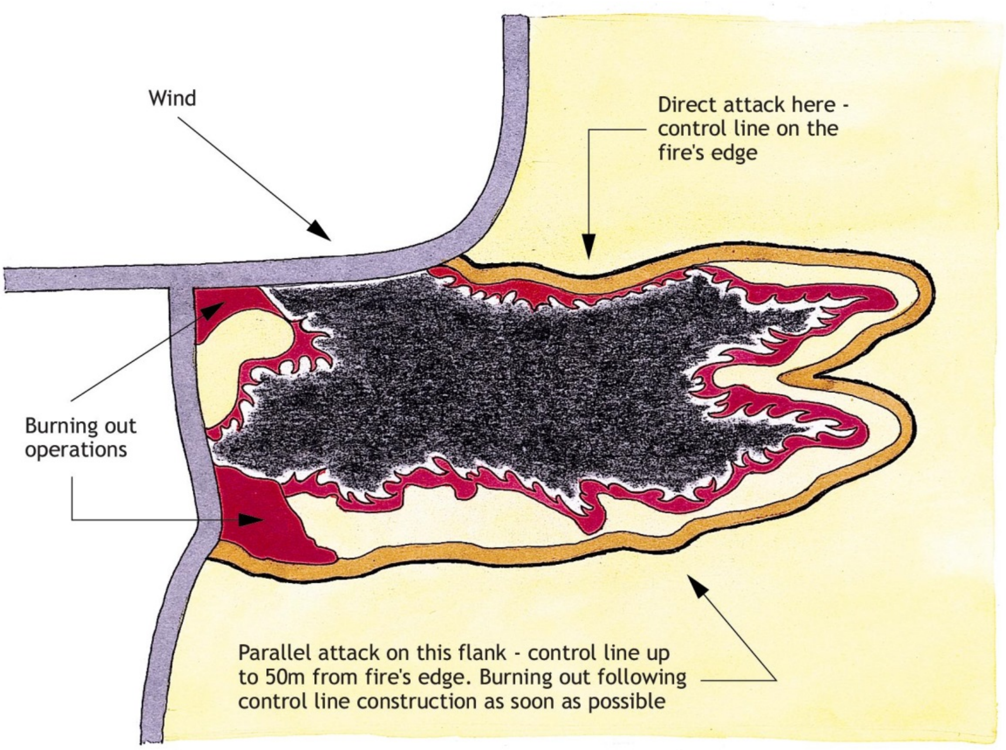


Figure 62: A parallel attack on a bushfire

The distance back from the fire will depend on:

- the intensity of the fire
- the type of fuel
- weather conditions
- topography.

In general, fire-control lines are constructed as close as possible to the flanks of the fire and irregularities in the fire's perimeter can be by-passed using this technique. You can use a range of equipment to construct fire-control lines, for example hand tools, ploughs, bulldozers, graders and chain saws. The fuel between the main fire and the fire-control line must be burnt out by other firefighters as the work on the fire-control line proceeds. This is known as 'taking the black with you' — in other words, keeping the safety zone of burnt ground close to where crews are working.

The **advantages** of a parallel attack are:

- fire-control line may be shorter and straighter than in direct attack
- crews may be less exposed to heat and smoke.

The **disadvantages** of a parallel attack are:

- there is an increased risk of fire escaping
- the total fire area will be greater
- fire-control line construction crews have unburnt fuel between them and the fire perimeter.

When using this technique, remember that the fire is constantly moving. You may start a fire-control line ten metres from the fire only to find that before it is complete, you are too close to the intense heat of the fire.

When using the **parallel attack** method, you must:

- monitor the progress of the fire front and note any weather changes
- have a clearly defined safety zone and escape route.

Note: *Parallel attack involves crews working with unburnt fuel between them and the fire. Therefore, safe anchor points and safety zones need to be identified before starting work. Burning out of unburnt fuel between the fire-control line and the fire must keep pace with fire-control line construction.*

Indirect attack

This technique is used for fast spreading, high intensity or inaccessible fires. The indirect attack method (Figure 63) requires the use of either a natural fire barrier or the construction of a fire-control line some distance from the fire's existing perimeter. The fuel between the fire-control line and the main fire is backburnt, or burned out by other means. By backburning from a control line some distance from the bushfire's existing perimeter, the fire is robbed of fuel.

Backburning must only be done with the approval of the Incident Controller. There are many calculations that need to be made to ensure that the backburn does not get overrun by the main fire, and to ensure that the backburn itself does not escape control.

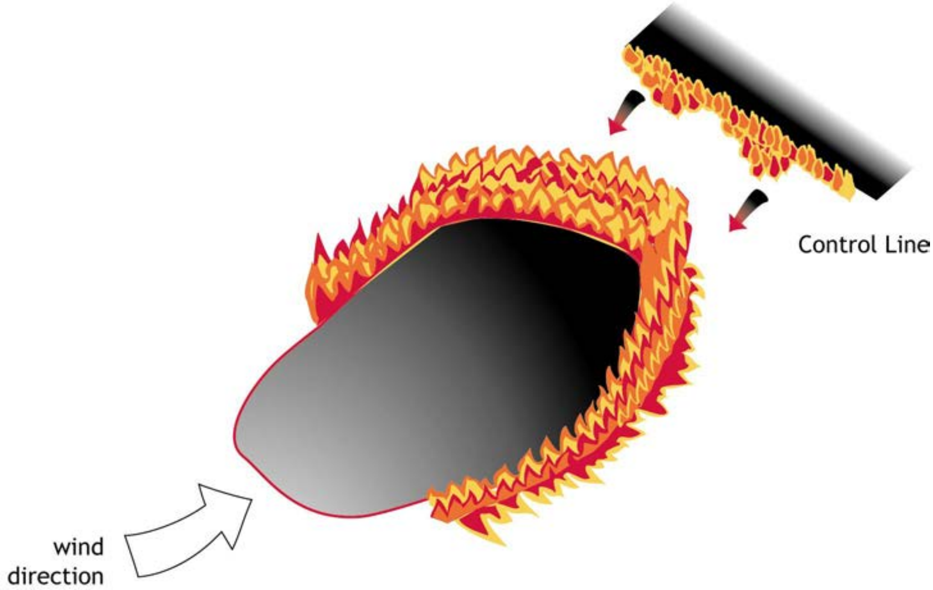


Figure 63: An indirect attack on a bushfire

The **advantages** of an indirect attack are:

- it can be used to attack bushfires of greater intensity than is possible using head or flank attack
- it reduces the risks to firefighters arising from the bushfire
- it allows greater choice of good locations for fire-control lines
- more time is allowed for fire-control line construction.

The **disadvantages** of an indirect attack are:

- the size of the fire is increased
- the increased size gives a greater area to be controlled and patrolled, and there is a greater chance of the fire breaking through the fire-control lines
- it requires time for planning and approval
- the fuel between the fire and the fire-control line may have to be backburned. The two fires joining may result in intense fire activity at the junction zone (where the fires meet) and create an increased chance of spotting.

Note: *Backburning is potentially hazardous and needs experience and knowledge. Backburns must be carefully planned, strictly supervised and approved in the Incident Action Plan.*

Combinations of techniques

When fighting bushfires, a combination of techniques is often used. The technique selected depends on several factors such as:

- rate of spread of the bushfire
- intensity of the fire (directly proportional to the height of the flames) at different parts of the fire
- spotting activity
- fuel ahead of and being burnt by the fire

- available firefighting resources
- safety, including access and escape routes.

In a small, low-intensity bushfire, where the flames are less than 1–1½ metres high, direct attack may be preferred, but if conditions become too intense, you must drop back and reassess the situation.

In some parts of a large bushfire, the conditions may require the use of the indirect technique. For example, work may be going on close to the main fire while a fire-control line is being prepared to serve as a barrier if the direct attack fails.

Defensive firefighting

Where the fire is too intense or too remote to be safely or effectively attacked, defensive strategies must be used.

Extreme fire behaviour means that the fire intensity is too great to enable any form of safe attack. While firefighting resources must concentrate on the defence of lives and defendable assets, ensuring firefighter safety is a priority. Adequate safety zones and escape routes must be available for firefighters. It is essential that you maintain good communications with your supervisor. Report the fire's position to your supervisor so that adequate community warnings can be issued. Once you can work from a position of safety, you can turn your attention to the protection of people and community assets.

Where fires are burning in very remote locations, or where resources available to attack remote fires are limited, a defensive strategy may simply mean maintaining careful observation of the fire until effective firefighting resources can be deployed, or until the fire conditions change.

Use of water

Water is the most commonly used and the most effective substance for extinguishing a fire of those commonly available. It acts by wetting the fuel and reducing its temperature. The efficient use of water is a major consideration in firefighting.

To cool the fuel, the water stream should be directed at the burning fuel and not at the flames (see Figure 64). Conserve water by using no more than necessary.

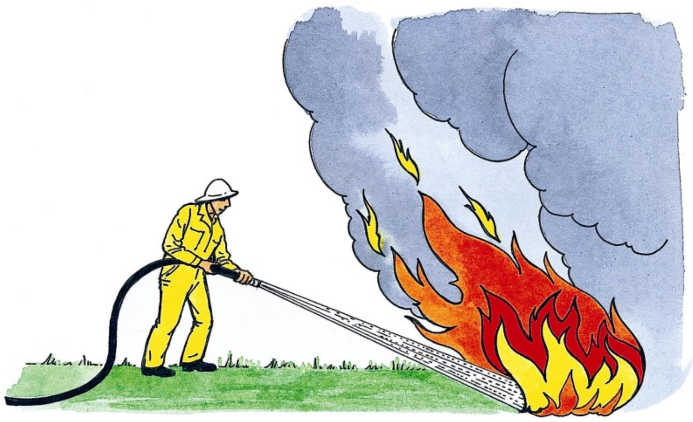


Figure 64: Directing the stream of water at the burning fuel, not the flames

The nozzle should be adjusted to obtain the most effective firefighting stream. It is a good tactic to initially attack a fire, where possible, with a strong stream of water and to cool down one area. Then move in and turn the nozzle to spray, widening the area covered. When you are able to move around the fire, use water wisely by spraying along, rather than across, the fire edge (see Figure 65).

Figure 65: Spraying along the fire edge (Photo courtesy of Bushfire CRC)

Mopping up

The activity of mopping up (or 'blacking out') involves making sure that a prescribed burn that has achieved its objectives does not escape. When the perimeter of the burn is extinguished, a strip inside the perimeter must be mopped up to extinguish all smouldering material. The width of this strip will vary. Your supervisor will tell you how far inside the fireline this work should be taken. The depth will depend on the factors listed below.

- The size of the burn – it may be possible to mop-up the entire area of small fires.
- Nature of the fuels – lots of heavy, smouldering fuels inside the blacked out perimeter increase the risk of re-ignition. The blacked out margin may need to be deeper.
- Terrain or topography – fire-control lines on slopes with burnt ground above have a risk of smouldering material tumbling down across the line. Blacking out must be extended further upslope to reduce this risk.
- Weather conditions – the likelihood of severe weather in the near future may mean that the blacked out zone must be widened.

Mopping up involves locating and extinguishing any smouldering fuel above or below-ground (see Figure 66). This is done manually with hand tools, or by wetting the fuel, or both. You should:

- extinguish any smouldering and hot materials
- place any smouldering fuel found outside the fire-control line into the burnt out area
- break up fuel concentrations to release the heat
- turn smouldering logs into a position where they will not roll into an unburnt area

- dig out and extinguish burning roots and stump holes
- extinguish any fresh outbreaks.

The felling of burning trees, which could fall into unburnt areas or provide windblown embers, should only be conducted by suitably trained personnel.

Figure 66: Mopping up

Section 7 summary

- Site conditions should be monitored throughout the burn. The person in charge of the burn should be prepared to stop the burn or change lighting patterns if necessary.
- To minimise injury to yourself and others, you should observe safe work practices at all times. This includes operating equipment and vehicles correctly and taking care when working near heavy machinery.
- A fire-control line is a man-made or natural fuel-free path. It is intended to prevent the spread of fire. Sometimes foam or retardants can be used to create temporary fire-control lines.
- A fire-control line should always be commenced at a suitable anchor point.
- Direct attack on a bushfire is when firefighters work directly on the edge of the fire and this edge then becomes the established fire-control line.
- A head attack involves directly knocking down the head of the bushfire, whereas, a flank attack involves approaching the bushfire from the rear and then moving along the flanks to the head.
- Parallel attack involves the construction of a fire-control line parallel to the fire, or just a short distance away from the fire's edge.
- An indirect attack requires the use of a fire-control line some distance from the bushfire. The fuel between the fire-control line and the main fire is then usually burned out.
- Defensive firefighting is used when a fire cannot be controlled, and at these times crew safety and public safety are priorities.
- Blacking out of burn perimeters should commence when burn objectives are achieved.
- Once the burn is extinguished, a strip inside the perimeter must be blacked out to extinguish all smouldering material. The width of this strip will vary.
- A blacking out operation involves locating and extinguishing any smouldering fuel above or below-ground manually with hand tools, or by wetting the fuel, or both.

Self-assessment questions

1. What needs to be monitored (and how often) during a burn?
2. What do you look for when patrolling the perimeter of a fire?
3. What is the key feature of the step-up method of fire-control line construction?
4. What is the key feature of the one-lick method of fire-control line construction?
5. List some factors that firefighters should consider when constructing a fire-control line.
6. When is a direct attack usually used at bushfires?
7. What is a head attack?
8. What is a flank attack?
9. When is a parallel attack used at bushfires?
10. When is an indirect attack used at bushfires?
11. List the factors to consider when deciding on the method to be used for fighting a bushfire.
12. How should a burn area be made secure?
13. What are the key elements of mopping-up operations?

Section

8

Post-burn activities

Section
8

Post-burn activities

While any fuels remain alight the possibility exists for escapes. In the case of coarse fuels such as logs, stumps and hollow trees, this possibility may exist for several days, and patrols must be taken to minimise this risk. Once the burn objectives have been achieved in any part of the burn area adjoining the perimeter, blacking out work can begin.

Assessing outcomes against burn objectives

As soon as practicable after the burn is secure or safe, an assessment should be undertaken to determine whether or not the objectives of the burn were met.

Burn objectives can relate to a range of issues such as fuel reduction, bushfire mitigation or ecological outcomes. Fuel reduction objectives are quite common and assessment of these may include the need to make observations of burn coverage, burn patchiness, fuel load or overall fuel hazard.

Personnel may be tasked to walk into the burnt area to make observations of burn coverage at different various locations to enable a map of estimated burn extent and coverage to be prepared. Or they may be tasked with making observation of residual fuel load or fuel hazard at various representative locations across the burn area. With regard to assessment of fuels, various guidelines are available such as the Victorian Overall Fuel Hazard Guide (*Hines et al.* 2010). The preferred guidelines will vary from agency to agency.

Maintain patrol

Periodic patrol of the burn perimeter must continue until it can be declared secure, and the fire safe to leave un-patrolled. Patrol crews must continually search for smouldering fuels near the burn perimeter which could provide firebrands (embers) under strong winds. They should also constantly look for, and make safe, dangerous trees or logs that could fall or roll outside the burn area, endangering traffic or persons on foot.

Debriefing

At the end of each day and at the end of a burn, the opportunity should be provided to burn personnel to participate in a debriefing. It is best done near the end of the day of burning when most personnel are still present. This is a valuable opportunity to review and evaluate performance of the crew or team and the organisation. Debriefs are also opportunities for the organisation and each crew member to better understand how human factors might have contributed - positively or negatively - to the resolution of issues confronted.

The purpose of the debriefing is to identify factors or information about the conduct of the burn that may be relevant to:

- operational procedure
- safety issues
- logistical issues.

Some of this detail may not have been apparent to the Operations Officer or other supervisors during the course of the burn. As well as contributing to a review of the day, burn personnel will gain a sense of ‘closure’ in a positive forum of information exchange. The debriefing can provide an overview of the day’s operation in terms of achieving the objective, and should seek information about things such as:

- Safety
  - Were there any ‘near miss’ incidents that have not been reported?
  - Are there suggestions for enhancing crew safety at similar operations?
  - Were escape routes, safety zones adequate?
- Lighting operations
  - Was the adopted lighting pattern and method effective, safe?
  - Was communication within, between and from lighting crews safely maintained throughout the operation?
- Perimeter control
  - Were resources (people, equipment) adequate?
  - Were resources deployed to best advantage?
  - Was fire behaviour near control lines as expected?
  - Did the traffic management plan work?
- Overall coordination of the burn
  - Did everyone understand the objective of the burn?
  - Was the objective considered to be achieved?
  - Was the command structure adequate or appropriate? (Did everyone, for example, know who their supervisor was?)
  - Did the communications plan work?

There should be genuine follow-up to issues raised at debriefings.

Post-burn works

The prescribed burn may have required construction of temporary control lines, turn-around areas, safety zones, helipads or other mechanically disturbed areas. Where such works were implemented solely for the burn and are not needed after the burn has been declared safe, activities to rehabilitate disturbed flora and to restore habitat requirements for native fauna may be needed.

During the course of the burn, there may also have been damage to values within or outside burn boundaries, such as burnt fence-posts, gates and signage, or encroachment of fire into sensitive vegetation. This may require a more formal incident investigation, but any restoration activities required should form part of the assessment for post-burn works.

This may require earthen or log barriers, and perhaps placement of vegetative material/debris at least at the start of the track to make it less obvious. In most cases natural regeneration will occur, however extra stabilisation measures, such as direct seeding, may occasionally be required.

Undertake any repairs on permanent tracks such as reforming drainage or mechanically moving felled trees from fireline edges or stabilising creek banks due to damage from fireline traffic.

Where practicable, undertake as much of the post-burn works as possible before burn resources leave the site. However in many cases the need for access for on-going patrolling until the burn is declared safe may require machinery to be brought back to the burn site days or weeks later.

Activity 8.1

Demonstrate the actions you would take to ensure the security of a simple prescribed burn in your locality burn following the completion of lighting up.

Section 8 summary

- There should be a double check for dangerous trees or logs on vulnerable perimeters before leaving the area.
- Under some seasonal conditions it may be important not to leave significant areas of unburnt fuel within control lines that could re-ignite under more severe weather conditions on succeeding days and threaten control lines
- Patrol of the burn must continue until it is safe.
- Debrief burn personnel as soon as practicable.

Self-assessment questions

1. What do you look for when patrolling the perimeter of a fire?
2. What must be done with significant areas of unburnt fuel inside the planned perimeters following the burn?
3. When is it usually best to hold a debriefing?
4. Nominate four broad topic areas about which information should be sought during a post-burn debriefing?

Section 9

Self-assessment answers
Glossary
Appendix
Bibliography

Self-assessment answers

Section 1: Policy for prescribed burning

1. A requirement to minimise fire hazards on their land.
2. Prescribed burning is undertaken to achieve one or more of the following purposes:
   - fuel reduction and/or modification in order to protect life, property and other assets
   - habitat maintenance or rehabilitation
   - control of weeds or invasive species
   - for production outcomes, such as silvicultural or pastoral purposes.
3. Prescribed burning may be restricted at particular times of the year when general prohibitions are in force or when specific authorisations (in the form of Fire Permits) must be applied for. Burning during critical lead ups to periods of high fire danger may also require enhanced safety precautions.

Section 2: Safe work practices

1. The five steps that should be followed to reduce the risk of injury occurring are:
   (a) Eliminate or remove the hazard
   (b) Replace the hazardous procedure with a safer procedure
   (c) Apply engineering controls
   (d) Apply administrative controls
   (e) Use personal protective equipment.
2. The key hazards on a fireground are heat stress, smoke and fatigue.
3. Heat stress is a condition where the body's cooling mechanisms are overcome by excessive external and internal (metabolic) heat loads.
4. The symptoms of heat exhaustion are cramps, pale clammy skin, light headedness (feeling faint), dizziness, headaches, nausea.
5. Heat stroke is a life-threatening condition of extreme heat stress.
6. To avoid heat stress:
   - protect yourself from external heat sources
   - protective clothing, avoid excessive exposure to radiant heat
   - seek shade whenever possible
   - maintain hydration
   - work at a sensible pace, share tasks
   - take rest breaks when possible.
7. You should examine each individual item of PPE before and after use. By examining your PPE and equipment prior to or during the course of cleaning them after the end of each shift, you can ensure they are in good repair or else replaced in good time before you next head out.

8. Routine examinations of PPE should include checks for:
   - physical damage such as rips, tears, cuts, damage to seams and/or other connections non-functional or missing
   - physical damage to hardware and other components, e.g. reflective and fluorescent applications
   - thermal damage such as charring, burn holes, melting or change in colour
   - on-going evaluation of system fit and interfaces, or overlaps and closure systems.
9. To minimise the effects of smoke avoid unnecessary exposure, use smoke masks and goggles.
10. To minimise fatigue work at a steady pace, use all available rest breaks, get adequate meals and maintain hydration.
11. Safety zones are areas that have been cleared or are characterised by low fuel hazard in which survival can be assured. It is in your interest to make sure they are adequate, that they can be safely accessed, that the escape routes leading to them are clear and will remain so in the event of a wind change, and that their location is adequately communicated during briefings.
12. LACES refers to the precautions required to avoid entrapment. WATCHOUT refers to the items to which attention should be paid in order to maintain situational awareness.

Section 3: Working in teams

1. A team is a small number of people with complementary skills who are committed to a common purpose, performance goals, and an approach for which they hold themselves mutually accountable.
2. Five characteristics of teams include any from the list below:
   - size
   - supportive leadership
   - challenge
   - shared values
   - results focus
   - team and individual accountability
   - right mix of skills
   - role clarity
   - sufficient resources
   - autonomy
   - open communication
   - team building
   - respect
   - recognition
   - decision making.
3. Features of an effective team arise when the common purpose of the team is understood by all team members and each member plays their assigned role to the best of their ability to achieve this purpose. People in a team depend on each other and share their skills and

experience to achieve outcomes that they could not achieve as individuals. The combined capability of the team is the key benefit for both individual team members and the organization.

4. Discuss your concerns with your supervisor, stating your opinions calmly and clearly. Provide relevant examples, facts or figures to illustrate your points. Try to be constructive in your remarks and explain why you disagree and offer an alternative approach.
5. Information in a report to a team leader from a team member should include:
   - progress you have made to achieve your individual work objectives
   - implications of your work progress for the team objective
   - any information that may affect the work of another team member
   - future resource requirements
   - future timeframes and timelines
   - any predicted problems in completing work and subsequently the team objective.
6. Key details that should be covered in crew briefings prior to a prescribed burn are:
   - **Situation** (the current and predicted situation, including the burn site and reason(s) for the burn, current and expected weather, at-risk values to be protected, and a summary of resources deployed)
   - **Mission** (the statement of the specific objectives set for the burn)
   - **Execution** (how the mission will be accomplished i.e. ignition patterns and times, constraints, task and resource allocation, access around the burn site, immediate tasks after briefing, contingency plans)
   - **Administration** (logistics for the operation, including key support locations and roles, the burn's staging area, catering, supply, ground/medical support)
   - **Command and communications** (the burn's management structure including, sectorisation, reporting relationships and times, the communications plan, contact numbers, radio channels)
   - **Safety** (identification of known or likely hazards including, weather, 'watch-out' situations, safety equipment required and protective clothing standards, welfare, hydration and first aid).
7. At the end of every briefing, it is important to check that participants have understood the key information. For this reason, opportunity to ask questions should always be provided. If no questions are forthcoming, it is good practice for the person conducting the briefing to ask 'open' questions to briefing recipients to check that they have heard and understood any important points.

Section 4: Fire behaviour for prescribed burning

1. The maximum values for flame height, rate of spread and intensity generally considered appropriate for low-intensity prescribed burns are:
   - flame height — less than 1.5 m
   - ROS — less than 100 m/hr
   - Intensity — less than 500 kW/m.
2. The greatest influences on scorch height are quantity of fine fuel consumed, air temperature, and drought index.

3. The circumstances for high-intensity burns appropriate are:
   - when maximum consumption of fuel is required, for example following timber harvesting
   - when maximum soil heating is required to provide optimum seedbed conditions for regeneration of some species of vegetation
   - when killing some target vegetation species is desirable
   - when a need exists to promote regeneration of vegetation that may require high-intensity fire to initiate germination.
4. In addition to fuel, weather and topography, fire behaviour at prescribed burns will be influenced by ignition pattern and technique.
5. Rate of spread (are fires allowed to spread upslope, or downwind) and the proportion of junction zone effect.
6. For low-intensity burning, the desirable maximum values of the KBDI or the SDI, and of the Fire Danger Index are 13—16% ODW.

Section 5: Equipment for prescribed burning

1. The main uses of an axe during burn operations are during patrol and mopping up operations, when an axe is used to split open logs and stumps, cut through branches and small logs, fell small trees and clean bark from trees.
2. The main uses of a rakehoe during burn operations are also found during patrol and blacking out operations, when a rakehoe is used to for raking and scraping away surface fuels to create fire-control lines, raking litter and vegetation into the burnt area, scraping bark from tree trunks and raking out hot coals from logs and stumps.
3. The advantages of using fuses (matches) to light prescribed burns are that they are cheap and easy to carry, and that they are unlikely to lead to over-lighting.
4. Some disadvantages to using drip torches to light prescribed burns are: they require regular refilling, which may be logistically awkward; they can be heavy and tiring to use; and they may lead to over-lighting.
5. The fuel a driptorch uses is kerosene or a mixture of petrol and diesel (in the ratio 1 part petrol to 4 parts diesel).
6. The use of vehicle-mounted flamethrowers is appropriate when trackside lighting is required over long distances, especially where fuels may be discontinuous and difficult to ignite.
7. The advantages of aerial ignition for prescribed burning are that it allows large areas to be ignited during favourable conditions, and it allows ignition of areas difficult to reach on the ground.
8. The two main types of fire hose are:
   - suction hose, used in draughting from static water supplies
   - delivery hose, used to deliver water from a pump to the fire edge.
9. Four different types of delivery hose are:
   - percolating
   - non-percolating synthetic
   - extruded
   - rubber.
10. A hose coupling joins two lengths of hose, or attaches a hose to a piece of equipment.

11. The three main types of hose coupling are screw (or threaded), Storz, and forestry external lug (Wajax).
12. An adaptor connects different sized hoses, or hoses with different couplings.
13. The difference between a branch and a nozzle is that a branch is fitted to the end of a hose to control and direct water (or foam), whereas a nozzle is fitted to a branch to control the size, pattern and velocity of water discharge.
14. A reticulated water supply is water available under pressure in permanent mains pipes, accessible via hydrants.
15. A static water supply is unpressurised water in an open surface situation, such as a dam, lake, river, tank, swimming pool, etc.
16. Hydrants are situated at regular intervals along water mains.
17. A standpipe is a portable piece of equipment used to bring the outlet of a below-ground hydrant to above-ground level.
18. The most common type of pump used on fire appliances is a centrifugal pump.
19. Wetting agents are chemicals that reduce surface tension of water, allowing it to spread further and penetrate fuels more easily.
20. Foam is a frothy liquid that blankets and cools burning fuels.
21. Class A foam is used during mopping up work, and in any situation where fuels need to be wetted for as long as possible.
22. A fire retardant is any firefighting substance applied on, or ahead of, the flame front of a fire in order to reduce its rate of spread or intensity, rather than to directly suppress combustion in the flaming zone.

Section 6: Burn ignition

1. The checks that should be carried out prior to ignition on the day of a burn are:
   - Entire approved burn plan is available
   - Authorisations are confirmed
   - On-the-day notifications are completed
   - Latest weather forecast is available
   - On-site fuel and weather are assessed
   - Ignition pattern is confirmed
   - briefing script is finalised
   - burn personnel are assembled and briefed
   - test burn is undertaken, if applicable.

   It should also be asked:
   - Are site conditions within the burn prescription?
   - Are prescribed resources available?
   - Is test burn behaviour within prescription?
2. The characteristics of a burn that determine the most appropriate burn technique are the size of the proposed burn, the nature of the fuels, the topographic constraints (especially slope), the desired fire behaviour, and what limitations on access exist at the burn site.

3. Generally, one-third of the area burnt by a fire spreading from a single ignition point is burnt by headfire.
4. In situations where fire intensity must be kept low a spot ignition is generally preferred to strip (or line) ignition because only one-third of the total area burnt will be burnt by headfire, as compared to five-sixths of the total area for line ignition.
5. Igntion point spacing for spot ignition is determined based on estimated ROS and available burning time.
6. The slope and/or wind conditions that make convection ignition risky in slash fuels are when a slope is greater than 10°, and/or the wind is greater than 15 km/h.
7. The major advantages of convection ignition for high-intensity slash burns are:
   — crew safety (high-intensity fire is drawn inwards from the perimeter)
   — good visibility for the lighting personnel (smoke is drawn to centre of area)
   — control (indraughts minimise risk of escapes over perimeter control lines).

Section 7: Prescribed burn monitoring and control

1. During a burn, site conditions for fuel moisture content, and the weather need to be monitored at a minimum frequency of 30 minute intervals.
2. When patrolling the perimeter of a fire look for:
   – burning material inside the fire-control line that could threaten the fire-control line (especially in trees overhead)
   – spot fires outside the fire-control line
   – weak spots where the fire-control line could be improved
   — dangerous overhead hazards.
3. With the step-up fire-control line construction method, each crew member retains their order in the line of team members, and completes their individual section of the fire-control line as they go. When a member reaches the end of a section, they yell out 'step-up'. This signal is repeated along the line. This method is usually used when the crew comprises no more than 10 to 12 firefighters.
4. With the one-lick fire-control line construction method, a team of firefighters construct a fire break in which each firefighter removes part of the vegetation as they move along. Every patch of ground is progressively worked on by all the crew as they pass along. This method suits situations where larger crews (more than 12) can be deployed as a unit.
5. Firefighters should consider the following when constructing a fire-control line:
   — always start a fire-control line at a suitable anchor point
   — use natural breaks
   — keep the fire-control line as straight as possible
   — keep the length of fire-control line to a minimum (by selecting appropriate anchor points)
   — avoid heavy fuel concentrations
   — cut saplings and small trees at ground level to minimise the risk of short stumps causing accidents
   — keep area clear of dead trees or stumps

— avoid areas of stringy bark trees with long unburnt bark
— achieve a clean mineral-earth surface
— look up to make sure that the fire cannot cross the trail through upper-storey vegetation.

6. A direct attack is used at bushfires when low-intensity bushfires can be easily and safely reached.
7. A head attack is a direct attack on the head of the fire.
8. A flank attack is a direct attack on the flank of a fire, usually working from the rear towards the head.
9. A parallel attack is used when fire-control line construction cannot be undertaken right at the fire's edge – burning out of fuels between the fire and the fire-control line must keep pace with fire-control line construction ('taking the black with you').
10. An indirect attack is used when fires are fast spreading, of high intensity or inaccessible.
11. Factors to consider when choosing bushfire fighting methods:
    — rate of spread
    — fire intensity
    — spotting activity
    — fuel factors at and ahead of the fire
    — available firefighting resources
    — safety of crews, including access and escape routes.
12. Commence perimeter mop-up as soon as possible, maintain patrols whilst any risk of escape or reignition remains. Make safe trees or logs that could fall or roll across control lines.
13. The key elements of mopping up are:
    — find hot spots by sight and feel
    — open up concentrations of heat by splitting open, digging out
    — ensure logs cannot roll
    — work progressively into the burnt area from the fire-control line.

Section 8: Post-burn activities

1. When patrolling the perimeter of a fire look for:
   — burning material inside the fire-control line that could threaten the fire-control line (especially in trees overhead)
   — spot fires outside the fire-control line
   — weak spots where the fire-control line could be improved
   — dangerous overhead hazards.
2. Significant areas of unburnt fuel inside the planned perimeters following the burn must either be burnt out with additional lighting, or isolated with internal control lines.
3. It is usually best to hold a debriefing near the end of the day of burning when most personnel are still present.

4. Areas about which information should be sought during a post-burn debriefing include:
   - safety
   - lighting operations
   - perimeter control
   - overall coordination of the burn.

Glossary

Adaptor	A fitting used to couple different sized hoses, hoses of the same size with different threads, or different types of couplings, or to connect the male to male, or female to female parts of the same type of coupling.
Adsorption	The taking in of water vapour from the air by dead plant material.
Advection	In meteorology, advection refers to the transport of some property of the atmosphere, such as heat or humidity
Aerial ignition	Ignition of fuels by dropping incendiary devices or materials from aircraft.
AFAC	The Australasian Fire and Emergency Service Authorities Council (AFAC) is the national body representing urban, rural and land management agencies within Australia and New Zealand with the responsibility for the protection of life and property from fire and other emergencies.
Atmospheric stability	The degree to which the atmosphere resists turbulence and vertical motion.
Available fuel	The portion of the total fuel that would actually burn under various environmental conditions.
Backburn	1. A fire started intentionally along the inner edge of a fireline during indirect attack operations to consume fuel in the path of a bushfire (Australia). 2. A counterfire commenced from within continuous fuel for the purpose of fighting a fire (New Zealand).
Backing fire	The part of a fire which is burning back against the wind or down slope, where the flame height and rate of spread are reduced.
Blacking-out	The process of extinguishing or removing burning material along or near the fireline, felling stags, trenching logs to prevent rolling and the like, in order to make the fire safe.
Burning out	To intentionally light fires to consume islands of unburned fuel inside the fire perimeter.
Bushfire	An unplanned fire. A generic term which includes grass fires, forest fires and scrub fires.
Canopy	The crowns of the tallest plants in a forest — the overstorey cover.
Central ignition	A method of prescribed burning in which fires are set in the centre of an area to create a strong convective column. Additional fires are then set progressively closer to the outer control lines causing indraught winds to build up. This has the effect of drawing the fires towards the centre.
Coarse fuels (or heavy fuels)	Dead woody material, greater than 25 mm in diameter, in contact with the soil surface (fallen trees and branches). Some researchers categorise forest fuels as: fine <6 mm diameter; twigs 6-25 mm diameter; coarse >25 mm diameter.
Combustion	Rapid oxidation of fuels producing heat, and often light.
Control line	See **Fireline**

Convection	1. As applied in meteorology, atmospheric motions that are predominantly vertical, resulting in vertical transport and mixing of atmospheric properties; distinguished from advection. 2. As applied in thermodynamics is a mechanism of heat transfer occurring because of the bulk movement of fluids.
Convection column	The rising column of smoke, ash, burning embers and other particle matter generated by a fire.
Dead fuels	Fuels with no living tissue in which moisture content is governed almost entirely by absorption or evaporation of atmospheric moisture (relative humidity and precipitation).
Desorption	The loss of moisture to the atmosphere from dead plant material.
Direct attack	A method of fire attack where wet or dry firefighting techniques are used. It involves suppression action right on the fire edge which then becomes the fireline.
Drought Index	(See **Keetch-Byram Drought Index**, **Soil Dryness Index**).
Elevated fuel	The standing and supported combustibles not in direct contact with the ground and consisting mainly of foliage, twigs, branches, stems, bark and creepers.
Fall-back control line	Any fireline which is at a distance from the fire perimeter, and is the second control line at which the fire perimeter may be stopped should it cross the first fireline. Also known as 'fall-back line'.
Fine fuel	Fuel such as grass, leaves, bark and twigs less than 6 mm in diameter that ignite readily and are burnt rapidly when dry.
F**ire behaviour**	The manner in which a fire reacts to the variables of fuel, weather and topography.
Fire control	See **Fire suppression**.
Fire control line	See **Fireline**.
Fire danger	Sum of constant danger and variable danger factors affecting the inception, spread, and resistance to control, and subsequent fire damage; often expressed as an index.
Fire Danger Index	A relative number denoting the potential rates of spread, or suppression difficulty for specific combinations of temperature, relative humidity, drought effects and wind speed.
Fireground	The area in the vicinity of a fire suppression operations, and the area immediately threatened by the fire. It includes burning and burnt areas; constructed and proposed fire lines; the area where firefighters, vehicles, machinery and equipment are located when deployed; roads and access points under traffic management control; tracks and facilities in the area surrounding the actual fire; and may extend to adjoining area directly threatened by the fire.
Fire intensity	See **Fireline intensity**
Fire retardant	A chemical generally mixed with water, designed to retard combustion by a chemical reaction. It is applied as slurry from the ground or air to fuels ahead of the fire.
Fire suppression (or fire control)	The activities connected with restricting the spread of a fire following its detection and before making it safe. (see **Response**).
Fireline	A natural or constructed barrier, or treated fire edge, used in fire suppression and prescribed burning to limit the spread of fire.

Fireline intensity	The rate of energy release per unit length of fire front usually expressed in kilowatts per metre (Kw/m). The rate of energy release per unit length of fire front, defined by the equation **I = Hwr**, where, I = fireline intensity (kW/m) H = heat yield of fuel (kJ/kg)-16,000 kJ/kg w = dry weight of fuel consumed (kg/m2) (mean total less mean unburnt) r = forward rate of spread (m/s) The equation can be simplified to **I = wr/2**, where, I = fireline intensity (kW/m) w = dry weight of fuel consumed (tonnes/ha) r = forward rate of spread (m/hr)
Flame angle	The angle of the flame in relation to the ground, caused by wind direction or the effect of slope.
Flame depth	The depth of the zone within which continuous flaming occurs behind the fire edge.
Flame height	The average maximum vertical extension of flames at the leading edge of the fire front. Occasional flashes that rise above the general level of flames are not considered. This distance is less than the flame length if flames are tilted due to wind or slope.
Flame length	The distance between the flame tip and the midpoint of the flame depth at the base of the flame (generally the ground surface), an indicator of fire intensity.
Flammability	The ease with which a substance is set on fire.
Flanks of a fire	Those parts of a fire's perimeter that are roughly parallel to the main direction of spread.
Foam	A mixture of foam concentrate and water specifically formulated for extinguishing bushfires. The foam is biodegradable, non-toxic and is used at very low concentrates. It may be delivered aspirated or non-aspirated. (See also **Foam solution**).
Foam solution	The mixture of water and foam concentrate.
Fuel	Any material such as grass, leaf litter and live vegetation which can be ignited and sustains a fire. Fuel is usually measured in tonnes per hectare. Related Terms: Available fuel, Coarse fuel, Dead fuel, Elevated dead fuel, Fine fuel, Ladder fuels, Surface fuels, and Total fine fuel.
Fuel arrangement	A general term referring to the spatial distribution and orientation of fuel particles or pieces.
Fuel load **(or fuel quantity)**	The oven dry weight of fuel per unit area. Commonly expressed as tonnes per hectare. (Also known as fuel loading)
Fuel moisture content	The water content of a fuel particle expressed as a percentage of the oven dry weight of the fuel particle. (%ODW).
Fuel quantity	See **Fuel load**
Ground fuel	All combustible materials below the surface litter, including duff, roots, peat and saw dust dumps that normally support a glowing or smouldering combustion without flame.

Heat transfer	The transfer of thermal energy from one physical system to another by conduction, convection or thermal radiation.
Indirect attack	A method of suppression in which the control line is located some considerable distance away from the fire's active edge. Generally done in the case of a fast spreading or high-intensity fire and to utilize natural or constructed firebreaks or fuel breaks and favourable breaks in the topography. The intervening fuel is usually backburnt; but occasionally the main fire is allowed to burn to the line, depending on conditions.
Instability	The tendency for air parcels to accelerate when they are displaced from their original position; especially, the tendency to accelerate upward after being lifted. Instability is a prerequisite for severe weather - the greater the instability, the greater the potential for severe thunderstorms.
Inversion	A layer of the atmosphere in which temperature increases with increasing elevation. A condition of strong atmospheric stability.
Junction zone	An area of greatly increased fire intensity caused by two fire fronts (or flanks) burning towards one another.
Keetch-Byram Drought Index (KBDI)	A numerical value reflecting the dryness of soils, deep forest litter, logs and living vegetation, and expressed as a scale from 0 - 200 where the number represents the amounts of rainfall (mm) to return the soil to saturation.
Ladder fuels	Fuels which provide vertical continuity between strata. Fire is able to carry from surface fuels into the crowns with relative ease.
Lag time	The time delay in fuel moisture content responding to changing environmental conditions (for example, relative humidity). Technically, it is the time necessary for a fuel particle to lose approximately 63% of the difference between its initial moisture content and its equilibrium moisture content.
Litter	The top layer of the forest floor composed of loose debris of dead sticks, branches, twigs and recently fallen leaves and needles, little altered in structure by decomposition. (The litter layer of the forest floor).
Litter bed fuel	Dead fine fuel, including surface fuel and fuel lower in the fuel profile.
Local winds	Winds which are generated over a comparatively small area by local terrain and weather. They differ from those which would be appropriate to the general pressure pattern.
Low-intensity fire	A fire which travels slowly and only burns lower storey vegetation, like grass and lower tree branches, with an average intensity of less than 500 $kW.m^{-1}$ and flame height less than 1.5 m. Usually causes little or no crown scorch and is easily controlled.
Mineral earth	When used in the context of fire control refers to a non-flammable surface (either natural or prepared) which provides a break in understorey, litter and humus fuels and hence a barrier (of varied effectiveness depending, amongst other things, on its width and the intensity of the approaching fire) to fire travelling on or near the ground surface.
Near surface fuel	Live and dead fuel, including suspended leaves, bark or twigs, effectively in touch with the ground but not lying on it, with a mixture of vertical and horizontal orientation.

Parallel attack	A method of suppression in which fireline is constructed approximately parallel to, and just far enough from the fire edge to enable workers and equipment to work effectively, though the line may be shortened by cutting across unburned bays. The intervening strip of unburned fuel is normally burned out as the control line proceeds, but may be allowed to burn out unassisted where this occurs without undue delay or threat to the line.
Patrol	1. To travel over a given route to prevent, detect, and suppress fires. Includes interaction with the public for wildland fire prevention and educational purposes. 2. To go back and forth vigilantly over a length of control line during and/or after construction to prevent breakaways, suppress spot fires, and extinguish overlooked hot spots. 3. A person or group of persons who carry out patrol actions.
Prescribed burning	The controlled application of fire under specified environmental conditions to a predetermined area and at the time, intensity and rate of spread required to attain planned resource management objectives.
Rate of spread	The speed with which a fire moves in a horizontal direction across the landscape at a specified part of the fire perimeter. See **also Forward rate of spread**.
Response	Actions taken in anticipation of, during, and immediately after an incident to ensure that its effects are minimised, and that people affected are given immediate relief and support.
Safe	The stage of bushfire suppression or prescribed burning when it is considered that no further suppression action or patrols are necessary.
Scorch height	1. The height above ground level up to which foliage has been browned by a fire. 2. A measurement for determining the acceptable height of flame during prescribed burning.
Scrub	Vegetation such as heath, wiregrass and shrubs, which grows either as an understorey or by itself in the absence of a tree canopy.
Slope	The angle the ground surface makes with the horizontal, and is normally expressed as a gradient. A gradient of 1:10 means that in a horizontal distance of 10 units, the ground rises or falls 1 unit.
Soil Dryness Index (SDI)	A form of Drought Index, usually with slightly more detailed inputs than the Keetch-Byram Drought Index. May be on a scale of 0-200 like the KBDI, but some versions have different scales (e.g. Western Australia: 0—2000; Tasmania: (Mount SDI) 0 — open-ended).
Spot fire	1. Isolated fire started ahead of the main fire by sparks, embers or other ignited material, sometimes to a distance of several kilometres. 2. A very small fire that requires little time or effort to extinguish.
Spotting	Behaviour of a fire producing sparks or embers that are carried by the wind and start new fires beyond the zone of direct ignition by the main fire.
Strip burning (or strip ignition)	1. An ignition pattern using lines of continuous fire. 2. In hazard reduction, burning narrow strips of fuel and leaving the rest of the area untreated by fire.
Strip ignition	See **Strip burning**

Surface fire	Fire that burns loose debris on the surface, which includes dead branches, leaves, and low vegetation.
Surface fuel	Litter fuels made up of leaves, twigs, bark and other fine fuel lying on the ground, predominately horizontal in orientation.
Time lag	See **Lag time**
Total fine fuel	Total of the litter bed, elevated dead and living shrub fuel loads.
Understorey	The lowest stratum of a multi-storeyed forest.
Water point	Any natural or constructed supply of water that is readily available for fire control operations.

Appendix

Example prescribed burn operations record

Burn name and number: ________________________________ Date: __ /__ /__

Administrative centre: ________________________________

FORECAST CONDITIONS (Adjust estimates for burn location, elevation differences)

Location	Temp (max)	RH (min)	WIND Direction	WIND (km/h)	WIND CHANGE Direction	WIND CHANGE (km/h)	WIND CHANGE Hrs
Forecast site							
Burn site							

Stability: ____________________ Inversion (m ASL): ____________________

Outlook: ________________________________

Last rain (mm): ________ No. days ago: ______ KBDI: _______ Max FDI:______

RECORD

Crew briefing (4 & time): _____ hrs. Ignition start (hrs): _____ Ignition finish (hrs): _____

Lighting pattern: ________________________________

Distance between lines (m): ________________________________

Distance between spots (m): ________________________________

Record the following information at least every hour:

Time (hrs)	FMC (%)	Temp(0C)	RH (%)	Wind direction	Wind (km/h)	FDI	FROS (m/h)	Flame ht. (m)	Comments on location of FMC sampling, lighting pattern, fire intensity, spotting, etc.

Total Nos.: Personnel: _____ Tankers: _____ Slip-ons: _____ Dozers: ________

Aircraft ID: _____ Operator: _____ Flight duration (hrs:min): ____________

Navigator: ______ Bombardier: ______ No. capsules used: ____________

Other resources used: ________________________________

Patrol requirements: ________________________________

BURN RESULTS

Area burned (ha): _______ Burn coverage (% of planned area burned): _________

Post-burn Overall Fuel Hazard: _______ Crown scorch (%): ______________

Objectives achieved this day: ___________ Subsequently: ____________

Comments on burn (annotate attached map): ________________________

Follow up actions: ________________________________

Follow up actions completed: ________________________________

Name of Burn OIC: ______________ Signature: ______________

Last update: __ / __ / __

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