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LEGISLATIVE COUNCIL
Question Without Notice

Thursday, 9 November 2023

C1554. Hon Dr Brad Pettitt to the Parliamentary Secretary representing the Minister for Environment

I refer to the answer to Question on Notice 1461 from 20 June 2023 which included Tabled Paper 2316, the Department of Biodiversity, Conservation and Attractions Prescribed Burn Planning Manual, and I ask:

1. Will the Minister table the following documents referred to in the Prescribed Burn Planning Manual:

a. DBCA's Bushfire Risk Management Framework.

b. DBCA's current Regional Fuel Management Plans; and

c. DBCA's current Regional Burn Programs.

Agency Answer

1. a. See tabled document titled Parks and Wildlife Service Bushfire Risk Management Framework – Managing fuel hazards on public lands to control bushfire risk.

   b. The Department of Biodiversity, Conservation and Attractions (DBCA) Regional Fuel Management Plans are currently in draft form and will be finalised and approved by 30 June 2024. The nine plans can be tabled upon finalisation.

   c. DBCA's Burn Options Program is available publicly on DBCA's website at https://www.dbca.wa.gov.au/management/fire/prescribed-burning/burn-options-program. This Burn Options Program covers all nine of DBCA's regions. As this website is interactive and contains live updates, a physical copy is unable to be tabled with this answer.

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Department of **Biodiversity, Conservation and Attractions**

GOVERNMENT OF WESTERN AUSTRALIA

PARKS AND WILDLIFE SERVICE

Parks and Wildlife Service

Bushfire Risk Management Framework

Managing fuel hazards on public lands to control bushfire risk

2019

Version 2.8

16/01/2019

Fire Management Services Branch

APPROVED BY

Stefan de Haan

24/01/2019

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Manager Fire Management Services Branch Date

Contents

Glossary

Term	Definition
95th percentile conditions	The weather conditions under which fire behaviour would be exceeded on only 5 percent of days during the fire season.
Acceptable risk	The level of risk that is tolerable according to an organisation's risk criteria. In the context of the framework, an acceptable level of risk is achieved when fuels are managed such that a bushfire is unlikely to cause unacceptable consequences.
Bushfire	Unplanned vegetation fire. A generic term which includes grass fires, forest fires and scrub fires both with and without a suppression objective.
Bushfire Risk Management Plan (BRMP)	An integrated planning strategy to treat bushfire related risk across all tenures, required to be developed by the local government authority in parts of the state where there is significant bushfire risk.
Bushfire Risk Management Zone (BRMZ)	Areas defined by broad consistency in land use, asset distribution, fire environment (vegetation, fuels and climate) and fire management practices, which combine to create a characteristic risk profile
Community	People and the property, infrastructure, economic systems and other things that provide for their well-being.
Conservation lands or CALM-Act land	Lands managed by Parks and Wildlife Services under the provisions of the Conservation and Land Management (CALM) Act 1984.
Critical Infrastructure Buffer (CIB) Fire Management Area	An area where fuels will be managed to protect items of critical infrastructure from bushfire.
Crown fire	A fire that advances from top to top of trees or shrubs.
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.
Fire behaviour model	A mathematical relationship that describes the potential fire behaviour (e.g. rate of spread, intensity, flame height, spotting distance) dependent upon characteristics of the fuel type climate, weather and terrain.
Fire Danger Index (FDI)	A relative number denoting the potential rates of spread, or suppression difficulty for specific combinations of temperature, relative humidity, drought effects and wind speed.
Fire intensity	A measure of the energy released by the combustion of fuel in a bushfire and is expressed in kilowatts per linear metre of fire line.
Fire Management Area (FMA)	Areas subject to a fuel management regime defined by the primary intent of fire management and the nature of fuels in the area.
Fire regime	The history of fire in a vegetation type or area including the frequency, intensity and season of burning.
Fuel	Any material such as grass, leaf litter and live vegetation which can be ignited and sustains a fire.
Fuel accumulation model	A mathematical relationship between the time elapsed since a fire and the quantity of fuel present in an area.
Fuel age	The time elapsed (usually expressed in years) since an area was last burnt.
Fuel management	Activities that alter the quantity, structure, arrangement or distribution of fuel in an area.
Fuel quantity	The mass of fuel that is present, usually measured in tonnes per hectare.
Fuel structure	The vertical and horizontal arrangement of elements of the fuel.
Landscape Risk Reduction (LRR) Fire Management Area	An area where fuel management is required at a broad scale to reduce the likelihood of large bushfires and protect distributed assets and the natural environment.

Term	Definition
National Emergency Risk Assessment Guidelines (NERAG)	A contextualised, emergency-related risk assessment and prioritisation approach, nationally consistent with the Australian Standard AS/NZS ISO 31000:2018 Risk management – principles and guidelines.
Natural values	Ecosystems, the taxa and communities that comprise them and the landscapes and processes that support them.
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.
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.
Prescribed fire plan (PFP)	A document prepared to assist with the safe implementation of a prescribed burn. It contains all relevant risk management information for the burn unit, as well as the operational procedures to be followed before, during and after the burn to ensure its safe conduct.
Regional Fuel Management Plan (RFMP)	A plan developed by each Parks and Wildlife Services region that interprets that risk criteria provided in the Framework into a regional context to guide the region's operational planning.
Remote Area Management (RAM) Fire Management Area	An area where there are few high value, fire vulnerable assets and fuel management is a lesser priority for the department.
Risk	The effect of uncertainty on objectives.
Risk management	Coordinated activities to direct and control an organization with regard to risk.
Settlement-Hazard Separation (SHS) Fire Management Area	An area where fuels will be managed to protect settlements and other locations where large numbers of people may be endangered by a bushfire.
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.
State Emergency Management Prevention and Mitigation Procedure (SEMPMP)	A State Government procedure supporting the effective implementation of the State Emergency Management Policy providing a step by step process to allow emergency management agencies and personnel to complete tasks in compliance with State EM legislation.
Surface fuel	Litter fuels made up of leaves, twigs, bark and other fine fuel lying on the ground, predominately horizontal in orientation.
Threshold intensity	Double the intensity at which direct attack on a fire is possible using machines and tankers. This equates to 10,000 kW/m in grassland and 4000 kW/m in all other fuels.
Tolerable fire interval	The lower and upper bounds of the inter-fire interval which, if exceeded, may result in negative outcomes for flora. The minimum interval is commonly estimated as two times the longest juvenile period for species killed by fire and relying on seed stores for reproduction so that species are provided with sufficient time to produce seed. The maximum interval is the period required for 50% of individuals in a population to reach senescence.

Executive summary

The Department of Biodiversity, Conservation and Attractions' Parks and Wildlife Service manages bushfire fuels on conservation lands and unallocated Crown land to reduce the risk of bushfire to people, communities, infrastructure, the economy and the natural environment. Fuel management activities, of which prescribed burning is the most widely applied, should be targeted to where they provide the most effective and efficient reduction in bushfire risk. The Parks and Wildlife Service's Bushfire Risk Management Framework (the Framework) provides the principles and rationale for programming fuel management, including identifying the indicators which demonstrate that bushfire risk has been reduced to an acceptable level. The acceptable level of bushfire risk is determined through a risk assessment and prioritisation process.

To accommodate the diversity in the natural and social environments across Western Australia, the Framework divides the State into Bushfire Risk Management Zones (BRMZs). These areas are defined by broad consistency in land use, asset distribution, fire environment (vegetation, fuels and climate) and fire management practices, which combine to create a characteristic risk profile. Eight BRMZs have been identified in Western Australia: South West, Midwest and Southern Coastal, Agricultural; Northern, Central and Southern Rangelands; Desert and Tropical.

The land managed by the department within each BRMZ is further classified into four fire management areas (FMAs), defined by the primary intent of fuel management in that area. Areas surrounding towns and subdivisions are assigned to the Settlement-Hazard Separation (SHS) FMA and those surrounding critical infrastructure to the Critical Infrastructure Buffer (CIB) FMA. These categories recognise that the primary reason for fuel management in the area is to protect highly valuable assets from bushfire. The Landscape Risk Reduction (LRR) FMA encompasses areas where the population is less dense, and where assets are important to individual livelihood, community sustainability or environmental integrity. These areas are managed for a range of outcomes, including the mitigation of bushfire risk at a landscape scale. Finally, areas where there are few high value, fire vulnerable assets are assigned to the Remote Area Management (RAM) FMA. Here, fuel management to reduce bushfire risk is a lower priority.

The extent of the area encompassed by each FMA is determined by the distribution of assets in the landscape and characteristics of fire behaviour. SHS and CIB FMAs form low fuel areas of sufficient depth to reduce the likelihood that a bushfire will affect the relevant assets via direct flame contact, radiant heat exposure or ember attack. The LRR FMA encompasses broad landscapes where there is a need to protect dispersed assets and reduce the likelihood of very large bushfires that cause environmental harm, necessitate costly suppression efforts and may jeopardize SHS and CIB FMAs. The RAM FMA covers relatively remote areas of the State where the nature of assets or fuels are such that routine fuel management is a lower priority for the department.

Indicators of acceptable bushfire risk are set for bushfire-prone fuel types in the SHS, CIB and LRR FMAs. No indicators are set for the RAM FMA, or for fuels that do not usually support bushfires, or where fuel management is not appropriate. Indicators are expressed in terms of the proportion of the landscape that is managed such that the treated fuels will not support fire behaviour of unmanageable intensity, under 95th percentile fire danger index weather conditions. Achieving these indicative measures demonstrates that bushfire risk is managed to an acceptable level in that area.

The indicators of acceptable bushfire risk described in the Framework are a key input to the department's strategic and program level planning for fuel management. The department reports against the indicators to measure the effectiveness of its fuel management program.

Fuel management activities, including prescribed burning, influence ecosystem attributes, and the framework recognises the potential impacts of management activities on biodiversity under the Department's care. Environmental risks associated with fuel management are addressed in strategic, program and operational level planning processes.

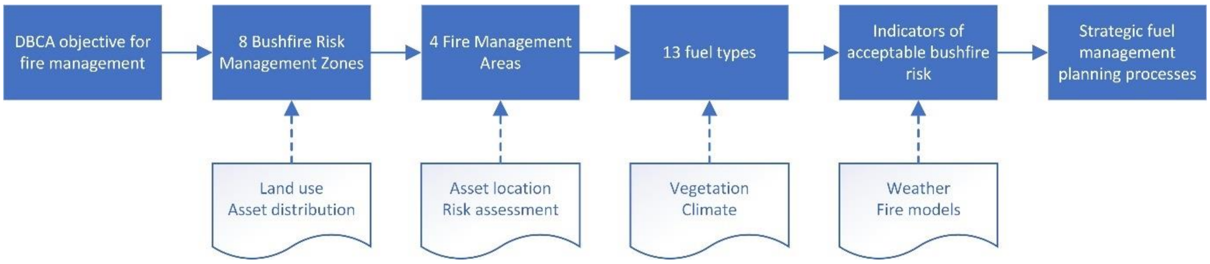

Figure 1: Summary of components of and inputs to the Parks and Wildlife Service Bushfire Risk Management Framework.

Purpose and scope of the framework

The Framework provides a transparent and evidence-based rationale for the management of bushfire risk on department-managed lands, in a manner that is consistent with Government and community expectations. It also provides a basis to prioritise investment and treatment options and apply available resources at an appropriate level to manage bushfire risk to the community and the environment. These outcomes are achieved by defining:

- bushfire risk and how the department assesses it
- principles and objectives underpinning the department's bushfire risk management
- rationale for the department's fuel management
- appropriate strategic planning units for bushfire risk management
- a process to determine acceptable levels of bushfire risk across the State, expressed as performance indicators of the effectiveness of the fuel management program.

The scope of the Framework is limited to the management of the fuel hazard to reduce the risk posed by bushfire. Other aspects of bushfire risk, such as the maintenance of bushfire detection and suppression capacity, are considered elsewhere in the department's procedures. The Framework's risk criteria emphasise the preservation of human life above the protection of economic and environmental assets and other things of value. The rationale for these foci is established by the current document.

The Framework provides criteria that indicate that bushfire risk is managed to an acceptable level at the scale of broad landscapes. It does not prescribe strategies by which these targets should be achieved, nor how they should be integrated with the department's statutory responsibilities to conserve Western Australia's natural environment and biodiversity. These issues are addressed via the department's strategic (five-year regional fuel management plans), program (annual and three-year indicative prescribed burn programs) and operational planning (prescribed fire plans and necessary operations) procedures. Figure 2 provides an overview of the Framework's relationship to key elements of the department's fire planning documents and procedures.

The framework applies to lands on which the Parks and Wildlife Service has responsibility for bushfire mitigation, as described in the Interim State Hazard Plan Fire (State Emergency Management Committee, 2017a). These are areas managed under the provisions of the *Conservation and Land Management (CALM) Act 1984*, regional parks and unmanaged reserves (UMR) and unallocated Crown land (UCL) outside gazetted townsite boundaries, regional centres and the Perth metropolitan area. The latter includes ex-pastoral leases that have been converted to UCL and are managed by the department.

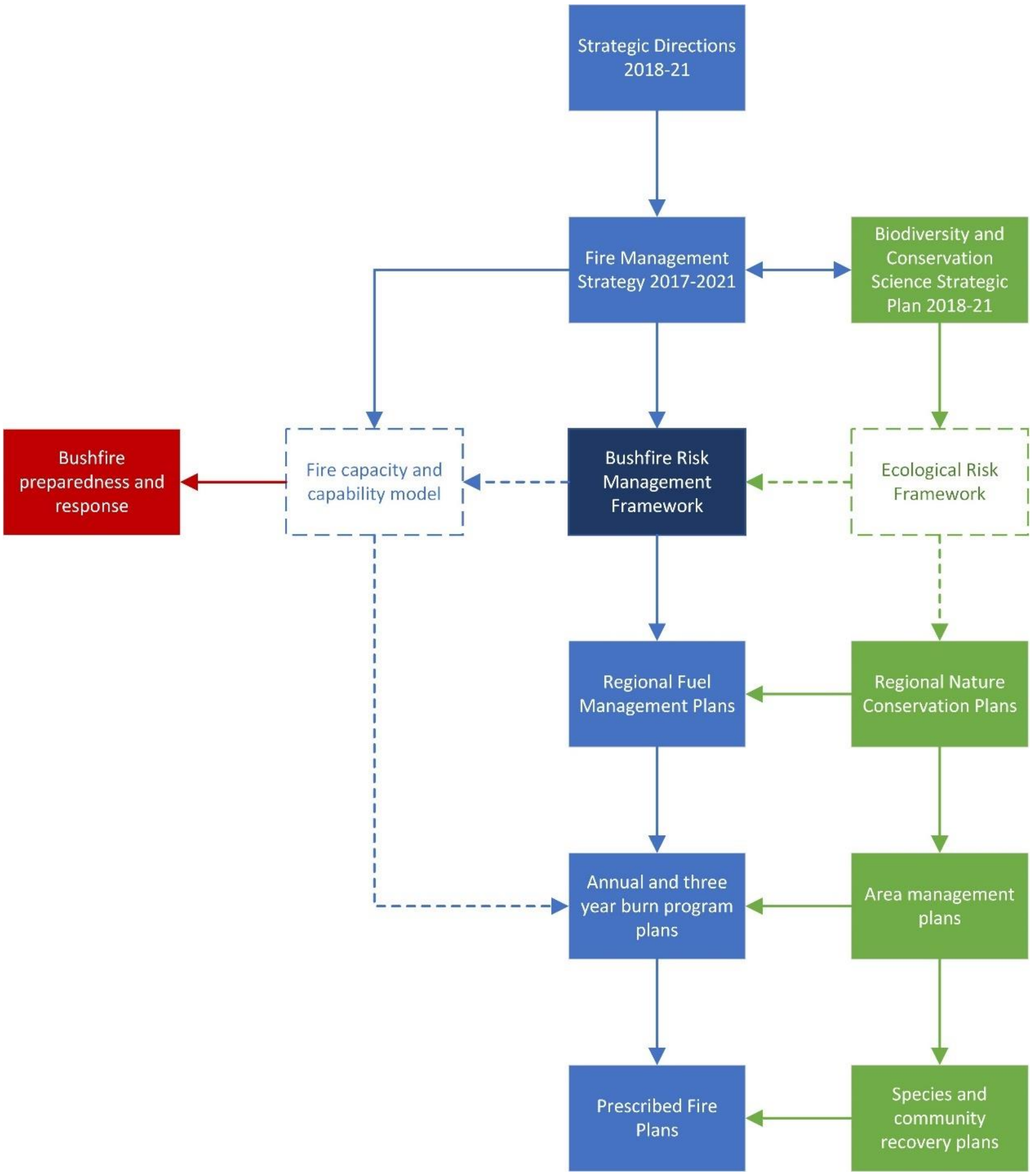

Figure 2: Overview of the department's fuel and fire management planning hierarchy (shown in blue), including connections to the department's conservation-focused planning instruments (shown in green). Dashed lines indicate desirable, but currently non-existent, components.

Regional Fuel Management Plans

Regional Fuel Management Plans (RFMPs) express the risk criteria described in the framework within a DBCA region. They identify assets within the framework categories, assess the exposure and resilience of assets to bushfire risk and map fire management areas based on asset and fuel distribution. In doing these things, RFMPs translate the framework's indicators of acceptable risk into prioritised regional targets for fuel management and provide the measures by which the effectiveness of the region's fuel management activities may be assessed. This is a crucial link between the framework and the works programming process. It is a requirement that every DBCA region maintain a current RFMP to give effect to the framework criteria.

1. The department's approach to bushfire risk

Western Australia's climate and vegetation make it naturally prone to bushfire and such fires occur regularly across much of the State. While fire is a natural process and not all bushfires are harmful, its effects may include social, economic and environmental harm. In recent decades, the frequency and magnitude of bushfires has increased (Dutta *et al.,* 2016) as average fire weather conditions have worsened (Clarke *et al.,* 2013) and severe conditions occurred more often (Hughes and Stefan, 2013). Meanwhile, the exposure of people and communities to bushfire has increased as the State's population has grown, development has spread into fire prone areas, and the area treated by prescribed burning in the southwest has diminished (Burrows and McCaw, 2013). As the threat posed by bushfires has grown, there has been a corresponding increase in the significance placed on their prevention and management.

The Department of Biodiversity, Conservation and Attractions' (DBCA) Parks and Wildlife Service manages about 26.9 million hectares of CALM Act land and has responsibility for fire prevention on a further 96 million hectares of UCL and UMR. Management responsibilities in these areas include taking reasonable measures to minimise the potential for damaging bushfires to occur. This must be achieved in a socially, financially and environmentally responsible manner, making it important that activities designed to reduce the effect of bushfires are planned and implemented judiciously.

There are many ways to reduce the threat posed by bushfire, such as reducing the potential for fires to start or become unmanageable, maintaining adequate resources to quickly detect and suppress fires, decreasing asset exposure to fire and increasing the resilience of assets to fire. The Western Australian experience has demonstrated, however, that managing the fuel available to bushfires is critical to managing the threat posed by bushfire (Boer *et al.,* 2009; Burrows and McCaw, 2013). This is because there is a correlation between the intensity of a bushfire and its potential to cause damage (McArthur and Cheney, 2015). Fire intensity is, in turn, significantly influenced by the quantity of fuel available to the fire (Byram, 1959). Additionally, fire intensity determines the ease of suppression, the likelihood of fire spread through embers and the safety of fire fighters (Burrows, 1984; Department of Fire and Emergency Services, 2014). Managing the quantity, structure and distribution of fuel available to burn has been demonstrated to be an effective and efficient way to prevent damaging bushfires. This axiom guides the department's approach to bushfire risk management. Other aspects of the departments approach to bushfire risk are addressed in the fire management strategy (Department of Parks and Wildlife, 2017).

1.1. What is bushfire risk?

Risk is the effect of uncertainty on objectives (ISO, 2009). It is often characterised by reference to potential events, their consequences and the likelihood that those consequences will occur.

DBCA's objective for fire management is, "Protecting communities and natural values from bushfires" (Department of Biodiversity, Conservation and Attractions, 2018b). In the context of this objective, 'bushfire risk' refers to the consequences and likelihood of a bushfire occurring and causing harm to communities or natural values. This includes people and the property, infrastructure, economic systems and other things that provide for their well-being and ecosystems, the taxa and communities that comprise them and the landscapes and processes that support them.

In keeping with the principle that managing fuels is the greatest contribution DBCA can make to preventing bushfire damage, the department characterises bushfire risk in terms of the type, quantity, structure and distribution of fuel in relation to valued assets. When fuels are managed such that a bushfire is unlikely to cause unacceptable consequences, bushfire risk is at an acceptable level. Likelihood, consequence and acceptable risk are further explained in sections 5 and 6.

1.2. What is bushfire risk management?

Risk management is the coordinated activities to direct and control an organisation with regard to risk (ISO, 2015). More simply, it means identifying events that might affect objectives being achieved and understanding and controlling their effects. The department's bushfire risk management is, therefore, all the activities it undertakes to protect communities and natural values from bushfire. These activities span a wide spectrum that includes community and interagency engagement and education programs, contributing to government policy development, training and development of staff, maintenance of bushfire detection and response capabilities, participation in arson prevention and investigation programs, maintenance of access and communication networks, and many other things. Fuel management, especially prescribed burning, is the department's primary bushfire risk mitigation tool (Department of Biodiversity, Conservation and Attractions, 2018b) and so is the focus of the Framework.

1.3. Principles of managing bushfire risk

The department's approach to managing bushfire risk is underpinned by the following principles based on scientific research, practical experience, community and government expectations and industry best practice.

1.3.1. Bushfire risk management is consistent with the Australian standard

The department is committed to applying risk management in a manner that is consistent with AS/NZS ISO 31000:2018 Risk Management. This means adhering to the eight principles of risk management and applying the risk management process where appropriate within the department's bushfire risk management planning.

The risk management process involves an iterative process of establishing the scope, context and criteria for risk management then identifying, analysing, evaluating and treating risk. Communication, consultation, monitoring and review occur throughout and inform, and are informed by, each step. The risk management standard does not prescribe a risk assessment technique; the department applies suitable methods as required.

The current document is not intended to demonstrate the entirety of the department's risk management framework for risks associated with bushfire. Rather, it establishes some of the critical risk criteria for the fuel management program, primarily the indicators of acceptable risk. Principle 1.3.1 confirms the organisational commitment to alignment with the risk management standard.

1.3.2. Fuels are managed to reduce the harm done by bushfire

Fire is a natural element of the Western Australian environment and plays a role in shaping the State's ecosystems. Fire management aims to reduce the negative consequences of bushfires, not prevent their occurrence. The elimination of bushfire from the landscape is neither a practical nor desirable ambition and both planned and unplanned fire can have benefits.

The potential for a bushfire to cause damage, and the difficulty of suppressing it, are directly related its intensity and speed (McArthur and Cheney, 2015) which are primarily determined by the weather, topography and the type, quantity and arrangement of the fuel (Byram, 1959). Fuel management aims to reduce the quantity of fuel and alter its arrangement, thereby reducing the potential for a damaging bushfire to become established and increasing the likelihood that suppression or other bushfire risk mitigation measures will be successful. Prescribed burning is the primary method by which the department manages fuel, but other mechanical and chemical methods are also used.

1.3.3. Fuel management puts people first

The department manages fuel to achieve multiple outcomes, but a prime consideration is contributing to Western Australia's State Core Objectives for emergency risk management:

- People: protect lives and wellbeing of persons.
- Economy: maintain and grow the State's productive capacity, employment and government revenue.
- Social setting: ensure that there is public order, that people are housed and fed in a safe and sanitary manner and have access to social amenities including education and health services, and that things of cultural importance are preserved.
- Governance: ensure that there is, at all times, an effective and functioning system of government and societal respect for rule of law.
- Infrastructure: maintain the functionality of infrastructure, particularly key transport infrastructure and utilities required for community health, economic production and effective management of emergencies.
- Environment: protect ecosystems and biodiversity.

Fuel management will often contribute to achieving multiple objectives in a complementary manner, but when this is not the case, the protection and preservation of human life is the primary consideration when planning and implementing the fuel management program.

This policy setting is further emphasised by the State strategic control priorities for all hazards (State Emergency Management Committee, 2017b) which identify the protection and preservation of life as the fundamental overarching priority for the State when managing hazards.

The principle of putting people first extends to recognising the social context when planning and implementing fuel management. The department acknowledges the interests of the community in its fuel management program and addresses these interests where possible. Although it is not always possible to achieve an ideal outcome for all parties, fuel management is planned, prioritised and undertaken with a full appreciation of its potential impacts on the community and local economy, as well as its benefits.

1.3.4. Fuel management does not eliminate risk

It is not possible to eliminate bushfire risk entirely; fuel management aims to reduce risk to an acceptable level. Residual risk is the risk posed by bushfire after fuel management is applied. The department employs many strategies to manage residual bushfire risk, including maintaining its bushfire detection and response capacity.

There are also risks created by undertaking fuel management, particularly prescribed burning. Fuel management is conducted where the risk associated with the activity is deemed to be manageable and is outweighed by the risk of not doing it. Risks associated with fuel management are mostly acute or short term and include escapes and effects of smoke from prescribed burns, predation pressure on native species, effects on the survivorship and breeding of flora and fauna, public inconvenience and the reduction of opportunities for industries and recreational pursuits that utilise natural areas. Longer term risks may include potential environmental effects of altering fire regimes, the spread of weeds or plant pathogens and soil erosion. Where relevant, these risks must be managed and balanced against the benefits of the proposed activity. In some instances, fuel management will not proceed because the risks associated with the activity are greater than the risk associated with a bushfire if the fuels are not treated.

1.3.5. Fuel management is planned

Planning is required to ensure fuel management activities are undertaken appropriately and safely. Planning for fuel management utilises the best available information, but specifically recognises and addresses uncertainties and assumptions in the process.

Planning for fuel management must incorporate the department's different land management objectives and social contexts. To allow for this, the department's strategic fire planning has a five-year horizon, while program planning is undertaken one to three years in advance. Operational planning may commence some months in advance of the activity and continues throughout the operational phase.

In the case of prescribed burning, operational planning is recorded in a Prescribed Fire Plan (PFP). A PFP records information relevant to the application of the risk management process for a prescribed burn. Clearly articulated objectives for the burn and criteria to measure whether these objectives are met are critical to this. Every prescribed burn undertaken by the department must have an appropriately approved PFP and be conducted in accordance with the procedures described in that plan.

The prescribed burn planning process specifies an area within which the prescribed burn will be undertaken. An inherent objective of all departmental prescribed burning is that the burn does not escape from this defined area and become a bushfire.

1.3.6. Fuel management planning is consistent

Despite the variation in fire environments across the State, the department's administrative regions all follow a consistent process to analyse risk, set targets and plan fuel management. This ensures that risk, and the effectiveness and efficiency of activities to manage it, can be compared and prioritised between regions and through time.

The Framework plays an important role in ensuring a consistent approach to managing bushfire risk across the State. It describes the context for the department's bushfire risk management process and provides the principles and supporting evidence underpinning the department's approach. The Framework is supported by the department's *Prescribed Burn Planning Manual*, and numerous operational procedures.

1.3.7. Fuel management is integrated

The department is not the only entity monitoring bushfire risk or undertaking fuel management. Consistent with the notion of 'shared responsibility', the Department of Fire and Emergency Services (DFES), local government authorities (LGAs), bush fire brigades and other landholders or managers also participate in bushfire risk management. Although DBCA operates primarily on lands that it manages, planning for fuel management considers the broader landscape context and aims to be synergistic with other planning processes and statutory requirements. An important reason for developing and communicating long, medium and short-term fuel management plans is to maximise the opportunities for engagement in parallel planning processes, such as LGA Bushfire Risk Management Plans.

Other organisations' bushfire risk planning may have a subtly different focus to that of the department due to their different organisational responsibilities. As such, it does not supplant the department's accepted processes or programs. Rather, the department's risk management should seek meaningful and appropriate integration with community and other agencies' parallel processes such that each can inform the other. The outcome should be landscape bushfire risk management implemented in a coordinated, effective and efficient manner.

The department's approach to risk management is also predicated on internal integration. Risk assessment and fuel treatment planning involves departmental staff from multiple disciplines to ensure that decisions are based on the best available information and fuel management is properly integrated with other departmental priorities. Fuel management program planning meetings form an important element of this integration, ensuring a common appreciation of bushfire risk and treatment options.

1.3.8. Risk is managed at an appropriate scale

Variation in climate, vegetation, terrain, land use, population density, arrangement of assets at risk, social or cultural attitudes toward fire, and resource availability mean that the threshold for acceptable bushfire risk will vary across the State. To accommodate this variation in the fire environment, the department assesses bushfire risk, sets targets and plans risk treatments at multiple scales. A State-wide perspective is important because it informs the appropriate allocation of resources across the department's regions and districts. Regional and sub-regional perspectives are also important because they allow a more detailed analysis of risk factors that informs fuel management program planning. There are also risk management processes applied at the scale of individual burns as well as at a range of temporal scales.

1.3.9. Ecological requirements are considered when managing fuel

Fuel management should be undertaken within the ecological tolerances of the environment being managed or it may cause environmental harm. In principle, the regular occurrence of high intensity summer bushfire is considered to have a deleterious effect on biodiversity and the environment. Conversely, biodiversity is best supported by varying the scale, seasonality and intensity of fire occurrence, within a tolerable range, to create an appropriate mosaic of vegetation floristic and structural states.

Ecological requirements are a key consideration when developing fuel management programs and prescribed fire plans. Applying fuel management to achieve acceptable levels of bushfire risk may involve short-term trade-offs between impacts on elements of the biota. The department supports research to ensure that ecological thresholds and tolerances are understood and managed and considers this knowledge when developing prescribed fire plans. This includes applying adaptive research in the prescribed fire program to improve our understanding of fire-ecology.

The principle of considering ecological requirements extends to avoiding unnecessary clearing and disturbance and implementing appropriate weed and pathogen hygiene management practices when undertaking fuel management. This means using natural and existing fuel breaks in preference to creating new tracks, where it is safe and practical to do so. Natural low fuel areas are incorporated into program planning to facilitate this.

More information on the ecological tolerance of the state's biomes is provided in Section 2.2.

2. Western Australia's fire environment

Western Australia's natural environment is highly diverse - spanning tropical, arid and temperate climate zones and featuring regional variation within these. The diverse nature of the State's climate and soils affects the distribution of bushfire risk, by driving patterns in vegetation composition and structure and so the flammability, arrangement and accumulation rates of fuels. Forests, woodlands, shrublands, grasslands and hummock grasslands each influence bushfire behaviour and risk differently and so require different fire management strategies. Climate also determines the seasonality of fire, and climate-driven weather patterns drive the behaviour of fires.

The department's indicators of acceptable bushfire risk must be framed with due consideration of the State's environmental diversity. To achieve this in a way that is appropriate for strategic planning, the State's fuels are generalised into several broad types. Each of these has been assigned a characteristic fuel accumulation model and, in most cases, an appropriate fire behaviour model, when setting indicators of acceptable bushfire risk.

2.1. Climate and weather

The indicators of acceptable bushfire risk have been defined here for different fuels according to the rates of fuel accumulation and the fire behaviour they may support. Mathematical models are used to estimate fuel and fire behaviour characteristics and these models require inputs of climate and weather variables. It is a widely accepted practice to use 95th percentile conditions[1] to model the potential behaviour of bushfires. These are the conditions under which fire behaviour would be exceeded on only 5 percent of days during the fire season. They are found by determining the 95th percentile Fire Danger Index (FDI) during the prohibited burning season for a location over several years, then deriving the weather conditions that gave rise to this FDI value.

Unfortunately, the weather data that are currently available to the department[2] are inadequate to reliably derive 95th percentile conditions as they are limited to a five-year period from 2011 to 2016. This means that the weather conditions used to model fire behaviour in the framework are provided by the expert judgement of experienced fire practitioners across the state. This will be reviewed as better data become available.

The 95th percentile conditions vary depending on the location in the State and whether the grassland fire danger index (GFDI) or forest fire danger index (FFDI) is the more appropriate metric. These conditions are specified in Table 1 for several locations to allow calculation of fire behaviour parameters in different planning units.

Table 1: 95th percentile grassland and forest (if applicable) fire danger index and weather conditions for key locations in Western Australia. Curing is assumed to be 100 percent and drought factor 10 for all locations.

Location	GFDI	FFDI	Temperature (°C)	Relative humidity (%)	Wind speed (km/h)
Bickley	26	34	35	22	25
Perth	42	49	40	20	30
Collie	40	46	38	20	30
Pemberton	24	31	35	25	25
Albany	25	38	34	15	22
Ravensthorpe	43	-	38	8	25
Merredin	57	-	40	10	30
Kalgoorlie	61	-	40	8	30
Jurien	54	-	38	30	40
Carnarvon	44	-	40	30	35
Paraburdoo	64	-	43	9	30
Kalumburu	33	-	37	15	25
Fitzroy Crossing	34	-	44	10	20

2.2. Bushfire fuels

The indicators of acceptable bushfire risk are influenced by the nature of the bushfire fuel within a management unit. The Framework classifies the state's vegetation into thirteen fuel types, based on potential fire behaviour (speed and intensity) within them and their rate of fuel accumulation post-fire. These factors are largely a function of the structure of the vegetation, rather than its floristic composition. Some genera names are included in the naming convention to aid communication of

[1] The 95th percentile has been widely used to characterise severe fire weather conditions since this threshold was adopted by the United States Bureau of Land Management in 1974 to define required staffing levels for fire suppression (Heinsch *et al.,* 2009). It has been used in Western Australia since at least 1993, when Chris Muller adopted it as the basis for fire behaviour calculations in Wildfire Threat Analysis (Muller, 1993).
[2] Sourced from the Bureau of Meteorology gridded weather reanalysis project.

the type of fuel but the classification considers the fire-ecology requirements of the vegetation in only a highly generalised way. The State's main fuel types are described in this context below.

2.2.1. Tropical savanna

Tropical savanna is the predominant fuel of the State's far north. The composition of savanna varies, but it is characterised by sparse to open woodland with an understorey of annual tussock grass. Tropical savanna exhibits very rapid post-fire accumulation of grassy fuels, potentially supporting an annual fire return interval (Russell-Smith *et al.,* 1998). Profuse grass growth during the wet season and the routine occurrence of extensive late dry season thunderstorms, mean that bushfire is a natural and pervasive influence on the environment. Many tropical species have evolved a degree of resilience to fire (Legge *et al.,* 2011), but fire sensitive ecosystems occur within the savanna including rainforest patches, sandstone pavement shrublands, *Acacia* thickets and *Callitris* stands (Fisher *et al.,* 2003). Fire management aims to minimise the occurrence of large, high intensity bushfires in the late dry season by creating a mosaic of burnt and unburnt patches in the early dry season. This has been shown to have positive ecological and environmental outcomes (Legge *et al.,* 2011; Radford *et al.,* 2017) as well as providing protection to communities, infrastructure and economic assets.

No fuel accumulation model is required for tropical savanna as the predominant fuel is annual grass. The quantity of fuel present is assumed to be zero for six months following a fire and 6 t/ha thereafter. Fire behaviour is modelled using the 'woodland' vegetation type of the CSIRO Fire Spread Meter for Northern Australia.

2.2.2. Pindan

Pindan is the characteristic vegetation of the south-west Kimberley. It consists of a dense, tall shrub layer (mainly *Acacia* and *Grevillea* species) with scattered low trees (mainly *Eucalyptus* and *Corymbia* species). The understorey contains herbs and grasses, particularly curly spinifex, ribbon grass and sorghum (Smolinski *et al.,* 2016). Fire cycles in pindan are primarily driven by the availability of these understorey grasses, with litter being a relatively small component of the fuel. It is common for the entire structure of the vegetation to be consumed in bushfire, due to the vertical continuity of fuels (Beard, 1967). Research suggests that key obligate reseeder species in pindan vegetation require at least 4 years following fire to re-establish, though the association may carry a fire as soon as one-year post-fire (Radford and Fairman, 2015).

There is no accepted fuel accumulation model for pindan. Based on preliminary work undertaken by the department (Radford, unpublished data) a prescribed burn in pindan is considered to reduce the risk of a subsequent fire for a period of three years. Fire behaviour in pindan is modelled using the 'woodland' vegetation type of the CSIRO Fire Spread Meter for Northern Australia.

2.2.3. *Acacia* woodland

Acacia woodland, most prominently mulga (*Acacia aneura* and closely related species), is the dominant vegetation of the south-western Pilbara, Gascoyne and Murchison. Throughout this area, varying densities of mulga form a pattern of groves (dense woodland) and inter-groves (sparse woodland). Mulga may occur as either a low tree (to about 9 m) or a tall shrub (2 to 5 m). Bunch and hummock grasses often dominate the understorey of mulga woodlands and may be dense in inter-grove areas (Page, 2013; Ward *et al.,* 2014).

Mulga is sensitive to fire, and individual trees may be killed by relatively low fire intensity (Griffin *et al.,* 1983). Fire stimulates seed germination, but germinants are slow-growing with a long juvenile period. A minimum fire return interval of about 26 years is required to maintain mulga populations (Ward *et al.,* 2014). The flammability of mulga communities is largely controlled by the density of understorey grasses. Areas with a spinifex understorey will be relatively flammable, while areas with bunch grass understorey may only carry significant fuel loads following periods of high rainfall. Fires are also more likely to occur if exotic grasses are present. In the absence of grass, mulga vegetation tends to have discontinuous ground fuel and is unlikely to burn, except under extreme conditions (Silcock *et al.,* 2016). In areas with a spinifex understorey, patch burning of inter-grove areas in mild conditions can reduce the chance of more severe and widespread fires.

Woodlands dominated by *Acacia acuminata* and related species occur throughout the wheatbelt. These have similar structural and ecological characteristics to mulga woodlands and the Framework applies the same rationale to these woodlands.

Fire is rarely required for asset protection in *Acacia* woodlands and a passive approach to fire management is recommended. As such, no fuel accumulation or fire behaviour models are applied to areas of *Acacia* woodland.

2.2.4. Hummock grassland

Hummock grasslands occur throughout the semi-arid and arid areas of the State, including areas of the Kimberley, Pilbara, Midwest and Goldfields. They are typified by species of *Triodia* (spinifex) forming mounds up to one metre high, separated by bare ground. Emergent shrubs or small trees (usually *Acacia* or *Eucalyptus*) often feature. The spaces between hummocks may be occupied by ephemeral plants after episodic rain events, increasing fuel load and continuity. Where mulga co-exists with spinifex, the cover and load of spinifex is usually lower than the surrounding landscape.

The ecology of spinifex communities is strongly driven by rainfall, with both cumulative rainfall and episodic events influencing community composition and rates of biomass accumulation (Allen and Southgate, 2002). Typically, hummock grasslands in the arid zone have the potential to burn within 5-7 years of a fire, although they may not reach maturity as a fuel for 18-20 years (Burrows *et al.,* 2009). In the tropics, high annual rainfall can promote the growth of seasonal grasses within spinifex communities, potentially facilitating much short fire return intervals (Rice, 1999). Studies of the regenerative capacity of hummock grasslands suggest that they are adapted to relatively short inter-fire intervals (Westoby *et al.,* 1988) though an interval of about 8 to 10 years is preferable and the vigour of the community declines after about 25-30 years (N. Burrows, unpublished).

The flammability of spinifex is determined by its cover density, moisture content and fuel load (live and dead material). Time since fire and rainfall will influence the rate of fuel development; cover density usually peaks at around 10-15 years and fuel load at around 15 -20 years (Burrows *et al.,* 2017).

Fuel accumulation and fire behaviour in spinifex grasslands are modelled using the model for predicting fire behaviour in spinifex grasslands of arid Australia (Burrows *et al.*, 2018).

2.2.5. Sandplain shrubland

Sandplain shrublands are dense, low to medium shrublands that occur on sandy soils in the southwest land division, particularly in near-coastal locations. They are species rich and variable in composition but are commonly dominated by Proteaceae (*Banksia* and *Hakea*), Myrtaceae (*Verticordia* and *Eucalyptus*) and Papilionaceae (*Daviesia* and *Jacksonia*).

Fuels in sandplain shrublands are predominantly held in a near surface layer of dense low shrubs, the flammability of which is increased by elevated fine fuels. There is relatively little surface fuel, as dead foliage tends to be retained on plants (Westcott *et al.,* 2014).

Much of the Western Australian research into the behaviour and effects of fire in sandplain shrublands has been conducted in the northern sandplains around Eneabba. In that area, shrublands regenerate rapidly after fire, due to the high proportion of species that can re-sprout from underground energy stores (Westcott *et al.,* 2014). The ecologically optimum inter-fire interval has been described as 10-15 years (Enright *et al.,* 2014), 13-15 years (Westcott, 2010) and 15-18 years (Enright *et al*., 1996) depending on the substrate and species composition. These intervals may not be compatible with the shorter burning intervals preferred for bushfire risk mitigation.

Prescribed burning in this vegetation type is difficult, firstly due to the high threshold for weather conditions needed to support running fire and secondly because the strongly wind-driven nature of shrubland fires means that it is not possible to employ a 'back burn'. Also, the lack of clear stratification of vegetation layers in coastal shrublands means that prescribed burns cannot exclude the overstorey and usually burn the entire vegetation profile.

Several variables have been shown to influence fuel accumulation rates in coastal shrublands (for example Westcott *et al.,* 2014), so fire return intervals are tailored to different areas based on expert practitioner judgement. Fire behaviour is modelled using the shrubland fire behaviour model of Anderson *et al*. (2015).

2.2.6. Thicket

Thickets consist of mixed shrubs greater than 1 m tall with 30-70% canopy cover found on leached sands in the western goldfields and northern and eastern wheatbelt. Generally, *Allocasurina* is the dominant genus in areas receiving more than about 325 mm of rain per year with *Acacia* species most common where rainfall is lower than this. Structurally similar associations dominated by *Melaleuca* species may occur in wet sites in the southwest land division (Beard *et al.,* 2005).

When mature (about 20 years post-fire), thickets may burn with considerable intensity under hot, dry and windy conditions. There has been relatively little research done on fuel accumulation rates in thickets, but Dalgliesh *et al.* (2015) found that scrub in the Yalgoo and Avon-Wheatbelt bioregions accumulated fuel at a rate of about 1 t/ha per year for about 10 years after a fire. The rate of accumulation then slowed such that a further 10 t/ha accumulated over the subsequent 30 to 50 years. Newbey *et al*. (1995) observed that thickets in the Boorabbin area required 20-25 years after a fire to accumulate sufficient fuel to carry another fire.

There is no accepted fuel accumulation model for thickets, so fire return intervals are based on expert practitioner judgement. Fire behaviour is modelled using the shrubland fire behaviour model of Anderson *et al*. (2015).

2.2.7. Mallee-heath

Mallee-heath is characterised by a closed-canopy of multi-stemmed eucalypt species between about 2 to 10 metres in height, over a sparse layer of mostly sprouting shrubs and sedges (Gosper *et al.,* 2012), though grasses and hummock grass may also be present (Bradstock and Gill, 1993). The fuel structure of mallee-heath communities may vary, depending on factors of the climate and soil (Sullivan *et al.,* 2012) and the time elapsed since the last fire (Cruz *et al.,* 2012). The surface fuel is predominantly eucalypt litter, which is usually clustered around individual plants and may total up to about 5 t/ha (Cruz *et al.,* 2012; McCaw 1998). Near surface fuels include shrubs, spinifex, grasses and herbs. Tussock grasses and herbs may contribute significantly to the fuel load after above average rainfall years (Bradstock and Cohn, 2002) but are less abundant otherwise. The elevated fuel layer includes taller shrubs (0.5 to 2 metres in height) and suspended material (bark strands, dead leaves and twigs) which play a prominent part in promoting crown fires (Cruz *et al.,* 2010).

The significance of each fuel layer to fire behaviour varies with time since last fire. Surface fuels have the greatest influence for about the first ten years, after which the elevated fuel layer becomes more significant. As the community matures, the increasingly closed canopy becomes the greatest contributor to the fuel profile, with lower layers decreasing in significance (Cruz *et al.,* 2010). Prolific spotting from burning strands of eucalypt bark or leaves may occur ahead of the fire front in mallee (Noble *et al.,* 1980).

Fires in mallee exhibit high rates of spread relative to other eucalypt assemblages (McCaw, 1998), although the discontinuous nature of fuel means that thresholds of wind speed, relative humidity and temperature must be exceeded before fire will spread (Cruz *et al.,* 2012). As such, the fire regime in many mallee areas is dominated by very large, infrequent fires (Avitabile *et al.*, 2013; O'Donnell *et al.* 2011). Following a fire, it may take several decades to develop the biomass and density required to carry another fire, although, in years of good rainfall, a grassy or herbaceous understorey may develop which provides continuity in the fuel bed (Bradstock and Cohn, 2002; Keith *et al.,* 2002).

Fuel accumulation in mallee-heath is modelled according to McCaw (1998). Fire behaviour is modelled using the semi-arid mallee heath model of Cruz *et al.* (2013).

2.2.8. Semi-arid woodland

Semi-arid woodlands occur in the transitional climatic zone between the State's southwest and the arid interior, including much of the wheatbelt and the Great Western Woodlands. They are characterised by an open canopy (10-30% cover) of medium to tall (10 to >25 m) single stemmed *Eucalyptus* species with a sparse understorey of shrubs (Herford *et al.,* 2011). The occurrence, structure and composition of woodlands is controlled by climate, underlying geology and soils (Shedley, 2007).

Semi-arid woodlands are not highly prone to bushfire, having an open canopy and little surface or near-surface fuel when mature (Gosper *et al.* 2014; O'Donnell *et al.,* 2011). This is exacerbated by vegetation fragmentation throughout agricultural areas which precludes the occurrence of landscape scale fires (McCaw and Hanstrum, 2003; Parsons and Gosper, 2011). In woodland with a sclerophyll shrub understorey, litter is discontinuous, with much of the ground surface either bare or with biological soil crust (mosses, lichens, cyanobacteria). Fires require strong wind to spread between discrete patches of fuel, but the available shrubs and litter will burn well under such wind conditions (O'Donnel *et al.,* 2011). Woodlands with chenopod shrub understoreys have very low flammability and will only burn under extreme weather conditions.

The fuel hazard in semi-arid woodlands peaks at an intermediate (20-200 years) time since last fire, then declines as the community matures (Gosper *et al.,* 2014). Many of the species that comprise these communities have long juvenile periods and community diversity is greatest following long periods without fire (Gosper *et al.,* 2013a). This means that semi-arid woodlands experience a period in which both fire proneness and fire-sensitivity is maximal (Gosper *et al.,* 2013b; O'Donnell, 2011). It has been suggested, that mild prescribed burning of surface fuels during this period may promote regeneration and protect against the recurrence of bushfire (Gosper *et al.* 2014; Shedley, 2007).

Fuel accumulation is modelled in semi-arid woodlands using the wandoo litter accumulation guide (Table 7.1.3) in the Forest Fire Behaviour Tables (Sneeuwjagt and Peet, 2011) in combination with the fuel hazard scores in Gould *et al.* (2007) and Department of Biodiversity, Conservation and Attractions (in prep). Fire behaviour is modelled using the Dry Eucalypt Forest Fire Behaviour Model (Cheney *et al.,* 2012).

2.2.9. Chenopod shrubland

Chenopod shrublands occur throughout the lower rainfall parts of the state on sites that are dry, salty or intermittently waterlogged. They comprise a layer of low shrubs with 30-70% canopy cover, predominantly of the genera *Sclerolaena*, *Atriplex* (salt bush), *Maireana* (blue bushes, cotton bush), *Chenopodium* and *Rhagodia*. Sites that are highly saline or prone to waterlogging tend to exhibit pure chenopod associations. Locations that are not prone to waterlogging may also have a scrubby or woody overstorey component, which increases in height and density with increasing clay content in the soil (Beard & Webb, 1981).

Chenopod shrublands are usually not flammable, due to the sparse nature of fuels and the high salt content of the shrubs. The exception to this is when rare periods of high rainfall result in a flush of grasses and herbs. Under these circumstances, chenopod shrublands may exhibit fire behaviour like a grassland, with some level of wind impedance from the shrub layer or overstorey.

Chenopod shrublands may be defined as non-flammable in fuel management planning processes. Where it is desirable to apply a fire behaviour model to them, the CSIRO Grassland Fire Spread Model (Cheney *et al.,* 1998) is used, with an appropriate wind modifier applied.

2.2.10. Dry eucalypt forest and woodland

Dry eucalypt forest and woodland are those vegetation associations dominated by a jarrah, marri and wandoo overstorey in the southwest of the state. Jarrah-marri forest is the predominant vegetation of the Darling Range and occurs in pockets on the Swan Coastal Plain. Wandoo woodlands replace jarrah-marri forest where there is less plant-available water. This is primarily to the north and east of the forested areas, but also includes areas of thin soils on slopes, rocky ground and ridge tops in the higher rainfall zone. The height and density of the vegetation generally increases as water availability increases, with a corresponding increase in fuel accumulation rates and maximum fuel accumulation.

Jarrah-marri open forest is composed of trees up to 25m in height with a canopy cover of about 25-35% (Burrows *et al.,* 2010). Low trees of *Banksia grandis, Casuarina fraseriana, Persoonia longifolia* and *P. elliptica* may form a midstorey stratum 10-15m in height. Understorey vegetation is low (0.3–0.5 m) and open, contributing not more than 25-40% cover. The ground cover is sparse and features various herbs and grasses (Beard, 1979). Wandoo woodlands have an open structure, usually with clumps of single-age trees separated by large open areas. Jarrah and marri commonly occur as lesser overstorey components, often in mallee habit. Wandoo woodlands generally lack an extensive secondary storey; low shrubs of species of *Dryandra*, *Gastrolobium* and *Xanthorrhoea* may occur in thickets, but don't generally form a recognizable stratum.

The relative scarcity of herbs and grasses in jarrah-marri forest means that leaf litter is the predominant ground fuel. In the aftermath of a fire, litter re-accumulates at an average rate of about 1 t/ha per year, reaching a maximum of about 10-16 t/ha after about 15 years. Understorey fuels may become a significant contributor to the fuel load within about 5 years of a previous fire. As the vegetation ages, structural change makes near surface and elevated fuels in the understorey vegetation, and bark on trees, increasingly important to potential fire behaviour (McCaw *et al.,* 2012).

Wandoo woodlands have little understorey, so the propagation of fire is heavily reliant on accumulated litter. Shed bark is a particularly important component of the litter load, as mature trees shed bark heavily to form dense beds around individual trees. Between these bark accumulations, surface fuels may be quite light. Overall, litter accumulates slowly in wandoo woodlands relative to jarrah forest and the maximum total accumulation is less. Measurements in wandoo woodland at Dryandra woodland showed that litter accumulated at a rate of about 0.5 tonnes per year for the first 10 years after fire. After that time, the rate of litter accumulation declined (Burrows *et al*., 1987). Litter fuel may be supplemented by a layer of short grasses and herbs.

Fires in forests are predominantly driven by surface fuel, with near surface and elevated fuels becoming progressively involved as fire intensity increases. Except under extreme weather conditions, fires in dry eucalypt forest may be direct attacked if the quantity of surface fuel present is less than about 8 t/ha. Above that mass, fires will be difficult to control unless conditions are very mild (Burrows, 1994). Spotting may result in fires spreading significantly more rapidly than expected in jarrah-marri forest (Sullivan *et al.,* 2012). Spotting occurs when burning fuels (commonly bark) are lifted by air currents and transported ahead of the fire front.

Most jarrah forest upland understorey plants flower within 3-4 years of fire, depending on rainfall. Some species growing in creek lines and rock outcrops can take 4-6 years to reach flowering age after fire (Burrows, 2008). Based on current information, the ecologically tolerable fire interval for jarrah-marri forest is about 5-7 years minimum to 40 years maximum.

Young wandoo trees are sensitive to fire and may be killed by relatively low scorch. Larger trees are more resilient and may resprout from lignotubers, coppice or epicormic shoots. New growth will mostly replace damaged crowns within about 14 months of a fire. Although potentially lethal to mature trees, periodic fire is needed for the regeneration of wandoo as it stimulates mass seed release and provides suitable conditions for seedling germination (Burrows *et al*., 1990).

Fuel accumulation is modelled in dry eucalypt forest and woodland using the litter accumulation guides in the Forest Fire Behaviour Tables (Sneeuwjagt and Peet, 2011) for northern jarrah (Table 7.1.1) and wandoo (Table 7.1.3) as appropriate, in combination with the fuel hazard scores in Gould *et al.* (2007) and Department of Biodiversity, Conservation and Attractions (in prep). Fire behaviour is modelled using the Dry Eucalypt Forest Fire Behaviour Model (Cheney *et al.,* 2012).

2.2.11. Wet eucalypt forest

Wet eucalypt forests are tall forests (up to 70 m) with a discontinuous canopy, dominated by karri (*Eucalyptus diversicolor)* or tingle (*E. jacksonii, E. brevistylis* and *E. guifoylei*), sometimes in association with jarrah and related species. They mostly occur where annual rainfall is greater than 1000 mm and evaporation less than 500 mm (Breidahl and Hewett, 2005), primarily south of a line from about Nannup to Denmark.

The relatively open canopy of wet eucalypt forests allows the development of a substantial understorey of small trees and shrubs. A secondary canopy of low tress and tall shrubs is often present at about 10 metres, with a continuous stratum of soft leaved shrubs at about 3 m. The ground layer consists of many low shrubs and creepers, a very light cover of grass with some mosses, liverworts and ferns (Beard, 1981).

Wet eucalypt forest is a distinctly different fuel type to dry forest, as it accumulates more fuel and develops a deeper litter bed, heavier trash layer and denser and taller shrub layer. Five years after a fire in karri dominated forest with a 50% percent canopy, about 15 t/ha of surface fuel will have accumulated. At 15 years since the last fire, the total fuel load will be between about 20 and 30 t/ha of fuel (McCaw, 1986). Litter continues to accumulate for up to seven decades and elevated dead fuel for at least three decades after a fire. Tingle forest accumulates fuel rapidly for at least the first 20 years after a fire, with the total fuel load likely to peak at more than 50 t/ha after 50 years (McCaw et al. 2000). Most of the available fuel is in a deep layer of leaf litter, bark and twigs that accumulates at the base of individual trees.

The depth of the fuel profile and the shading effect of multiple canopies means that wet forest fuels retain a large amount of moisture. A study of karri forest to the west of Manjimup found that the deep fuel profile was saturated until the beginning of December and after mid-March but approximated the surface moisture content through the peak of the fire season (January-February). Through the study, litter fuel was found to be dry enough to sustain fire on about 80 days and to burn at high intensity on about 25 of these days. (McCaw & Hanstrum, 2003). The surface and profile fuel moisture content are important factors determining fire occurrence and behaviour and the feasibility of prescribed burning in these fuels

The juvenile period[3] of wet eucalypt forest understorey species is longer than for dry forest equivalents (4-5 years as opposed to 3 years) (Christensen and Annels, 1985). As such, management of karri forest by the department has traditionally aimed to maintain fuel ages of about 7-9 years.

[3] The juvenile period of a plant is an important indicator of the minimum fire interval required to ensure its persistence, particularly for those that depend on seed stored in the canopy for regeneration. In obligate seed species, the juvenile period is defined by the time to first flowering after fire. The recommended inter-fire period for these species is usually double the juvenile period (Burrows and Friend, 1998).

Fuel accumulation is modelled in wet eucalypt forest using the litter accumulation guide in the Forest Fire Behaviour Tables (Sneeuwjagt and Peet, 2011) for karri (Table 7.1.2), in combination with the fuel hazard scores in Gould *et al.* (2007) and Department of Biodiversity, Conservation and Attractions (in prep). Fire behaviour is modelled using the Dry Eucalypt Forest Fire Behaviour Model (Cheney *et al.,* 2012).

2.2.12. *Banksia* woodland

Vegetation associations dominated by *Banksia* species can vary in structure from low shrublands to low woodlands. Those of the state's southwestern coastal plains are predominantly tall shrublands and low woodlands, featuring an overstorey of *Banksia* with occasional emergent trees of species including *Eucalyptus, Corymbia, Allocasuarina* and *Nuytsia*. The understorey is species rich and includes sclerophyllous shrubs, sedges and herbs (Commonwealth of Australia, 2016).

Banksia woodlands accumulate fuel rapidly after a fire; 5.5 t/ha of fuel may have collected within four years. This is sufficient to support an intense and fast-moving fire under extreme fire weather conditions. Within 6 years of a fire, the total quantity of fine fuels reaches its maximum of 6-8 t/ha. About 50 percent of the total fuel weight is live biomass, with the remainder being dead, suspended scrub and ground litter. Rapid initial accumulation of fuel means that buffers burnt for bushfire mitigation purposes may only remain effective for about 3-4 years (Burrows and McCaw, 1990).

Banksia woodlands of the Swan coastal plain have been listed as a threatened ecological community, with grass invasion and changed fire regime identified as threatening processes (Commonwealth of Australia, 2016b). They are sensitive to overly frequent fire as many of the flora taxa are reseeder species. Key indicator plant species have juvenile periods of 4-6 years for reseeder species and 8 years for resprouters (Wilson *et al.,* 2010). Many Banksia woodland fragments have grassy weed species present which alters fuel and fire risk profiles.

Fuel accumulation is modelled in *Banksia* woodland using the fuel hazard scores in Gould *et al.* (2007) and Department of Biodiversity, Conservation and Attractions (in prep). The Dry Eucalypt Forest Fire Model (Cheney *et al.,* 2012) is used to model fire behaviour.

2.2.13. Pine plantation

Pine plantations (*Pinus pinaster* and *P. radiata*) occupy significant areas of land in the southwest of the State. The predominant species in plantations is *P. pinaster* to the north of the Perth metropolitan area and *P. radiata* across the remainder of the southwest. Plantations represent both a source of fuel and an asset to be protected from bushfires, but there are distinct differences in the way they are managed. *P. radiata* is highly sensitive to fire, so prescribed burning is not a viable option in these plantations. Instead, fire protection measures concentrate on fire detection and response measures, including maintaining adequate fire access. Low intensity prescribed burning is conducted in *P. pinaster* plantations, allowing needle bed and prunings to be disposed of.

The fuel profile of pine plantations is dynamic, changing as the plantation ages and is managed for silviculture. Fuels may be dominated by grass in the first few years after first-rotation planting, after which the developing trees progressively contribute both needle litter and standing biomass to the fuel profile. Pruning and thinning operations, undertaken at various times during the plantation's lifecycle, will contribute large quantities of slash to the available fuel load and alter the vertical distribution of fuel and wind impedance caused by the canopy.

This variability in the fuel profile makes it problematic to generalise about fuel availability within pine plantations. As an example, many of the plantations in the Swan Region are at least twenty years old and have been thinned and pruned and are progressing toward harvest. Unless they have been burned, surface fuels may be extremely heavy, particularly in recently thinned stands, and relatively compact. Total fuels load may be about 19 t/ha, plus any recent thinning slash, and about two thirds of this will be in a duff layer. In thinned and high pruned stands elevated fuels are absent, with a minimum six metre gap between surface fuels and the crown base. Bark fuels become increasingly platy with age and may contribute to short distance spotting (Cruz *et al.,* 2011).

Old multi-thinned stands with well compacted slash and dry surface fuels will typically support surface fires with flame heights of 3 to 6 metres under moderate fire conditions. The rate of spread in such areas will be about 500 to 1000 m/h. Under high winds, some intermittent crown fire development is expected. Crown fire development can be rapid and will escalate the rate of spread two to three-fold. It will also increase the intensity and distance of spotting (Cruz *et al.,* 2011).

Younger pine plantings may not have been thinned and pruned. In this case, the closed canopy and high stand density can delay surface fuel drying and reduce wind penetration. This reduces the range of conditions under which a fire will spread. When litter fuels are sufficiently dry to support a vigorous surface fire, however, crown fire development can be expected. This will occur even in relatively light winds, due to an abundance of elevated fuels (Cruz *et al.,* 2011).

Fuel accumulation and fire behaviour in pine plantations are modelled using an adjusted version of the Forest Fire Behaviour Tables (Sneeuwjagt and Peet, 2011).

Table 2: Summary of fuel and fire behaviour models used when setting thresholds for acceptable bushfire risk in each vegetation type.

Fuel type	Fuel accumulation model	Fire behaviour model
Tropical savanna	CSIRO Grassland Fire Spread Meter for Northern Australia	CSIRO Grassland Fire Spread Meter for Northern Australia (woodland)
Pindan	Expert judgement	CSIRO Grassland Fire Spread Meter for Northern Australia (woodland)
Acacia woodland	None	None
Hummock grassland	Burrows *et al*. (2018)	Burrows *et al*. (2018)
Sandplain shrublands	Expert judgement	Anderson *et al.* (2015)
Thicket	Expert judgement	Anderson *et al.* (2015)
Mallee	Expert judgement	Cruz *et al.* (2013)
Semi-arid woodland	Forest Fire Behaviour Table & Dry Eucalypt Forest Fire Model	Dry Eucalypt Forest Fire Model
Chenopod shrubland	None	None
Dry eucalypt forest	Forest Fire Behaviour Table & Dry Eucalypt Forest Fire Model	Dry Eucalypt Forest Fire Model
Wet eucalypt forest	Forest Fire Behaviour Table & Dry Eucalypt Forest Fire Model	Dry Eucalypt Forest Fire Model
Banksia woodland	Dry Eucalypt Forest Fire Model	Dry Eucalypt Forest Fire Model
Pine plantation	Forest Fire Behaviour Table	Forest Fire Behaviour Table

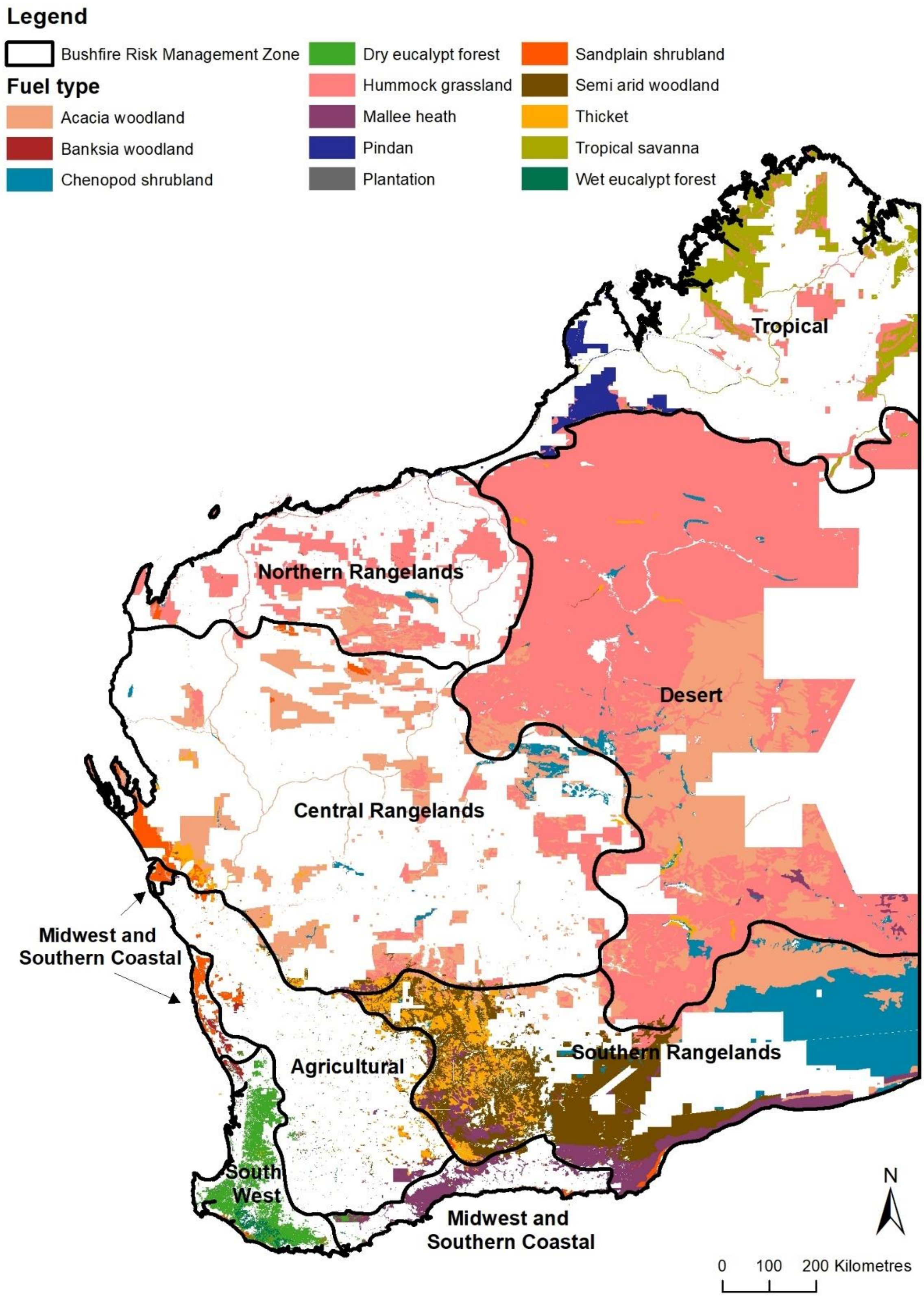

Figure 3: Bushfire Risk Management Zones and the fuel models applied to define bushfire risk criteria on department-managed land.

3. Bushfire Risk Management Zones

Bushfire risk is not distributed evenly across the State. The concentration of population, urban development and infrastructure is greatest in the State's southwest. Beyond this are landscapes dominated by agriculture, pastoralism and mining. These areas feature settlements and nodes of development, often separated by large expanses of land that are economically important but have relatively little infrastructure. Even more remote are the undeveloped areas of the interior which mostly lack infrastructure but are valued for their support of biodiversity, culture, spirituality and tourism.

The diversity in the natural and social environments must be considered when setting targets for fuel management to achieve the indicators of acceptable bushfire risk across the State. This is accomplished by characterising bushfire risk at the scale of the Bushfire Risk Management Zone (BRMZ). There are eight BRMZs in WA, defined by patterns of land use and vegetation; these are: South West, Midwest and Southern Coastal, Agricultural, Northern Rangelands, Central Rangelands, Southern Rangelands, Desert, and Tropical Savanna.

3.1. South West BRMZ

The South West BRMZ aligns with the department's Swan, South West and Warren regions. It contains most of the State's population and the greatest density of high value assets. It includes two predominant landscapes, a coastal plain dominated by Banksia woodlands and coastal shrublands and an upland plateau dominated by forest. Eucalypt woodlands occur on the drier eastern fringe of the forest. The coastal plain is extensively developed, with department-managed land predominantly occurring as isolated remnants within an anthropogenic landscape. The upland is characterised by nodes of development and interconnecting infrastructure among natural and agricultural landscapes. Here, the department's tenure comprises a significant portion of the landscape and features large areas of contiguous forest and woodland with extensive asset interface.

The department has a long history of fire management in the South West BRMZ, so fire behaviour and fire ecology are understood better here than elsewhere in the State. It also has the greatest concentration of fire management resources, both departmental and otherwise.

The main fuel types used to derive the indicators of acceptable bushfire risk in the South West BRMZ are Banksia woodland and sandplain shrubland on the coastal plain, dry eucalypt forest in the Darling Range and wet eucalypt forest in the far south.

3.2. Midwest and Southern Coastal BRMZ

The Midwest and Southern Coastal BRMZ extends northwards and eastwards along the coastal plains from the South West BRMZ. It is a relatively small zone, incorporating the areas between Lancelin and Dongara and between Denmark and Cape Arid and extending up to about 50 km inland. Although not contiguous with these areas, Kalbarri National Park is also included in this BRMZ as it has a similar risk profile.

The Southern Coastal BRMZ is characterised by relatively large blocks of department-managed land which interface frequently with communities, infrastructure corridors and agricultural areas.

Vegetation is dominated by shrublands which burn rapidly and with high intensity in wind-driven runs.

The main fuel type used to derive the indicators of acceptable bushfire risk in the Midwest and Southern Coastal BRMZ is sandplain shrubland.

3.3. Agricultural BRMZ

The Agricultural BRMZ spans the extensively cleared agricultural landscape between Kalbarri and Esperance. It extends from the edge of the South West and Midwest and Southern Coastal BRMZs to the clearing line. Vegetation varies with climate and soil, with various woodlands, thickets and mallee-heath predominant.

Privately owned land used for grain and sheep farming dominate the Agricultural BRMZ, with department-managed land restricted to isolated remnants and several larger reserves. Bushfire risk is at its highest between November and mid-January when crops have cured but not yet been harvested. As the fire season progresses, the risk of large bushfires diminishes as paddocks are harvested and grazed. Although little of the department's tenure is adjacent to high value assets, fuel management tends to focus on these limited areas of interface. Across the remainder of the BRMZ, fire management is limited and focused on the maintenance of biodiversity and ecological processes. Fragmentation of the landscape and active bushfire suppression have greatly reduced the incidence of bushfire in the landscape.

The main fuel types used to derive the indicators of acceptable bushfire risk in the Agricultural BRMZ are thicket, semi-arid woodland and mallee-heath.

3.4. Northern Rangelands BRMZ

The Northern Rangelands encompasses the spinifex-dominated pastoral lands of the western Pilbara. The area is critical to the State's economic output due to extensive mining. Minesites, often with office and accommodation complexes and transport and communications infrastructure, are significant assets requiring protection from fire. Tourism is also an important industry, particularly around the Exmouth peninsula and Karijini and Millstream Chichester National Parks. The vegetation of the Northern Rangelands is predominantly hummock grassland with a sparse overstorey of tall *Acacia* shrubs or low *Eucalyptus* and *Corymbia* trees. Bushfires are a frequent occurrence in these fuels, often ignited by widespread lightning storms.

The main fuel type used to derive the indicators of acceptable bushfire risk in the Northern Rangelands BRMZ is hummock grassland.

3.5. Central Rangelands BRMZ

The Central Rangelands BRMZ encompasses much of the State's Gascoyne and Murchison regions. These areas are predominantly vegetated with *Acacia* woodlands, which are often degraded by management practices. Pastoralism is the dominant land-use, with some mining. These landscapes are largely not prone to fire, which combined with the relative lack of high value assets, means the department has little exposure to bushfire risk.

The main fuel type used to derive the indicators of acceptable bushfire risk in the Central Rangelands BRMZ is *Acacia* woodland.

3.6. Southern Rangelands BRMZ

The southern Rangelands BRMZ encompasses the Great Western Woodlands and the Nullarbor Plain. Much of the area is unallocated Crown land, with pastoralism the dominant land use on the remainder. Important road and rail routes that link Western Australia to the eastern States pass through the BRMZ. Other regionally significant land uses are mining and tourism.

The Great Western Woodlands is an important natural environment, as it is the largest intact temperate woodland on earth. It comprises a mosaic of open woodlands, mallee, thickets and chenopod shrublands. In general, the thicket and mallee vegetation types burn during bushfires while woodlands and large salt lake systems fringed by chenopod shrublands do not.

The Nullarbor plain is predominantly vegetated by chenopod shrublands which are usually not flammable, except in the aftermath of occasional high rainfall periods when a flush of grasses and herbs adds to the fuel load.

The main fuel types used to derive the indicators of acceptable bushfire risk in the Southern Rangelands BRMZ are semi-arid woodland in the west and chenopod shrubland in the east.

3.7. Desert BRMZ

The Desert BRMZ encompasses the State’s arid interior, an area which is predominately unallocated Crown land, land held under native title, and conservation estate. A small number of Aboriginal communities and mine sites are found within the Desert BRMZ, but for the most part there are very few economic land uses and little infrastructure. This, and the remoteness of the area, means that there has been relatively little active fire management for several decades. The spinifex vegetation of the zone is highly fire prone, however, and the lack of fire management in contemporary times has resulted in a trend toward very large bushfires. These have negative environmental effects and are considered undesirable by land managers. The department and Traditional Owner groups are now working toward addressing this situation in some parts of the Desert BRMZ by reinstituting more traditional fire regimes.

The main fuel type used to derive the indicators of acceptable bushfire risk in the Desert BRMZ is hummock grassland.

3.8. Tropical BRMZ

The Tropical BRMZ occupies the northern extremity of the State, approximately north of the 600 mm isohyet. It is a mix of pastoral leases, Aboriginal managed land, conservation estate and unallocated Crown land. The BRMZ has a small population, mostly concentrated in just a few towns, with the remainder distributed between Aboriginal communities and stations. Pastoralism and tourism are the two main economic land-uses, though the cultural and biodiversity value of the landscape is substantial.

Much of the Tropical BRMZ is vegetated with open woodland, with an understorey of tussock grasses in higher rainfall areas and hummock grasses where rainfall is lower. Bushfire is a frequent and natural element of the landscape due to rapid fuel return times and the annual occurrence of extensive monsoonal lightning storms. The southwest of the area is dominated by pindan shrublands, which are fire prone but have a slower fuel return rate than the tropical savanna.

The main fuel types used to derive the indicators of acceptable bushfire risk in the Tropical BRMZ are tropical savanna in the north and east and pindan in the southwest.

4. Assessment of bushfire risk

The department's indicators of acceptable bushfire risk are expressed in terms of the condition of fuel in relation to assets that may be threatened by bushfire. To ensure the indicators are appropriately calibrated, the department applies the National Emergency Risk Analysis Guidelines (NERAG) (Australian Institute for Disaster Resilience, 2015), as described in the State Emergency Management Prevention and Mitigation Procedure (SEMPMP) (State Emergency Management Committee, 2016). The NERAG method is used to determine the relative magnitude of the most significant bushfire risks to the W.A. State Core Objectives for Emergency Risk Management. The department's approach to fuel management is then guided by prioritisation of mitigation measures for the highest risks.

4.1. Risk identification

The Framework uses generalised risk statements rather than the scenario-based approach recommended by the SEMPMP. This is because scenario modelling is designed to identify appropriate mitigation measures for a specific event. The department's fuel management program addresses many spatially distributed risks of different magnitude, which are better reflected by a description of a type of risk event. The most significant risk events associated with bushfire on department-managed land are shown in Table 3, categorised according to the State core objective themes.

Table 3: Significant risk events associated with bushfires, categorised according to the W.A. State Core Objectives for Emergency Risk Management.

State Core Objective	Risk statement
People	A bushfire affects a settlement resulting in numerous deaths or critical injuries.
	A bushfire affects scattered houses, road users or other distributed populations resulting in deaths or critical injuries.
Economy & Infrastructure	A bushfire damages or destroys critical infrastructure, supply chains or industry function causing significant, long-lasting economic disruption at a State scale.
	A bushfire damages or destroys infrastructure, supply chains or industry function causing economic disruption that is significant at a local to regional scale.
Social setting	A bushfire affects a settlement resulting in the loss of many dwellings or important community facilities.
	A bushfire significantly reduces the ability of individuals in the affected area to derive a livelihood for an extended period.
Environment	Bushfire destroys a large proportion of the total population of a species or extent of an ecological community which is unlikely to naturally recover.
	Bushfire causes significant lasting harm to ecosystem health and function over an extensive area.

4.2. Consequence

Consequences were assigned to the risk events described Table 3, according to the schema shown in Table 4 (adapted from the Attachment to the SEMPMP) (State Emergency Management Committee, 2017c). Consequences were considered at State, regional and local scales and the likelihood of the event at each scale estimated (See Section 4.3) to calculate which constitutes the highest level of risk to the department's objectives (See Section 4.4).

Table 4: Consequence table for risk events, adapted from State Emergency Management Committee (2017c).

State Core Objective	Minor	Moderate	Major	Catastrophic
People	At least 1 death or critical injury per 10,000,000 people	At least 1 death or critical injury per 1,000,000 people.	At least 1 death or critical injury per 100,000 people.	At least 1 death per 10,000 people.
Economy & infrastructure	Economic decline of 0.004% of the area's gross product.	Economic decline of 0.04% of the area's gross product.	Economic decline of 0.4% of the area's gross product.	Economic decline of 4% of the area's gross product[4].
	Significant industry suffers short-term profit loss.	Significant industry suffers significant profit loss for at least 1 year.	Major structural adjustment required by industry to recover from event.	Failure of a significant industry or sector.
Social setting	Community social fabric damaged, some external resources required for recovery, no permanent dispersal of residents.	Community social fabric broken, significant external resources required for recovery, some permanent dispersal of residents.	Community social fabric significantly broken, extraordinary external resources required for recovery, significant permanent dispersal of residents.	Community social fabric irreparably broken, community ceases to function effectively, community disperses in its entirety.
	Isolated / temporary reduction in community services.	Ongoing reduction in community services.	Reduced quality of life due to loss of services.	Community unable to support itself.
Environment	Minor damage to item of State significance. Significant damage to item of local significance.	Minor damage to item of national significance. Significant damage to item of State significance. Severe damage to item of local significance.	Significant damage to item of national significance. Severe damage to item of State significance. Permanent destruction of item of local significance.	Permanent destruction of item of national or State significance.

[4] Western Australia's gross state product of $247.7 billion in 2016-17 (Government of Western Australia, 2018).

4.3. Likelihood

The likelihood of each risk event occurring and having the described level of consequence is rated according to the methodology described in the Attachment to the SEMPMP. This requires two separate calculations. Firstly, the annual exceedance probability (AEP) is the chance that a bushfire will occur that threatens the asset in question. Secondly, the percentage probability of occurrence for the risk event is the chance that the described level of consequence will result, given that bushfire scenario. These two factors are combined using the WA Risk Register Tool (State Emergency Management Committee, 2017d) to calculate the overall likelihood of the risk statement, according to the categories shown in Table 5. Assigning likelihood levels is a qualitative process informed by expert opinion, as there are insufficient data available to allow a quantitative approach.

Table 5: Likelihood table for risk events, adapted from State Emergency Management Committee (2017c).

Likelihood term	Likelihood level	Indicative frequency
Almost certain	63% per year or more	At least annually
Likely	10-63% per year	Annually to once in 10 years
Unlikely	1-10% per year	Once in 10 to 100 years
Rare	0.1-1% per year	Once in 100 to 1000 years

4.4. Risk level

The outcome of the risk assessment is shown in Table 7. That table provides consequence and likelihood scores for each risk event and applies the matrix shown in Table 6 to calculate a risk level. The risk matrix was adapted from the Attachment to the SEMPMP (State Emergency Management Committee, 2017c).

Table 7 also provides a priority for treatment of each risk event. These priorities are calculated using the WA Risk Register Tool (State Emergency Management Committee, 2017d) and guide the identification of the assets that are most important to protect from bushfire. The department's indicators of acceptable bushfire risk are defined in relation to the assets affected by the highest priority risk events.

Table 6: Consequence / likelihood matrix applied to define the risk level for each identified risk event, adapted from State Emergency Management Committee (2017c).

	Consequence level			
Likelihood	**Minor**	**Moderate**	**Major**	**Catastrophic**
Almost certain	Medium	High	Extreme	Extreme
Likely	Medium	High	Extreme	Extreme
Unlikely	Low	Medium	High	Extreme
Rare	Low	Medium	High	High

Table 7: Risk register for events associated with bushfires.

State Core Objective	Risk event	Consequence Category	Likelihood	Risk level	Priority
People	A bushfire affects a settlement resulting in numerous deaths or critical injuries.	Catastrophic	Unlikely[1]	Extreme	1
	A bushfire affects scattered houses, road users or other distributed populations resulting in deaths or critical injuries.	Major	Likely[2]	Extreme	2
Economy & Infrastructure	A bushfire damages or destroys critical infrastructure, supply chains or industry function causing significant, long-lasting economic disruption at a State scale.	Major	Unlikely[3]	High	2
	A bushfire damages or destroys infrastructure, supply chains or industry function causing economic disruption that is significant at a regional scale.	Minor	Likely[4]	Medium	3
Social setting	A bushfire affects a settlement resulting in the loss of many dwellings or important community facilities.	Moderate	Likely[5]	High	2
	A bushfire significantly reduces the ability of individuals in the affected area to derive a livelihood for an extended period.	Minor	Likely[6]	Medium	3
Environment	A bushfire destroys a large proportion of the total population of a species or extent of a community which is unlikely to naturally recover.	Major	Rare[7]	High	2
	Bushfire causes significant lasting harm to ecosystem health and function over an extensive area.	Moderate	Unlikely	Medium	3

Notes on the risk register:

1. A catastrophic consequence in this context is defined as tens of deaths (local scale). Such an event has never occurred in W.A. but has in other Australian States.
2. A major consequence in this context is defined as fewer than 10 deaths (local scale). Such events have occurred every few years in recent decades in W.A.
3. A major consequence is defined as economic impacts of tens of millions of dollars, up to 100 million dollars (State scale). Such events have occurred in the past but are not common.
4. A major consequence is defined as economic impacts of millions of dollars, up to tens of millions of dollars (regional scale). Such events have occurred occasionally in the recent past.
5. A moderate consequence is described (regional scale). A bushfire with this level of consequence occurs every few years.
6. A minor consequence is described (local scale). A bushfire with this level of consequence occurs in most years.
7. There are very few species or communities in Western Australia that are susceptible to a single bushfire event, with altered fire regimes being a more common threatening process.

4.5. Asset classification

The risk events shown in Table 7 relate to six classes of assets that may be affected by bushfire. In Table 8, these are classified, described and prioritised according to the SEMPMP criteria. Sections 5 and 6 establish the standards for fuel management in areas surrounding assets of each type to reduce the risk posed by bushfire to an acceptable level. Occurrences of these assets, and the strategies that will be employed to manage bushfire risk to them, are identified in each region's Regional Fuel Management Plan (RFMP). The RFMP also applies a resilience rating to each identified asset to guide the prioritisation of bushfire risk mitigation works (see Section 4.6).

Table 8: Prioritised asset classes in the DBCA bushfire risk management framework.

Asset class	Asset Class Priority	Description
Settlements	1	Areas with significant human populations: • settlements, towns and subdivisions • recreation and camping sites with high fire-season visitation.
Dispersed population	2	Areas with smaller or transient populations: • individual dwellings • roads with high usage in fire-vulnerable areas. • recreation and camping sites with moderate fire-season visitation
Critical Infrastructure	2	Locations where there is an appreciable threat to critical infrastructure with State-level significance and no redundancy: • major highways and other primary distributors • major rail routes • major infrastructure associated with electricity generation • gas transmission pipelines • water supply, pipelines and associated pumping stations • major optical TELCO cables • major water and waste water treatment sites
Protected species and communities	2	Areas that are critical to the survival of a legislatively protected species or ecological community with low resilience to fire.
Economic assets	3	Locations where bushfires may have a significant effect on the livelihood of individuals or community financial sustainability, e.g.: • farmland • plantations • infrastructure of local to regional significance • major industry e.g. mine sites, refineries, industrial plants • native and plantation timber resources • water supply catchments
Other assets	3	Other significant built, natural or cultural assets, such as: • infrastructure of local significance • significant ecological communities or species habitat • areas with specific fire regime requirements • fire vulnerable Aboriginal or European heritage sites

Settlements are locations where there is a foreseeable and appreciable threat to multiple human lives in the event of a bushfire. Although the consequences of bushfire are very difficult to model, it is possible to identify some characteristics which increase the threat posed to these assets. Most important is the regular presence of a significant population. To be classified as a settlement asset, an area must exceed a threshold building density[5] of at least 3 buildings per hectare over an area of at least 15 hectares. Bushfire prone locations where significant numbers of people routinely camp or recreate during the bushfire season may also be classified as settlements.

Bushfires may also threaten human life in areas with lower population density or transient populations. Such areas include individual dwellings in rural and semi-rural areas, roads and other transport corridors and campsites. These locations are classified as dispersed population assets.

Critical infrastructure is defined as “those physical facilities, supply chains, information technologies and communication networks which, if destroyed, degraded or rendered unavailable for an extended period, would significantly impact on the social or economic well-being of the nation, or affect Australia’s ability to conduct national defence and ensure national security.” (Commonwealth of Australia, 2015). This definition is used here, but with the threshold being State-level effects, rather than national ones. To meet this threshold, the effect of damage or disruption to an asset must be noteworthy at a State scale due to economic or social disruption and a lack of redundancy.

Susceptible habitat assets are natural areas that support endangered, fire-vulnerable species or communities. To be in this class, a proportion of the total range of the species or community that is essential to maintaining the viability of the species must occur in an area that could reasonably be expected to be affected by a single bushfire event. The species or community should also have low resilience to fire and be unlikely to recover from a bushfire event without significant intervention.

Economic assets are areas where a bushfire may have significant economic impacts on an individual or community. This includes productive agricultural land, and plantations and infrastructure which, if disrupted, may incur financial costs of local to regional significance, including flow on effects such as job losses with resultant breakdown in community cohesion. Any other elements of the built, natural or cultural environments are placed in the ‘other assets’ class if they are of sufficient significance to warrant consideration in strategic planning processes.

4.6. Asset resilience

The prioritisation of asset classes using the SEMPMP criteria assumes that the risk events in Table 3 will have the consequences described in Table 7. This assumption is necessary and reasonable when considering generalised events and broad classes of asset at a state scale. To prioritise the treatment of risks to specific assets within a region, however, the resilience of those assets to bushfire must also be considered, as this will moderate the consequences experienced.

Resilience is a complex concept and can be influenced by culture and individual psychology as well as considerations of an asset’s construction or composition, configuration in relation to bushfire fuels and capacity to be quickly repaired or restored if damaged. As such, it is not practical to provide a method for a quantitative definition of asset resilience to bushfire here. Instead, some guiding

[5] Building density is used as a surrogate measure of population because population density data is not available at the required spatial scale.

criteria are provided (below and Table 9) which must be combined with expert judgement, including from asset managers where appropriate, to classify asset resilience as low, medium or high. An asset with low resilience would usually be expected to be destroyed or extensively damaged by a bushfire burning under 95th percentile weather conditions. An asset with medium resilience is likely to sustain some damage under these conditions but would not usually be destroyed. An asset with high resilience would usually be expected to survive the passage of a bushfire with minimal damage.

In the context of settlements, low resilience means that people at the location will have limited capacity to defend the location, evacuate or safely shelter in situ in the event of a severe bushfire. Some of the pertinent considerations for determining the resilience to bushfire of a town, settlement or subdivision are shown in Table 9. This is not a scoring system as these characteristics may combine in different ways to affect community resilience. Rather, it provides rationales to guide decision making about the vulnerability of locations to bushfire. Some of these factors are also applicable to recreation sites (e.g. access, refuge and proximity to vegetation) and other elements of the built environment (e.g. construction, proximity to vegetation).

Table 9: Guidelines for assessing the resilience of towns, settlements and subdivisions to bushfire.

More resilient to fire →	**Less resilient to fire**
Interface community[6]	Intermix community[7]
Hardened urban area without vegetation	Vegetation exists within developed area
Multiple access routes	One access route
Access routes highly trafficable	Access routes have limited trafficability
Access routes protected by low fuel buffers	Access routes have adjacent vegetation
Surrounding vegetation is fragmented	Surrounding vegetation is continuous
Adequate refuge available (oval, beach etc.)	Little refuge available
Most residents are capable of self-evacuation	Large population of elderly, infirm or children
Local population well prepared for fire	Population has low level of preparedness
Adequate water supply	Limited water available for fire fighting
Most dwellings constructed of brick	Dwellings constructed of timber or fibro
Building APZs[8] well maintained	Building APZs poorly maintained
Permanent resident population	Campsite or tourist / transient population

It can be difficult to define the resilience to fire of species, communities and ecosystems because of the complex interaction of many factors related to single fire events and fire regimes. The frequency, seasonality, intensity and extent of fires are particularly influential in determining the effects of fire on the natural environment. It is possible, however, to identify several characteristics of elements of the biodiversity that tend to be indicative of their relative resilience to fire. Some of these are shown in Table 10; as above, these should be treated as guiding principles when assessing the resilience of natural assets to fire, rather than a definitive list of considerations.

[6] An interface community is where a clear demarcation exists between urban areas and native vegetation and bushland does not continue into the developed area.
[7] An intermix community is where structures occur throughout a bushland area without a clear demarcation between urban and bushland areas.
[8] Asset Protection Zone: a low-fuel area maintained around a building to increase the likelihood that it will survive a bushfire.

Table 10: Guidelines for assessing the resilience of natural assets to bushfire.

More resilient to fire →	**Less resilient to fire**
Key plant species are resprouters	Key plant species are obligate seeders
No other threatening processes occurring	Fire may exacerbate other threatening process
Species have short juvenile periods	Species have long juvenile periods
Species have wide distributions	Species have restricted distributions
Species have multiple populations	Species have few populations
Connections exist between populations	Populations are isolated
Fauna is more mobile	Fauna is less mobile
Fauna is adapted to persistence in refugia	Fauna has limited ability to persist in refugia
Fauna can utilise a variety of habitats	Fauna has specialised habitat requirements
Habitat re-establishes rapidly post-fire	Habitat slow to re-establish post-fire
Fauna has a broad diet or can vary diet post-fire	Fauna has specific dietary requirements
Fire has little effect on predation rate	Fauna vulnerable to post-fire predation
Fauna has high rate of population increase	Fauna has low rate of population increase

Asset resilience is combined with the asset class priority rating (described in Table 8 based on the SEMPMP criteria) to provide a regional priority for each asset. This is done using the matrix in Table 11. The regional priority is recorded in the RFMP and will guide the programming of works to treat bushfire risk.

Table 11: Matrix for determining the regional priority of assets in each class. The asset class priority is shown in Table 8 and the asset resilience is set in the RFMP with guidance from the criteria in Table 9 and Table 10.

Asset Class Priority	**Resilience**		
	High	**Medium**	**Low**
1	3	2	1
2	4	3	2
3	5	4	3

4.7. Risk treatment strategies

The department applies two broad strategies when managing fuels to reduce bushfire risk. Firstly, fuel-managed buffers are relatively narrow (usually metres to hundreds of metres in depth), linear features established proximal to assets or in strategic locations to interrupt a fire run. Buffers may be established and maintained by prescribed burning or by mechanical or chemical fuel modification. Secondly, landscape-scale fuel management uses prescribed burning to create a mosaic of fuel availability within which there is reduced potential for the development of large bushfires and increased opportunities for successful fire suppression.

These two fuel management strategies are complementary and best used in combination. Fuel management in the broader landscape is important to reduce the likelihood of very large bushfires developing. Such bushfires may cause harm to dispersed assets and the natural environment and can require large suppression efforts, limiting the State's capacity to respond to subsequent fires. Large bushfires may also burn over or through small-scale fuel reduced buffers or asset protection burns due to the high intensity and large-scale ember attacks they may generate.

Fuel-reduced buffers afford a degree of protection to settlements and other high value assets, provided they are of enough breadth and are installed in association with landscape-scale fuel reduction that reduces the potential for high intensity fire runs to reach them or breach them. Spotting is the primary factor that limits the effectiveness of small-scale buffers. As such, buffers have greater effect where they are used in fuels with low spotting potential. In fuels with higher spotting potential, landscape-level fuel reduction is required to lower the intensity of bushfires, thereby reducing the spotting potential of a fire approaching a buffer.

In moderate to densely developed areas, it is not practical to create low fuel buffers on public land proximal to all houses, roads and critical infrastructure. Buffers may be established at strategic locations where appropriate but departmental experience has demonstrated that managing fuel at a landscape-scale is the most efficient way to reduce bushfire risk to dispersed and linear assets. In areas of sparse development, it may be more efficient to target fuel management proximal to assets, rather than manage entire landscapes.

5. Fire Management Areas

DBCA divides the land that it manages into four fire management areas (FMAs), to better guide bushfire risk assessment and fuel management planning. These areas are defined according to the primary purpose of fuel management in that area and are described relative to the six asset classes in Table 8:

- The Settlement-Hazard Separation (SHS) FMA provides a low-fuel area proximal to towns, subdivisions and other settlements. The primary intent of fuel management in this FMA is to reduce the opportunity for direct flame contact, damaging intensities of radiant heat and ember attack to endanger people and buildings. Fuels are managed relatively intensively to minimise the likelihood of a bushfire being sustained. Fuel management to protect settlements takes precedence over other land management objectives, though these may be pursued where they are not in conflict with the primary management intent.
- Critical Infrastructure Buffer (CIB) FMA provides an area of low-fuel around items of critical infrastructure. The management intent and intensity of fuel management is like SHS, but the CIB will generally be applied to a less extensive area than the SHS due to these assets' higher level of resilience to ember attack. The CIB only applies in BRMZs where the most appropriate strategy to protect critical infrastructure from bushfire is localised, rather than landscape scale, fuel management.
- Landscape Risk Reduction (LRR) FMA comprises areas where the significance of infrastructure, economic activity or environmental assets necessitates fuel management at a landscape scale. Fuels are managed to achieve a range of management outcomes, including reducing the likelihood of the occurrence of large bushfires that may endanger people, damage infrastructure, cause financial or social disruption, degrade the natural environment or overwhelm the localised protection provided by SHS or CIB FMAs. Where landscape scale treatments are not appropriate or adequate, landscape risk may also be managed by providing fuel reduced buffers proximal to valued assets.
- Remote Area Management (RAM) FMA is where remoteness, inaccessibility, resource constraints and a lack of consequential assets make it impractical or unnecessary to intervene in the prevailing fire regimes. Fuel management activities are a lower priority in these areas but may still occur where required to achieve land management outcomes.

The department's indicators for acceptable bushfire risk allow management to be tailored according to the fuel type and risk profile of the land, including designating areas where there are no fire management targets because of the limited capacity or requirement to manage fuels. Each region's RFMPs then identifies the assets within the region that fit each asset category and, based on this, maps the relevant FMAs.

It is important to note that the effective management of bushfire risk requires complementary fuel management activities in each of the SHS, CIB and LRR FMAs. These categories do not represent a hierarchy of priorities for fuel management, but describe areas requiring different intensities of management to achieve an acceptable level of bushfire risk (see Sections 5.4 and 6). The performance measures for fuel management in each FMA and fuel type are provided in Section 6.

5.1. Breadth of FMAs

Asset loss or damage by bushfire may be caused by direct flame contact, radiant heat exposure or ember attack. The exposure of an asset to these threats decreases quickly as the separation distance increases between the burning fuels and the asset. Research has shown that in Australian bushfires, over 80 percent of losses of human life and houses has occurred within 100 m of bush fire prone vegetation (McAneney *et al.,* 2009). Ember attack acts over the greatest distance and causes the most building losses (in fuels that are prone to spotting) followed by radiant heat and direct flame contact (Chen and McAneney, 2004; Blanchi *et al*., 2013). The breadth of the reduced-fuel areas represented by the SHS and CIB FMAs are calculated to be sufficient to meaningfully reduce the likelihood of damage to assets from all three modes of bushfire damage and to provide opportunity for fire suppression. This calculation is based on a combination of data derived from the fire behaviour models described in Section 2.2 and expert practitioner judgement. Note that there is a distinction between the maximum distance that a fire brand may carry (spotting distance of the fuel) and the shorter distance over which an ember attack is likely to pose a significant hazard to an asset.

The management objective in the SHS and CIB FMAs is to maintain fuels in a condition that minimises the likelihood of a bushfire damaging valued assets. The minimum requirement to achieve this is a low-fuel area of sufficient breadth to reduce the likelihood of assets being exposed to a Bushfire Attack Level (BAL) of greater than BAL-LOW[9]. AS 3959-2009 (Standards Australia, 2009) prescribes a minimum distance of 50 m of managed fuel in grassland and 100 m in all other fuels to ensure that a building is exposed to BAL-LOW, regardless of terrain and weather conditions. This distance is adequate for the protection of critical infrastructure and a proportion of fuel managed (see Section 4.5) in this area constitutes the acceptable risk criteria for the CIB FMA.

A more conservative approach is taken to setting the breadth of the SHS FMA, in recognition of the potential for bushfires in these areas to have more severe consequences. This greater breadth also compensates for fuel reduction strategies that are temporary in effect or patchy in distribution, such as prescribed burning. The breadth of the SHS FMA is set with consideration for the nature of the

[9] Bushfire Attack Level (BAL) is a measure of assets' potential exposure to flame contact, radiant heat and ember attack using units of radiant heat in kilowatts per square metre. The Australian Standard for Construction of Buildings in Bushfire Prone Areas (AS 3959-2009) provides a method to calculate the BAL a building will be exposed to under different conditions of FDI, fuel, slope and distance. BAL-LOW is the level of exposure at which there is insufficient risk to warrant any specific construction requirements for buildings.

fuels of the area, being greater in fuels that are prone to causing ember attack and where fire suppression is more difficult.

The management objective in the LRR FMA is to reduce the potential for bushfires to damage assets, degrade the environment or cause social and financial disruption. This is usually achieved by creating a mosaic of fuel ages that reduces the likelihood of fires igniting and spreading and provides improved opportunities for suppression. The LRR FMA encompasses the remainder of the landscape in which fuel is managed.

Areas are designated as RAM FMA if they are remote from both significant assets and management resources. They are a lower priority for fuel management, and it is usually only undertaken in response to specific issues. RAM FMA encompasses all areas not included in any of the other FMAs.

Table 12: Summary of Fire Management Areas

Fire Management Area	Purpose	Location	Extent
Settlement-Hazard Separation (SHS)	To protect human life by reducing potential exposure to direct flame contact, radiant heat or ember attack.	Surrounding fire vulnerable towns, settlements, subdivisions and camping areas.	5 km: Dry eucalypt forest, Wet eucalypt forest
			1 km: Pindan, sandplain shrubland, thicket, *Banksia* woodland
			500 m: Tropical savanna, hummock grassland, mallee-heath, *P. pinaster* plantation
			N/A: *Acacia* woodland, semi-arid woodland, chenopod shrubland
Critical Infrastructure Buffer (CIB)	To protect critical infrastructure by reducing potential exposure to direct flame contact, radiant heat or ember attack.	Surrounding fire vulnerable critical infrastructure.	100 m: Pindan, sandplain shrubland, thicket, mallee-heath, *Banksia* woodland, *P. pinaster* pine plantation
			50 m: Tropical savanna, hummock grassland, grassland
			N/A: Dry eucalypt forest, wet eucalypt forest, *Acacia* woodland, semi-arid woodland, chenopod shrubland
Landscape Risk Reduction (LRR)	To prevent the occurrence of large, intense bushfires that may threaten neighbouring lands, infrastructure or the natural environment within the LRR.	Surrounding property, individual livelihood community sustainability, and environmental assets	Remainder of South West BRMZ: Wet eucalypt forest, dry eucalypt forest
			5 km: Banksia woodland, *P. pinaster* plantation
			1 km: Sandplain shrubland, thicket
			N/A: Tropical savanna, pindan, *Acacia* woodland, hummock grassland, mallee-heath, semi-arid woodland, chenopod shrubland
Remote Area Management (RAM)	To provide ecologically and culturally appropriate fuel management where required and practicable.	Where there is a low density of fire-vulnerable assets.	All other Parks and Wildlife Service managed lands

5.2. Amalgamating areas of the same FMA

Where two or more areas of the same FMA occur near one-another, they may be amalgamated to a single area that includes the intervening space. This recognises the potential for fire to spread between nearby areas and simplifies the boundaries of planning units. The threshold distance for amalgamating areas of the same FMA is the maximum spotting distance of the fuel under 95th percentile conditions or the distance to achieve BAL-Low in fuels that are not prone to spotting.

5.3. Frequency of fuel treatment in an FMA

The intent of fuel management is to reduce the quantity or alter the arrangement of fuels so that a bushfire is less likely to become established, will spread more slowly, burn with lower intensity, be easier to suppress and cause less damage. Fuel age is often used as an indicator of these factors, but potential fire intensity is a more meaningful measure as it has a more direct relationship to them.

Studies of the effectiveness of fire suppression have identified ranges of fire intensity at which different approaches to suppression are likely to succeed (Table 13) (Burrows 1984, Muller 1993, Muller, 2008). The indicators of acceptable bushfire risk in each FMA require that a proportion of fuel (see Section 5.4) be in a condition such that it will burn with no more than double[10] the intensity at which machine and tanker attack on the headfire is possible under 95th percentile weather conditions. This value (10,000 kW/m in grassland and 4000 kW/m in all other fuels) is described in the framework as the 'threshold intensity'.

Fire intensity is a measure of the energy released by the combustion of fuel in a bushfire and is expressed in kilowatts per linear metre of fire line. It is a product of the bushfire's rate of spread, the mass of fuel available and the heat yield of the fuel. The quantity of fuel available for combustion is determined by the age and structure of the vegetation, moderated by weather and climatic factors. The time required for vegetation to reach the identified threshold intensity is determined by using fuel accumulation and fire behaviour models and is described in each region's RFMP[11]. The models applied to each vegetation type are described in Table 2. These calculations are performed without applying a multiplier for the effect of slope because they are designed to provide landscape-scale targets, so do not consider localised effects.

[10] The intensity values for machine and tanker attack are doubled because the thresholds in Table 13 relate to headfire intensity, while the department's usual approach to a direct attack on a bushfire is to begin from the tailfire and work along the flank to the head. This means that most of the suppression effort is undertaken on parts of the fire exhibiting much lower fire intensity than the head fire. Flank fire intensity may be up to four times lower than head fire intensity, but a more conservative two-fold factor is used to set the risk indicators.

[11] Where this period is unknown, an alternative figure of 1.5 times the minimum period required post-fire before the vegetation will again sustain a bushfire under 95th percentile FDI conditions is used instead.

Table 13: Fire behaviour thresholds for different suppression options (from Muller, 1993).

Category	Description	Fuel	Intensity (kW/m)	Rate of spread (m/hr)
1	Indirect attack unlikely to succeed.	Forest.	>3000	
		Shrubland & grassland	>8000	
2	Direct attack not possible/unlikely to succeed.	Forest	>2000	>400
		Shrubland	>2000	>1000
		Grassland	>5000	>6500
3	Machine and tanker attack possible.	Forest	<2000	<400
		Shrubland	<2000	<1000
		Grassland	<5000	<6500
4	Hand tool attack possible with water support	Forest & shrubland	<800	<140
		Grassland	<800	<300
5	Readily suppressed	All fuels	<800	<60

5.4. Proportion of fuel managed in an FMA

Boer *et al*. (2009) studied bushfire occurrence in relation to prescribed burning in the State's southwest forests between 1953 and 2004. They found a prescribed burn has a significant effect on reducing the size of a subsequent bushfire for six years following the burn. The suppressive effect of prescribed burning on bushfires was shown to be most pronounced between the late 1960s and the end of the 1970s, coinciding with the period when the area of prescribed burning was greatest. During that period, about 10 to 15 percent of public land was prescribed burnt annually, but a significant effect on bushfire extent was detected in any period when this figure was at least about 8%. Similarly, Sneeuwjagt (2008) and Burrows and McCaw (2013) found that the area burnt by bushfire in the southwest forests increased significantly during periods when the area of prescribed burning fell below about 8 percent per annum. Similar findings were made by Florec (2016) who undertook an analysis of the cost of fire management in the southwest of WA at differing levels of prescribed burning. This analysis was based on simulated fire occurrence and considered the costs of implementing the prescribed burning program, suppression costs associated with subsequent bushfires and the costs of repairing damage caused by those bushfires. She found that financial benefits accrue rapidly as the area subject to prescribed burning increases from zero to about 10% of the landscape per annum. Thereafter, the rate at which benefit accrues slows, compared to the cost of implementing the additional treatments. Burning 15% of the landscape annually was shown to be optimal for reducing bushfire risk, but the study conceded there may be non-financial constraints that prevent this being achieved.

The research referenced above, combined with firefighters' experience and expert opinion, has led to the judgement that bushfire risk can be managed to an acceptable level in contiguously vegetated landscapes by maintaining at least 45 percent of fuels in a condition such that they will not support high intensity fires (see Section 5.3). This equates to burning about 7.5 percent, or 200,000 ha, of department managed land annually in the Swan, South West and Warren regions. Burning at a rate greater than this will lead to further reductions in bushfire risk, but this needs to be balanced against the financial and social costs of the additional treatment. DBCA will continue to support research on this topic as part of the ongoing review of the indicators of acceptable risk.

The department's management objective for forested areas of LRR FMA is to maintain 45 percent of fuel in a condition such that it will burn at less than its threshold intensity under 95th percentile FDI conditions. In Banksia woodland, *P. Pinaster* plantation, sandplain shrubland and thicket fuel types, the proportional target for the LRR FMA is 30 percent. This figure is based on expert practitioner judgement as there is no research in these fuel types equivalent to Boer *et al*. (2009). This target recognises that fuel reduced buffers and open edged burning is the preferred management strategy in these fuels and, as such, reducing the fuel age across a larger proportion of the landscape is usually impractical and unnecessary. The respective targets for the SHS and CIB FMAs are 60 percent and 50 percent of fuel in a condition such that it will burn at less than its threshold intensity under 95th percentile FDI conditions. These more stringent targets reflect the need for more targeted fuel management proximal to high value assets.

6. Indicators of acceptable bushfire risk

An acceptable level of bushfire risk is achieved in a BRMZ if the targets in Table 14 are met in each of its FMAs. These targets can be achieved using any form of fuel treatment that is suited to the vegetation type being managed. Where prescribed burning is used, the target refers to a 'treatment area' where 'treatment is complete'. These terms are defined in the department's Prescribed Burn Planning Manual (Department of Biodiversity, Conservation and Attractions, 2018) and form the basis of the department's reporting on its prescribed burning program.

Table 14: Targets for the department's fuel management program in each Fire Management Area.

Fire Management Area	Fuel type	Location	Target
Settlement Hazard Separation	Dry eucalypt forest, wet eucalypt forest	5 km surrounding settlements	60% of fuel less than threshold intensity
	Pindan Sandplain shrubland Thicket *Banksia* woodland	1 km surrounding settlements	
	Tropical savanna Hummock grassland Mallee-heath *P. Pinaster* plantation	500 m surrounding settlements	
	Acacia woodland Semi-arid woodland Chenopod shrubland	N/A	No targets apply
Critical Infrastructure Buffer	Pindan Sandplain shrubland Thicket Mallee-heath *Banksia* woodland *P. Pinaster* plantation	100 m surrounding critical infrastructure	50% of fuel less than threshold intensity

Fire Management Area	Fuel type	Location	Target
	Tropical savanna Hummock grassland	50 m surrounding critical infrastructure	
	Dry eucalypt forest Wet eucalypt forest *Acacia* woodland Semi-arid woodland Chenopod shrubland	N/A	No targets apply
Landscape Risk Reduction	Dry eucalypt forest Wet eucalypt forest	Remainder of South West BRMZ	45% of fuel less than threshold intensity
	Banksia woodland *P. Pinaster* plantation	Within 5 km of private property interface	30% of fuel less than threshold intensity
	Sandplain shrubland Thicket	Within 1 km of private property interface	30% of fuel less than threshold intensity
	Tropical savanna Pindan *Acacia* woodland Hummock grassland Mallee-heath Semi-arid woodland Chenopod shrubland	N/A	No targets apply. Managed as required to meet land management objectives
Remote Area Management	Dry eucalypt forest Wet eucalypt forest	N/A	N/A
	Tropical savanna Pindan Acacia woodland Hummock grassland Sandplain shrubland Thicket Mallee-heath Semi-arid woodland Chenopod shrubland *Banksia* woodland Pine plantation	All other Parks and Wildlife Service managed lands	No targets apply. Managed as required to meet land management objectives

Table 15: Threshold intensity for each of the State's fuel types and the indicative time required for sufficient fuel to accumulate to support a fire burning with this intensity under 95th percentile weather conditions. The indicative burning rotation is the approximate time between prescribed burns at a location if all DBCA managed lands were included on a consistently repeated burning rotation. Fuel accumulation rates are based on average rainfall for that fuel type.

Fuel type	**Threshold intensity**[12]	**Minimum fire interval (years)**[13]	**1.5x minimum interval (years)**[14]	**Indicative burning rotation (years)**		
				SHS-FMA[15]	**CIB-FMA**[16]	**LRR-FMA**[17]
Tropical savanna	10,000 kW/m	1	1-2	2-3	2	N/A
Pindan	4000 kW/m	1-2	2-3	2-3	4-6	N/A
Acacia woodland	N/A	N/A	N/A	N/A	N/A	N/A
Hummock grassland	10,000 kW/m	5-7	8-11	13-18	16-22	N/A
Sandplain shrubland	4000 kW/m	4-6	6-9	10-15	12-18	20-40
Thicket	4000 kW/m	10-12	15-18	25-30	30-36	50-60
Mallee-heath	4000 kW/m	10-15	15-23	25-38	30-46	N/A
Semi-arid woodland	N/A	N/A	N/A	N/A	N/A	N/A
Chenopod shrubland	N/A	N/A	N/A	N/A	N/A	N/A
Dry eucalypt forest	4000 kW/m	4	6	10	N/A	13
Wet eucalypt forest	4000 kW/m	6	8	13	N/A	18
Banksia woodland	4000 kW/m	5-7	8-10	13-17	16-20	27-33
P. pinaster plantation	4000 kW/m	2	3	4-5	6	10

[12] Double the intensity at which headfire attack with machines and tankers is possible in the fuel type under 95th percentile conditions.
[13] The minimum age at which the fuel type will burn under 95th percentile weather conditions.
[14] 1.5 times the minimum period required post-fire before the vegetation will again sustain a bushfire under 95th percentile FDI conditions may be used to define the threshold age at which the fuel will burn at double the intensity at which machine and tanker attack on the headfire is not possible under 95th percentile weather conditions. This figure has been rounded to the nearest whole number in the table.
[15] 60% of the FMC managed to less than 1.5x minimum interval.
[16] 50% of the FMC managed to less than 1.5x minimum interval.
[17] 45% of the FMC managed to less than 1.5x minimum interval.

7. Monitoring and review

The department's risk criteria and indicators of acceptable risk were developed using the best available science, practitioner judgement and supporting data. These inputs will be monitored by the department to ensure that the Framework continues to reflect industry best-practice. It is expected that ongoing adjustment to the Framework will be required as the State's social, political and natural environments change; better data become available or knowledge of bushfire risk management is refined or improved. The Framework will also be updated to incorporate the findings of any relevant research or adaptive management, and as new models are developed and refined.

Monitoring of the Framework will be facilitated by an annual review of each region's risk criteria, undertaken when reviewing the RFMP prior to developing an annual burn program.

8. Conclusion

DBCA manages bushfire risk in partnership with other government departments, local government, volunteers and private land managers. It considers socio-political expectations and characteristics of the natural environment to set levels of acceptable bushfire risk for each of the State's BRMZs. These thresholds of acceptable risk are established in the Framework and guide the department's fuel management program. The department will assess its proposed activities against these criteria to confirm that an appropriate quantum of fuel management is planned and that it is prioritised appropriately.

Each region's RFMP will translate the indicators of acceptable risk to a hectare-based target for fuel management. These targets, combined with the requirements to manage fuels for other land management outcomes and to maintain an effective bushfire suppression response capacity, will be inputs to the department's fire capability model. The capability model will establish a clear relationship between bushfire risk management and fire capability and, in conjunction with factors such as the complexity of the fire management landscape and workforce integration considerations, assist in guiding the investment and resourcing required to manage bushfire risk on DBCA managed lands.

The Framework and subsequent RFMPs aim to complement contemporary strategies for managing bushfire risk on lands neighbouring those managed by the department, such as Local Government Bushfire Risk Management Plans. This is achieved by increasing the transparency of the department's planning processes and the visibility of its bushfire risk criteria. The development of RFMPs will also generate spatial datasets of the inputs to the department's fuel management planning processes, which will inform complementary planning strategies.

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