

Framework to Incorporate Bushfire Resilience into Road Infrastructure



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How to use this framework

The purpose of this Framework is to prompt and guide road agencies toward optimised bushfire preparedness across the transport infrastructure lifecycle. This Framework summarises the findings from workshopping the best practices identified in the research project's literature review, which has a separate report titled *Incorporating Bushfire Impacts into Road Design Literature Review Report (v1.0)* published by the Western Australian Road Research and Innovation Program (WARRIP) and the National Asset Centre of Excellence (NACOE). While the Framework does not address an individual road agency's specific governance and resourcing contexts, the Framework provides valuable generic insights for a road agency considering implementation by suitably qualified and experienced personnel at each of the key stages. Appendix C provides consolidated forms for each phase of a road asset life cycle, prompting consideration of key aspects of the Framework including identifying which sections of the Framework are of relevance to the respective asset.

1 Introduction

1.1 Background

Unprecedented bushfires across Australia have highlighted the fact that roads and associated infrastructure are critical enablers of bushfire prevention, preparation, response and recovery activities. However, these bushfires have also highlighted the vulnerability of road infrastructure and the travelling public during and after a bushfire. Severe bushfires have the potential to produce numerous economic, social and environmental impacts, which can range from short-term inconveniences to long-term life-changing effects.

1.2 Purpose of this Document

This framework has been developed to assist road agencies with managing the potential risk to road infrastructure caused by the impacts of bushfires. This includes:

- preventing bushfire ignition in the road corridor through roadside vegetation design and maintenance
- preventing the impact from a bushfire in a road corridor by minimising the damage which could be done to infrastructure in the road corridor
- facilitating evacuation routes and protecting road users during an emergency, in collaboration with emergency services
- enabling quick recovery of road operations following a bushfire.

This document provides a framework for the integration of the prevention, preparedness, response and recovery (PPRR) bushfire risk management model into the planning, design, construction, maintenance and operations of road infrastructure. This includes:

- **Section 1 Introduction:** provides an overview of the purpose and basis of this framework including limitations to consider.
- **Section 2 Bushfires:** provides an overview of bushfires and why bushfires are an issue for road infrastructure.
- **Section 3 Governance:** provides the typical responsibilities of bushfire management for various parties. A critical part of bushfire management is collaboration and stakeholder consultation, and this is a common theme throughout this framework. In addition, Section 3 provides guidance on undertaking the two key requirements in understanding potential network vulnerability due to bushfires: (1) undertaking a risk assessment to identify bush-fire prone areas; and (2) using this risk assessment to identify all assets, critical links and assets for emergency access.
- **Section 4 Implementing the PPRR Model:** provides (1) an explanation of the PPRR model and how this will be implemented as part of this framework, and (2) guidance for the incorporation and consideration of bushfire impacts when undertaking the planning, design, construction, maintenance and operations of road projects.
- **Section 5 Overarching Management Considerations:** provides a summary of the overarching management considerations for incorporating bushfire impacts into road infrastructure design and management.

1.3 The PPRR Model

This framework uses the PPRR spectrum or risk management model which includes the following areas for consideration:

- **Prevention** through risk avoidance and risk reduction strategies
 - all activities concerned with minimising the occurrence of incidents, particularly those of human origin.
- **Preparedness** through strategic and/or policy solutions

- all activities undertaken in advance of the occurrence of an incident to decrease the impact, extent, and severity of the incident and to ensure more effective response activities.
- **Response** strategies for disaster management
 - all activities undertaken immediately before, during and after an incident to ensure that its effects are minimised and that those immediately affected are given relief and support.
- **Recovery** strategies for improvement in post-disaster recovery
 - all activities undertaken after the occurrence of an incident to provide ongoing support to affected communities in reconstruction of the physical infrastructure and restoration of emotional, social, economic and physical wellbeing.

1.4 Documents

Appendix A details the guidance documentation and specifications to be read in conjunction with this framework from the Queensland Department of Transport and Main Roads (TMR) and Main Roads Western Australia (Main Roads WA). If utilising this framework in another jurisdiction, the documentation will need to be substituted.

Key terms used throughout the framework are outlined in a glossary presented in Appendix B.

1.5 Limitations

The recommendations made throughout are derived from a literature review (O'Connor et al. 2022) undertaken by the Australian Road Research Board (ARRB) on bushfire strategies that focused primarily on a review of road agency documentation in addition to international practice. Due to the uncertainties associated with bushfire modelling and prediction, and specific practices within road agency documentation, other literature and academic research may conclude different, and potentially contradictory, outcomes to the information presented in this document.

It is also important to note that where there were knowledge gaps, experts from ARRB, TMR, and Main Roads WA have applied a first principles approach to identify potential steps to manage the risks associated with a bushfire event.

The 'How to use this framework' box is a critical part of the document. It sets up the framework as a guideline, detailing factors to consider in relation to bushfire management and tools that can be used, while acknowledging that these are not binding and the road agency representative will determine which practices are preferred or applicable to a given situation.

2 Bushfires

2.1 What is a Bushfire?

A bushfire is an unplanned vegetation fire. It is a generic term that includes grass, forest and scrub fires. Bushfires are characterised as a natural disaster or natural hazard. They are a natural hazard, due to their ability to cause harm to people, property, infrastructure and the environment. Bushfires are classified as a disaster when a widespread, unacceptable level of loss occurs. The movement and severity of a bushfire is influenced by several factors:

- Ignition source location and season: fires can be started by lightning, directly by people or indirectly through human presence (e.g. powerlines), either deliberately or accidentally.
- Vegetation fuel loads, arrangement and continuity: fires need fuel of sufficient quantity and dryness. A wet year creates favourable conditions for vegetation growth. If this is followed by a dry season or year, fires are more likely to spread and become intense.
- Topography: landscape can affect a fire's ability to spread and the behaviour of the fire.
- Weather conditions including humidity, temperature, and wind speed: fires are more likely to spread on hot, dry and windy days. Hot weather also dries out fuel favouring fire spread and intensity.
- People: fire may be deliberately started or be started by accident. Human activities can also reduce fire, either by direct suppression or by reducing fuel load e.g. by prescribed burning and vegetation removal.

In Australia, the period of peak bushfire activity varies with seasonal weather patterns. For northern Australia, the peak bushfire period is during the dry season, which is generally throughout winter and spring. In southern Australia, the bushfire season peaks in summer and autumn. While these are the traditional peaks of the bushfire season, local conditions can drive dangerous bushfire activity at any time of the year (however, severe fire behaviour and resultant loss are much less likely outside the fire danger period).

2.2 The Impact of Climate Change

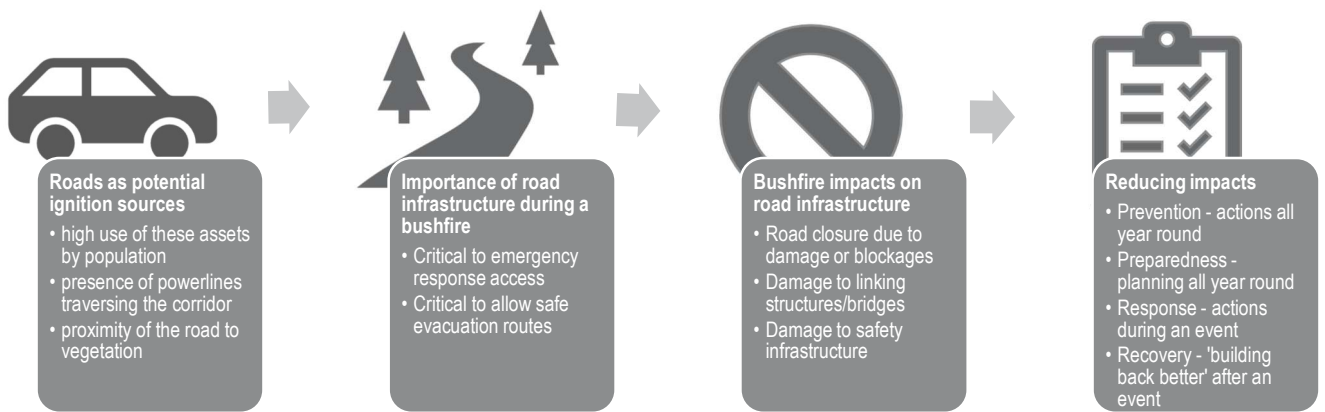
Climate change is the long-term shift in global or regional temperatures and weather patterns. These shifts can be a natural phenomenon but more recently have been linked to human activity. The consequence of climate change on bushfire characteristics and high-risk conditions is pronounced and includes:

- longer fire seasons
- a decrease in the opportunity for hazard reduction works
- larger and more intense fires caused by prolonged high-risk weather conditions
- increased severity of bushfires due to increased temperatures, more severe winds and changes to rainfall patterns
- new high-risk areas previously deemed low or medium risk
- increased available fuel caused by lower rainfall
- increased ignition opportunities caused by increased storm activity.

2.3 Bushfires and Road Infrastructure

The importance of road infrastructure during a bushfire, bushfire impacts on road infrastructure, and measures for reducing those impacts are described in Figure 2.1.

Figure 2.1: Bushfires and road infrastructure



3 Governance

Governance encompasses the systems by which a road agency operates and the mechanisms by which it, and its representatives, are held to account. In the context of bushfire management, governance refers to the strategic objectives set through legislation and regulations and the procedures used to ensure consistency in implementation. This includes understanding network vulnerability and undertaking risk assessments using consistent methodologies, setting strategic objectives in bushfire management, and undertaking stakeholder engagement.

3.1 Understanding Network Vulnerability

There are two key requirements in understanding potential network vulnerability due to bushfires:

- undertaking a risk assessment to identify bushfire-prone areas
- using this risk assessment to identify all assets, critical links and assets for emergency access.

3.1.1 Undertaking a Risk Assessment to Identify Bushfire-prone Areas

Management objective: The road agency representative should ensure a risk assessment is undertaken in accordance with the documentation outlined in Appendix A to identify bushfire-prone areas, including the likelihood and consequence of the risk in order to provide an overall representative risk score.

Once the bushfire risk profile specific to a region is known, the functional characteristics of the bushfire hazard, exposure to the bushfire hazard, and the level and type of vulnerability in a given location can be identified.

Road agency risk assessment methodologies are detailed in the documents referenced in Appendix A. It should be noted that there may be differences between how fire services and road agencies consider risk or define bushfire-prone areas. Therefore, consideration needs to be given to both identified risks by fire services and the road agency when determining if a road project or activity is to be undertaken in a bushfire-prone area.

It should be noted that the risk assessment inputs and outputs may change over time due to climate change and other local factors and, therefore, should be undertaken in full for any new project or activity and reviewed during prolonged works to ensure applicability.

3.1.2 Identifying Assets and Critical Links for Emergency Access

Management objective: The road agency representative should ensure all assets within the bushfire-prone area have been identified. This will assist with maintenance identification and prioritisation of works. In addition, the road agency representative should identify the road networks and links that will be critical in disaster response and recovery.

Part of understanding network vulnerability is identifying what assets are present in bushfire-prone areas and the criticality of the assets in relation to response and recovery activities. This will ensure that any management strategies implemented are appropriate to the asset types. The assets include roads (sealed or unsealed), bridges, culverts and roadside furniture. It is also essential to document this information in an asset inventory to ensure all assets within the bushfire-prone area have been identified. Knowing what assets are within a region will assist with prioritising maintenance, inspections and subsequent activities following an event.

Another part of understanding network vulnerability is ensuring that the road networks and links that will be critical in disaster response and recovery have been identified. These include roads to access evacuation facilities, those designated for emergency services access, or used as strategic fire-control lines.

3.2 Legislative Requirements

Management objective: The road agency representative should ensure that all bushfire management actions and works determined using this framework align with legislation and regulatory frameworks.

In some circumstances, planning approvals, works permits, and/or specific licences may be required to undertake certain activities. Other documentation such as local building codes may also need to be consulted depending on the activity.

Terramatrix Pty Ltd was commissioned by the Australian Road Research Board (ARRB) to undertake a review of road and bushfire legislation in Queensland and Western Australia to support this project.

This review outlines legal obligations and risk factors for incorporating bushfire considerations into road design for:

1. Queensland Department of Transport and Main Roads (TMR); and,
2. Main Roads Western Australia (Main Roads).

Table 3.1 and Table 3.2 provide an overview of Queensland and Western Australian legislation respectively.

Table 3.1: Road and bushfire legislation relevant to Queensland TMR

Legislation	Section	Application to Qld TMR
<i>Disaster Management Act 2003</i>	Section 4	Details the objectives of the legislation.
	Section 29	TMR actively collaborates with local governments to ensure integrated approaches to fire and road management planning.
	Section 49	Requires the preparation of disaster management plans and guidelines, including the Queensland State Disaster Management Plan.
	Section 63	Details the Queensland Prevention, Preparedness, Response and Recovery Disaster Management Guideline.
<i>Transport Infrastructure Act 1994</i>	Section 50	Approval (road corridor permits) required from Chief Executive of TMR for a third party that are not a contractor engaged by TMR to undertake bushfire prevention activities as part of routine, periodic or emergency maintenance (i.e. burning or mechanical treatment).
<i>Fire and Emergency Services Act 1990</i>	Whole	Information for fire and disaster management groups / committees on: <ul style="list-style-type: none"> • management of bushfire risk within the State-controlled Road (SCR) corridor; • identifying bushfire risk on land management by TMR; and • enacting appropriate mitigation strategies.
	Section 65	Permit to light a fire required for TMR and/or third parties to undertake planned burning operations in a SCR corridor.
<i>Environment Protection and Biodiversity Conservation Act 1999 (Cwlth.)</i>	Section 12	TMR required to obtain relevant approvals prior to undertaking any works ('actions') in a SCR corridor that have, will have or are likely to have a significant impact on matters of national environmental significance (e.g. species or communities of national significance).
<i>Civil Liability Act 2003</i>	Whole	Potential use for legal pursuit of roadside managers if inappropriate or insufficient bushfire risk mitigation activities are conducted.

Table 3.2: Road and bushfire legislation relevant to Main Roads Western Australia

Legislation	Section	Application to Main Roads WA
Emergency Management Act 2005	Section 38	Collaborate with local governments and other agencies to ensure integrated approaches to fire and road management planning, including representation by Main Roads WA on Local Emergency Management Committees (LEMCS).
Main Roads Act 1930	Section 15	Main Roads WA to facilitate approval for any individual or organisation (e.g. non-government utility service provider), Local Government or utility provider (e.g. water corporation, electricity, gas, telecommunications) that proposes to undertake relevant and appropriate works within a Main Roads road reserve.

Legislation	Section	Application to Main Roads WA
Environment Protection and Biodiversity Conservation Act 1999 (Cwth.)	Section 11	Main Roads WA required to obtain relevant approvals prior to undertaking any works ('actions') in a Main Roads WA road reserve that have, will have or are likely to have a significant impact on matters of national environmental significance (e.g. species or communities of national significance).
Environment Protection Act 1986	Part V (Division 2)	Main Roads WA to ensure the exemption provisions of the <i>Environment Protection Act</i> are followed when undertaking vegetation clearing for fire management purposes in road reserves.
Biodiversity Conservation Act	Section 40	Main Roads WA to obtain a permit to take or disturb a threatened species, including by cutting or removal. This applies to mechanical treatment of road reserves for fire management.
	Section 45	Main Roads WA to obtain a permit to modify an occurrence of a threatened ecological community. This may apply to mechanical treatment of road reserves and/or planned burning operations.
Energy Operators (Powers) Act 1979	Section 54	Main Roads WA (as 'occupier of land') has the duty of any land on or over which planted or cultivated vegetation is growing to fell or lop, or to remove or otherwise deal with, in such a manner as is reasonable in the circumstances, so much of any vegetation as is necessary to prevent it interfering with or obstructing, or becoming likely to interfere with or obstruct, the construction, maintenance or safe use of any supply system.

3.3 Roles and Responsibilities

Management objective: The road agency representative should understand the roles and responsibilities of each party and ensure that road agency bushfire-related works are coordinated with relevant parties.

Bushfire mitigation and response is a joint effort requiring cooperation from communities, individuals, and agencies. Multi-agency coordination is necessary for both community readiness and for coordination between disaster response agencies. It is, therefore, important that the roles and responsibilities of each party are clearly defined and understood to ensure appropriate, efficient responses when required.

The typical responsibilities of bushfire management for various parties are detailed in Table 3.3. The focus is collaboration and stakeholder consultation, which is a common theme throughout this framework.

It should be noted that emergency authorities have statutory roles and responsibilities defined in legislation and/or supporting ordinances or procedures. It is important that these are followed when implementing the general roles and responsibilities defined in this section of the framework.

The roles and responsibilities of road agencies should be considered in conjunction with their current practices, for example, consideration of what is specified in maintenance contracts.

Table 3.3: Roles and responsibilities

Authority / organisation		Role / responsibility			
		Prevention	Preparedness	Response	Recovery
Federal government				<ul style="list-style-type: none"> To provide proportionate emergency resourcing and funding. To deploy the national defence force where required. 	<ul style="list-style-type: none"> To offer emergency funding and assistance to the state authority.
State government		<ul style="list-style-type: none"> To set appropriate chains of responsibility. To prioritise asset protection and plan infrastructure strategically to support local emergency authorities. To incorporate lessons learnt on effective bushfire management techniques. 	<ul style="list-style-type: none"> To ensure firefighting infrastructure is available and capable to manage and forecast a bushfire. To ensure that the allocated budget to fire authorities, including equipment, is deemed satisfactory year on year. To liaise with local government on condition and availability of relief centres for use. 	<ul style="list-style-type: none"> To provide timely and accurate warnings. To provide swift activation of relief centres. To provide real-time communication on relief centres open, locations and their status and what they are providing. 	<ul style="list-style-type: none"> To offer emergency funding to the community and assistance to the Federal Government.
Department of Fire and Emergency Services (community outreach)		<ul style="list-style-type: none"> To provide education and campaigns on factors contributing to bushfires, and the importance of respecting the regulations on days of total fire ban. 	<ul style="list-style-type: none"> To ensure that communities in bushfire-prone areas are aware of what they should do in the event of a bushfire. This includes identifying and communicating the evacuation routes along the road network. 	<ul style="list-style-type: none"> To ensure real-time communication with communities at risk i.e. evacuation orders and recommended evacuation routes. Note: community outreach should balance discussion of evacuation routes etc. with warnings against late evacuation. 	
Road agency	Planners and designs	<ul style="list-style-type: none"> To design road corridors in bushfire-prone areas to be resistant to the impacts of bushfires. To ensure all road assets are designed for resilience. To work with adjacent developers and residential planners (e.g. internal roads along boundaries as buffers, reduction of land gradients). To incorporate lessons learnt on effective bushfire management techniques. 	<ul style="list-style-type: none"> To ensure roads are designed to allow for response to emergency events (i.e. for emergency vehicle access). To ensure all emergency vehicle access routes have been defined in the planning stages of the road corridor. To ensure roads are designed to allow for alternative exit routes for the community. 		<ul style="list-style-type: none"> To assist with the development of maintenance and renewal plans for major works.

Authority / organisation		Role / responsibility			
		Prevention	Preparedness	Response	Recovery
Road agency	Asset management	<ul style="list-style-type: none"> To plan hazard reduction works. To incorporate lessons learnt on effective bushfire management techniques. To implement revegetation practices to ensure slope stability and land management. To liaise with the asset managers of other infrastructure in the road corridor (e.g. utilities providers). 	<ul style="list-style-type: none"> To prioritise the protection of assets and work strategically with emergency response agencies when it comes to prioritising critical access routes. 	<ul style="list-style-type: none"> To close unsafe roads and inform the responsible department within the road agency of the closure. To undertake inspections of structures and other critical infrastructure and apply appropriate administrative controls. 	<ul style="list-style-type: none"> To prioritise maintenance for critical and/or essential assets for community accessibility. To undertake asset upgrades, where possible, to prevent further impacts of bushfires. To provide detailed information on the requirement for repairs.
Road agency	Maintenance contractors	<ul style="list-style-type: none"> To undertake and maintain hazard reduction practices via identified works plan. 	<ul style="list-style-type: none"> To ensure appropriate prequalification documents, equipment, policies and procedures are in place to conduct work for state road agencies. To implement and action all prevention activities to be undertaken as part of road maintenance activities. 	<ul style="list-style-type: none"> Inform the contract manager and the responsible department within the road agency of the closure. 	<ul style="list-style-type: none"> To clear fallen trees and other debris which could inhibit access or road use. To ensure slopes have been stabilised. To undertake road maintenance on damaged road assets to ensure safe operation. To implement revegetation practices to ensure slope stability and land management.

Authority / organisation		Role / responsibility			
		Prevention	Preparedness	Response	Recovery
Road agency	Network operations*		<ul style="list-style-type: none"> To identify critical routes in disaster response. To develop traffic management plans for disaster situations. To incorporate lessons learnt on effective bushfire management techniques. To coordinate with emergency services when it comes to road closures and road condition. To provide information to emergency response authorities on which roads have been designed for and/or maintained for emergency vehicle access. To assess which roads need to remain open during an emergency response and to prioritise them. This includes roads identified in the critical route analysis, roads to evacuation centres and roads that are key water access routes for firefighting. To provide advice to those working in the road corridor. For example, major projects, public utilities maintenance and installation activities, road corridor permit (or ancillary works and encroachments) activities, roadworks. 	<ul style="list-style-type: none"> To coordinate the closure of unsafe roads, maintain the single source of information for road closures on the network and provide detours as appropriate. To constantly monitor the network and quickly identify compromised evacuation routes and relay this information to the public. To provide real-time communications on road closures to road users and other agencies. 	<ul style="list-style-type: none"> To coordinate with maintenance crews in identification of critical routes and priorities for reopening of the network.
Road agency	Community outreach	<ul style="list-style-type: none"> To provide education and campaigns on factors contributing to bushfires and the importance of respecting the regulations on days of total fire ban. 	<ul style="list-style-type: none"> To ensure that communities in bushfire-prone areas are aware of what they need to do in the event of a bushfire. This includes identifying and communicating the evacuation routes along the road network. 	<ul style="list-style-type: none"> To ensure real-time communication with communities at risk i.e. evacuation orders and recommended evacuation route. Note: community outreach should balance discussion of evacuation routes etc. with warnings against late evacuation. 	
Road agency	Environment and heritage	<ul style="list-style-type: none"> To liaise with other departments on environmental regulations when undertaking prevention activities. 			<ul style="list-style-type: none"> To liaise with other departments on environmental regulations when undertaking recovery activities.

Authority / organisation	Role / responsibility			
	Prevention	Preparedness	Response	Recovery
Emergency authorities (fire services) (including local rural fire brigade, etc.)	<ul style="list-style-type: none"> To undertake controlled burning of identified areas. Note: fire services do not undertake burns without consultation with, and consent of, the landholder/manager. To provide updates to the public during high-risk weather, including the introduction of daily total fire bans. To incorporate lessons learned on effective bushfire management techniques. 	<ul style="list-style-type: none"> Planning fire control lines (or firebreaks) that are often based on the road network 	<ul style="list-style-type: none"> To coordinate with police for the command and control of bushfire events. To provide reactive damage assessment and communicate applicable information to the broader public minimising the utilisation of hazardous routes and infrastructure 	
Environmental authorities (Department of Biodiversity, Conservation and Attractions, Department of Parks and Wildlife, Department of Environment and Science, etc.)	<ul style="list-style-type: none"> To provide clear information on native vegetation clearance specific to the area. To provide updates to the public during high-risk weather including the closures of national parks etc. To provide or review permits for roadside prevention activities that involve vegetation. To manage fuel loads through prescribed burning and other means in forests, parks and nature reserves and other lands managed by the authority. 	<ul style="list-style-type: none"> To ensure firefighting infrastructure is available and capable to manage and forecast a bushfire event. To ensure the allocated budget to fire authorities, including equipment, is deemed satisfactory year on year. To prioritise the protection of their assets and work strategically with emergency response agencies when it comes to prioritising critical access routes. 	<ul style="list-style-type: none"> To ensure real-time communication with communities at risk in coordination with fire agencies and police i.e. evacuation orders and recommended evacuation routes. Note: community outreach should balance discussion of evacuation routes etc. with warnings against late evacuation. 	

Authority / organisation	Role / responsibility			
	Prevention	Preparedness	Response	Recovery
Local government **	<ul style="list-style-type: none"> To have a thorough system in place for processing burn permits. To provide education and campaigns on factors contributing to bushfires, and the importance of respecting the regulations on days of total fire ban. To provide fire prevention work permits for roadsides and private landowners in local government areas. To set conditions for development applications regarding the appropriate location of land uses relative to roadside vegetation, and the management of bushfire risk by developers on their land. 	<ul style="list-style-type: none"> To ensure the local community is prepared. To ensure that evacuation facilities are available. To identify current works on all local roads to ensure they are not impacting on the planned evacuation route. 	<ul style="list-style-type: none"> To close unsafe roads, and offer alternative routes when available. To report road closures to the state road agency. 	<ul style="list-style-type: none"> To ensure the community is involved in emergency and recovery planning and in debriefs to record its experience and help prepare for future disasters.
Meteorological organisations	<ul style="list-style-type: none"> To provide advice on suggested days of total fire ban. 	<ul style="list-style-type: none"> To have accurate predictive services outlining seasonal outlook and expected risks in advance. To provide advice on fire weather forecasts and updates. 	<ul style="list-style-type: none"> To provide advice on smoke management and updates on forecasts. 	
Households and businesses	<ul style="list-style-type: none"> To respect and adhere to the requirements of a total fire ban day. To ensure safe practices are implemented to avoid accidental ignitions on roadsides. 	<ul style="list-style-type: none"> To have appropriate individual plans for bushfire response, businesses to have continuity plans in place. 		

Authority / organisation	Role / responsibility			
	Prevention	Preparedness	Response	Recovery
Public and private landowners and infrastructure managers (including power, electricity, water companies etc.)***	<ul style="list-style-type: none"> To undertake hazard reduction practices. To maintain their assets in good condition and respect total fire bans to reduce the risk of ignition. To provide updates to the public during high-risk weather, including the closures of privately owned parks etc. To incorporate lessons learnt on effective bushfire management techniques. 	<ul style="list-style-type: none"> To have appropriate individual plans for bushfire response, businesses to have continuity plans in place. 		
First Nations Australians	<ul style="list-style-type: none"> To be consulted on activities undertaken on relevant land. 	<ul style="list-style-type: none"> To be consulted in understanding historical fire patterns in the region. 	<ul style="list-style-type: none"> To be consulted on activities undertaken on affected land. 	

Note: The roles and responsibilities in this table are restricted to those in relation to the road.

* There will be differences in network operations and network planning between urban and rural locations.

** The road agency roles should be applied to local government for roads managed within their jurisdiction.

***Where roads are privately owned, road agency practices should be reviewed.

3.4 Engagement Strategy Framework

Management objective: Engagement of appropriate stakeholders should be undertaken as part of the bushfire management activities by developing a standardised and consistent engagement strategy.

Stakeholders should be engaged in decisions pertinent to their roles and responsibilities in bushfire management. The relevance of stakeholders will depend on the road infrastructure project life-cycle phase and the type of PPRR activity being undertaken.

It is important that stakeholders are engaged in a formal and consistent manner to ensure ongoing representation of all key opinions and needs. To aid this, an engagement strategy framework for bushfire management activities for road projects is provided in Table 3.4.

An engagement strategy should document:

- who the relevant stakeholders are for the current stage of the bushfire management activities
- what the role of each stakeholder will be, based on the roles and responsibilities identified for the PPRR activities in Table 3.3
- any project documentation that will need to be disseminated as part of the engagement process
- what the process will be for receiving feedback on project plans and opportunities for improvement.

Table 3.4: Engagement strategy framework

Stage of engagement strategy	Description	Questions to consider
1. Clarify your community engagement objective.	Be clear about why you are engaging with the community and stakeholders.	<ul style="list-style-type: none"> • Why do you need to engage? • What would successful engagement look like?
2. Identify who you are going to engage.	Determine who should be involved in the process and their level of interest in the program, based on the roles and responsibilities identified for PPRR activities in Table 3.3.	<ul style="list-style-type: none"> • Who is responsible for bushfire management activities? (see Table 3.3) • Who will be impacted by the outcomes of bushfire management activities? • Who are the beneficiaries? • Who can make the activities more effective? • Who may be able to contribute resources (funding, materials, support)?
3. Analyse your stakeholders and select your level of engagement.	The five levels of consultation: inform, consult, involve, collaborate and empower. The type of engagement will depend on the goals, timeframes, resources and levels of concern in the decisions to be made.	<ul style="list-style-type: none"> • Are you going to keep stakeholders informed? • Are you going to listen to and consider alternative ideas proposed by stakeholders? • Are you working with the stakeholders to find solutions?
4. Select your engagement activities; determine timelines, communication messages and potential risks.	Engagement options include: <ul style="list-style-type: none"> • face-to-face in groups or individually • surveys or web-based questionnaires • customised solutions for different stakeholders or stakeholder groups. 	<ul style="list-style-type: none"> • What is the most effective way of engaging the different types of stakeholders?
5. Review and evaluate your stakeholder and community engagement results.	Stakeholder and community engagement activities will occur at different phases of the road infrastructure project life cycle. As part of the development of the engagement strategy, identify key points throughout the program where the strategy will be reviewed to update it based on the project stage, and to address any issues.	<ul style="list-style-type: none"> • What are the milestones and what is the progress toward the objectives of bushfire management?

There are several relevant stakeholders, in addition to those with key roles and responsibilities (as defined in Table 3.3), that may be appropriate to be included in engagement. These include:

- the community
- hospitals, schools, and other key community locations
- First Nations Australians
- local government authorities
- vegetation, horticultural and landscaping specialists
- infrastructure designers and construction partners
- law enforcement authorities and first responders
- incident responders (including emergency services and maintenance contractors)
- industry associations (construction, housing, master builders, etc.).

3.4.1 Community Readiness

Management objective: The road agency representative should work with the fire service authorities to ensure that communities in bushfire-prone areas are aware of what they need to do in the event of a bushfire. This includes identifying and communicating the evacuation routes along the road network.

A key aspect of bushfire management is the engagement of the community to ensure its readiness, as a well-informed and prepared community will be more resilient, reducing pressure on the road and transport networks during and in the aftermath of a bushfire.

Community readiness should be undertaken, in collaboration with the fire services authority, through hosting information sessions, or disseminating educational materials, on key issues including (but not limited to):

- identifying and communicating the evacuation routes along the road network
- evacuation procedures and sources of information during an event
- understanding alerts and warnings
- understanding total fire bans
- developing a personal fire and evacuation plan
- preparedness and fire management of property and land.

4 Implementing the PPRR Model in the Road Infrastructure Project Life Cycle

Management objective: The road agency representative should implement the prevention, preparedness, response and recovery model into road agency practice.

4.1 Strategic Bushfire Plan

Management objective: The road agency representative should develop a strategic bushfire plan to specify the road agency objectives in strategic asset management when considering bushfire risk.

Note: Strategies in bushfire management need to also account for the limited resources and funding which may be available, so that the resources can be incorporated into targeted management strategies.

Prior to commencing any works in relation to the prevention of, preparedness for, response to or recovery from bushfires, the strategic objectives of the task need to be identified. This allows for the minimisation of the impact of major bushfires on human life, communities, essential and community infrastructure, industries, the economy and the environment. This includes articulating:

- what functions the road agency wants the road network to perform before, during and after a bushfire and how these functions contribute to public safety
- what conditions need to be in place for the road network to effectively perform each of these functions and what can be practically done to increase effectiveness
- what the cost-benefit relationship and management practicalities of implementing solutions would be.

4.2 Continuous Improvement

Management objective: When setting strategic planning objectives, the road agency representative should ensure that the findings from previous bushfire prevention, preparedness, response and recovery activities are incorporated in planning practices.

Lessons learnt may include:

- recent bushfire events which may reduce the need to undertake future prevention activities
- prevention activities that have been effective in both road design and ongoing road maintenance
- preparedness strategies which have been shown to be effective in lessening the impacts of disaster events
- response activities which have demonstrated immediate and effective action
- best-practice in recovery to 'build-back-better'
- reviewing historical plans that may no longer meet current bushfire risk mitigation requirements
- treatments that are best to minimise impacts in the operations phase based on experience.

4.3 Elements of the PPRR Model

This section of the framework provides detailed definitions of the PPRR stage of bushfire management activities.

4.3.1 Prevention

While bushfires cannot be fully prevented, mitigation activities can be undertaken to reduce the likelihood of a bushfire, the vulnerability of assets and the consequences to the community, and ensure asset resilience during and after an event. Prevention is defined as:

- all activities concerned with minimising the occurrence of incidents, particularly those of human origin
- regulatory and physical measures to ensure that emergencies are prevented, or their effects mitigated
- measures to eliminate or reduce the incidence or severity of emergencies.

This framework is focused on infrastructure managed by road agencies. However, it is important when implementing preventative strategies to improve bushfire resilience that ancillary infrastructure, potentially managed by other authorities, is considered. This highlights the importance of stakeholder engagement with the authorities when selecting prevention strategies. The authorities may include utility providers, local councils, fire and emergency services and other agencies.

Items to be considered when selecting prevention strategies are as follows:

- The offset requirements (offset refers to the distance from the road pavement where utilities are installed) of utilities, prior to implementing any roadside management strategies for bushfire prevention. Consultation with the utility providers or authorities is recommended.
- Development of a database and mapping tool system to identify when areas have been managed with prevention activities or when these areas are due to be managed, relative to their vegetation type and category.
- Implementation of a multi-agency stakeholder group for risk identification and treatment selection.
- Development of a work plan including identifying the location of the works to be completed, the roadside management objective being managed, and the type of treatment being carried out – for all selected and prioritised treatments.
- Ensuring all relevant and current environmental legislation has been reviewed prior to implementing any bushfire prevention programs.
- Ensuring that emergency vehicles have adequate access and emergency egress for all road users by following available guidelines for public and property access roads.

4.3.2 Preparedness

Preparedness is defined as all activities undertaken in advance of the occurrence of an incident to decrease the impact, extent and severity of the incident and to ensure more effective response activities. In this framework, preparedness refers to the strategic solutions which can be made at the policy and management level to assist with developing the resilience of road infrastructure against bushfire risk.

All emergency preparedness strategies presented in this section need to be considered along with all other current jurisdictional practices and requirements. In addition, where effective processes are in place for other natural disaster types (e.g. cyclones, floods) these strategies should be adapted to bushfire preparedness. As an example, TMR's Northern District currently has a joint emergency management committee with local governments and other relevant stakeholders for how to prepare for the cyclone season. Similar communication and coordination processes could be developed for preparation for the fire season.

4.3.3 Response

The road infrastructure is an important asset to the community and its serviceability following a major fire will be critical to community recovery. Management of the road network during and in the immediate aftermath of a bushfire needs to be coordinated with the locations of fire evacuation centres in order to ensure that safe passage can be provided for the community.

As important as road infrastructure is to the response effort, it is important to note that during a bushfire the amount of civilian traffic in the road corridor within the immediate threat area should be minimised. This is to allow for free-following emergency vehicle access but to also ensure the welfare and safety of civilian road users. Furthermore, parts of the road reserve such as roadside stopping bays and/or rest areas should not be used as informal evacuation points as they typically provide no protection against a bushfire threat and have limited facilities available for evacuees to self-manage their welfare.

4.3.4 Recovery

Recovery refers to the strategies which can be implemented as part of the recovery effort following a bushfire. This includes reconstruction activities such as how to maintain and rehabilitate damaged infrastructure, and how to upgrade or improve assets to build resilience against future events.

4.4 Approach

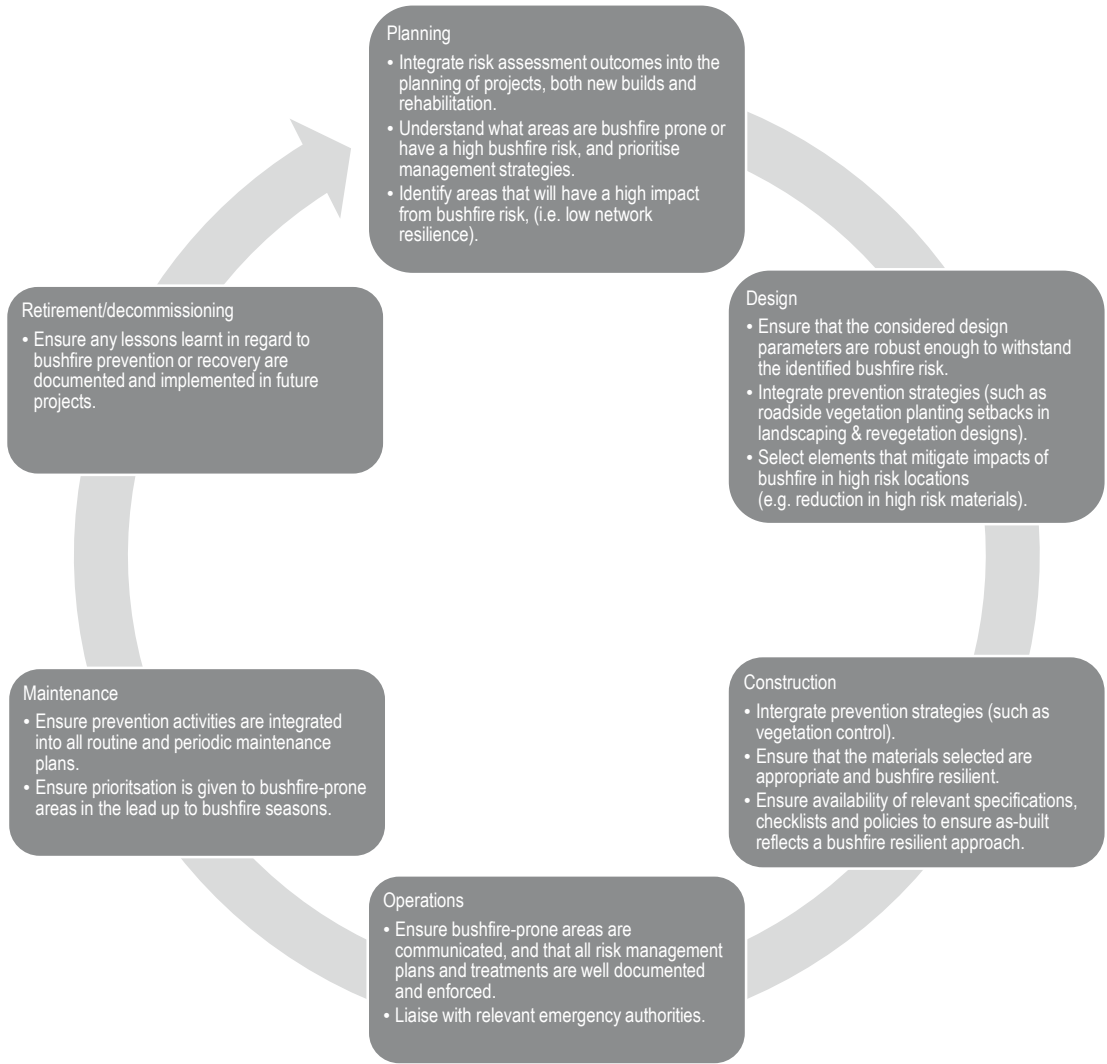
There are three key strategies for protecting life and assets from bushfires; these are:

1. the incorporation of bushfire protection measures, in addition to firefighting and evacuation planning, into road design and construction considerations
2. the planning and implementation of bushfire hazard reduction and prevention activities (e.g. roadside vegetation management), including the ongoing maintenance of the bushfire protection measures by land owners and asset owners, into road maintenance and operations
3. building of communication networks, using intelligent transport systems, and emergency response planning across the network to provide real-time information to drivers about fire hazards, in order to prevent harm to the public on the road.

Management objective: The road agency should develop an overarching plan for implementing these three strategies into ongoing road agency practices based on the guidance provided in this framework.

These elements are summarised in the road infrastructure project life-cycle decision-making process, as shown in Figure 4.1.

Figure 4.1: Incorporating bushfire risk into the life cycle of a road infrastructure project

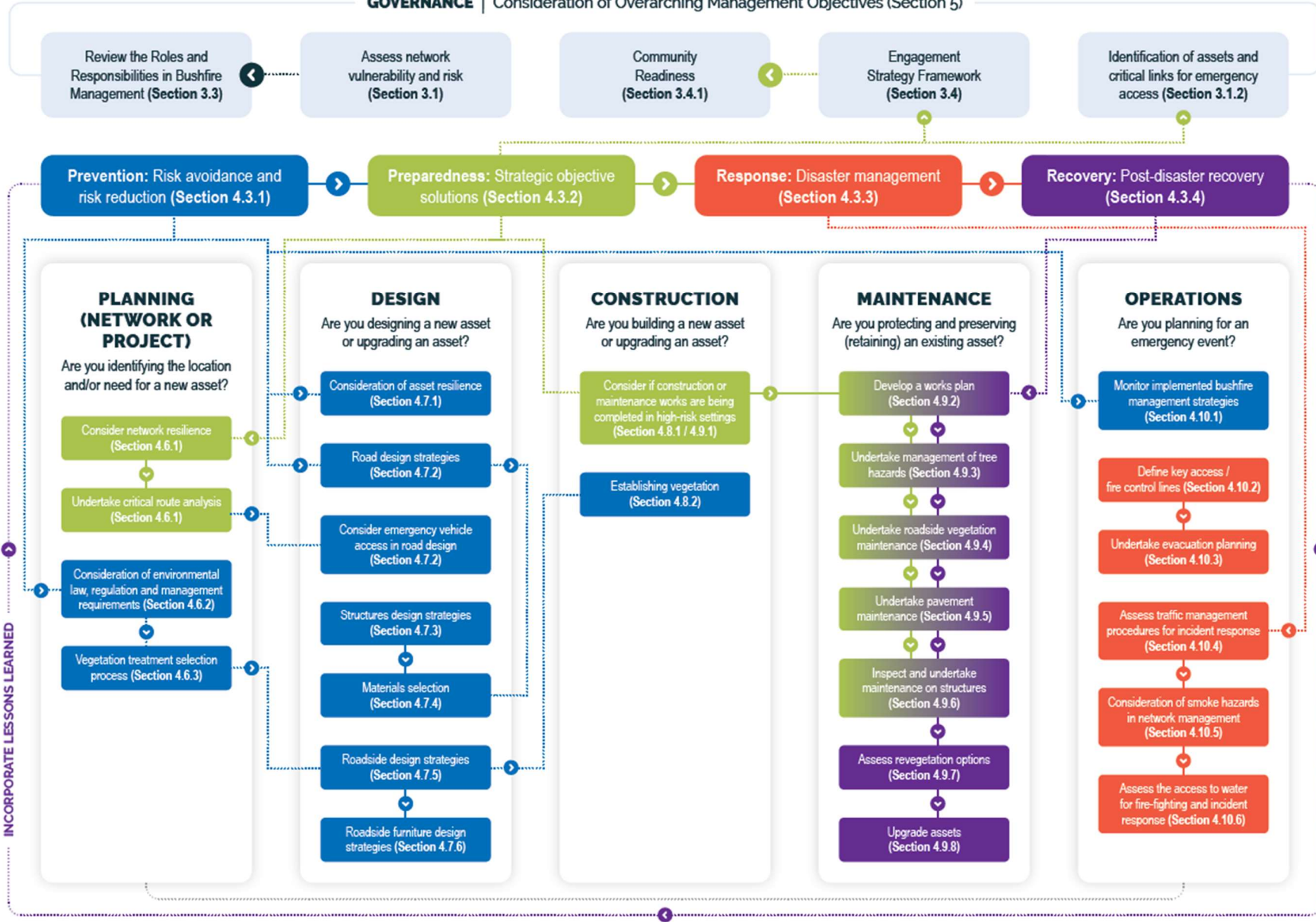


4.5 Methodology

This section of the framework details the methodology to be undertaken in order to identify the specific strategies which should be implemented to reduce or manage bushfire risk at each phase of the road life cycle. Each of the phases of a road infrastructure project life cycle have been defined to ensure that consistent definitions are understood when using the framework. Figure 4.2 provides a flow diagram of how to use this framework to select bushfire management strategies, based on the PPRR model, within the road life cycle.

Figure 4.2: Strategy selection process

GOVERNANCE | Consideration of Overarching Management Objectives (Section 5)



4.6 Planning

Management objective: The road agency representative needs to ensure the bushfire risk of a region is considered when undertaking infrastructure project planning to prevent or minimise the impacts on road infrastructure and protect road users in the event of a bushfire.

Project planning is the phase of the project where the road agency representative addresses how to complete the project within a certain timeframe, through defined stages or milestones with designated resources.

4.6.1 Network Resilience

Road network resilience refers to system performance under disruptive conditions and gives a quantitative measure for network resilience, showing the performance of the network in terms of traffic flow in an unusual circumstance. While a road network may be designed in a way that makes it more resilient, the activities that are performed during the aftermath of a disaster also play an important role in its resilience. As road network resilience requires a multi-agency approach, stakeholders identified in Section 3.3 should be consulted when reviewing it.

Critical route analysis

Management objective: The approach to managing bushfires and any plans and procedures should be driven by a broader resilience process (i.e. to ensure practical measures are implemented considering conflicting needs).

The road agency should develop a classification and prioritisation system for the road network. This system should ensure that critical routes and the risk of bushfire impact have been considered when prioritising periodic and routine maintenance activities to ensure that these roads are available to provide sufficient access for both evacuation and emergency services.

The identification of whether or not a road or structure is part of a critical route should be undertaken in the planning stages of a road project (i.e. construction, maintenance, rehabilitation, etc.) where possible, to ensure that it is designed adequately. The identification of the risk of bushfire impacts should be undertaken as part of the risk assessment process.

Further guidance for defining key access roads is provided in Section 4.10.2.

In addition, critical route analysis can be used to determine network and infrastructure deficiency, and thus this can be used to inform investment planning. This information can be used as part of the decision-making process for asset upgrades, particularly where renewal maintenance needs to be undertaken following a bushfire. Guidance on asset upgrades is outlined in Section 4.9.8.

4.6.2 Consideration of Environment Law, Regulation and Management Requirements

Management objective: Ensure that environmental legislation, regulations and management guidelines have been consulted prior to implementing any bushfire prevention programs.

Road managers must take into account the implications of the regulatory framework when planning for and undertaking works on road corridors. The most influential legislation in the current regulatory environment includes that defined in Section 3.2.

Australia's key national environment law is the *Environment Protection and Biodiversity Conservation Act 1999*, also known as the EPBC Act. This legislation regulates activities that are likely to have a

significant impact on nationally protected assets. Prevention activities only need federal environmental approval if they are likely to have a significant impact on a nationally protected asset, and they are not specifically exempted by the national environment law.

In addition, each state and territory have specific environment legislation, regulations and management requirements which will need to be referred to and followed, as required. Whether a particular activity will have a significant impact on a protected asset is influenced by a variety of factors and must be considered on a case-by-case basis.

Environmental management guidelines, regulations and legislation are outlined in Appendix A.

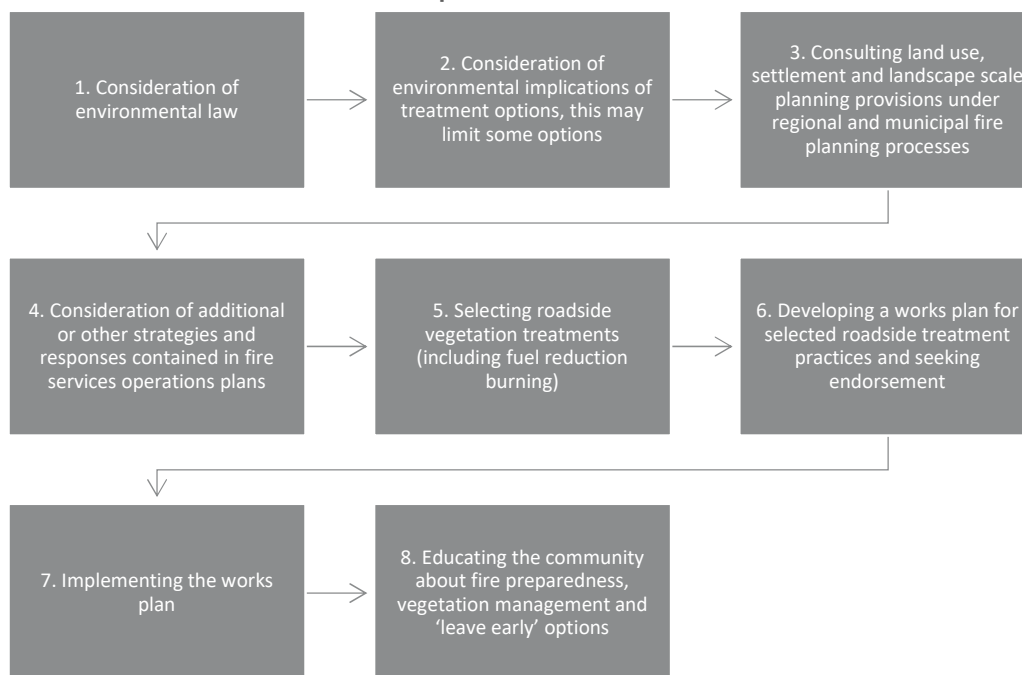
4.6.3 Roadside Treatment Selection Process

Management objective: When planning a new project, the maintenance of a road, or an asset upgrade, the roadside treatment selection process should be reviewed in order to determine the appropriate treatments. The vegetation treatment selection process should include multi-agency consultation to assist with selecting and assessing high-priority roads, and to determine the appropriate fire mitigation treatments, including any required vegetation treatments.

Prior to the commencement of the treatment selection, the multi-agency group needs to ensure that all environmental and cultural issues associated with vegetation removal have been resolved. Relevant legislation should be consulted (e.g. *Environmental Protection and Biodiversity Conservation Act, Aboriginal Torres Strait Islander Heritage Protection Act, Australian Heritage Council Act*).

The treatment selection process may include, but is not limited to, the steps outlined in Figure 4.3.

Figure 4.3: Roadside treatment selection process



Once the treatments have been established for each high bushfire-risk road, they need to be prioritised and the works budgeted for. A workplan should then be developed, identifying the location of the works to be completed, the roadside management objectives being addressed, and the type of treatment being carried out.

4.7 Design

Management objective: The road agency representative should ensure that fire design requirements are considered in bushfire-prone areas and guarantee all components have been thoroughly reviewed for a design fire event and mitigated where possible.

The road agency representative should consider the existing controls that are in place for bushfire management, including what is currently budgeted for.

Design is the process of selecting and combining appropriate elements that will develop a fit-for-purpose solution. It is an iterative process that requires a designer to exercise judgement and use experience while also applying accepted technical guidelines and continually evaluating the design to assist in the selection of the appropriate values for the design elements.

4.7.1 Consideration of Asset Resilience

Resilience is defined as the capability to anticipate, prepare for, respond to and recover from threats with the minimum damage to social wellbeing, the economy and the environment. When designing an asset, various types of asset adaptation can be implemented in order to improve the resilience of an asset. The identification of these options should be based on the identified key risks, the practicality of the options and the criticality of the assets to assist in the prioritisation of options. Examples of adaptation options to achieve asset resilience are outlined in Table 4.1.

Table 4.1: Adaptation options to achieve resilience

Adaptation treatment	Description	Expected financial implication	Example
Avoidance (build for end of design life scenario)	<ul style="list-style-type: none"> Build to maintain standards and level of service for the climate change scenario expected at end of life against standard design lives. Avoid locations where bushfire prone area projections are expected to be significant. 	<ul style="list-style-type: none"> Potentially high upfront costs, although no further costs for adaptation are required. Provides a higher level of service for entire design life. Risk that actual climate change will exceed prediction. 	<ul style="list-style-type: none"> Bridge is designed and constructed to consider increased flood risk due to climate change. Alignment is moved to avoid coastal hazard zones.
Planned adaptation	<ul style="list-style-type: none"> Plan an upgrade program to progressively adapt the infrastructure as climate change occurs. Initial design considers predicted climate changes and provides functionality to adapt the infrastructure at another time. Consultation with program and asset managers required to secure investment program. 	<ul style="list-style-type: none"> Moderate upfront costs expected, although further investment is required during infrastructure life cycle. Provides some increase in level of service. 	<ul style="list-style-type: none"> Bridge components are selected and integrated into the design and constructed based on having a shorter design life than is usual and can be replaced when required.
Progressive modification or redundancy (existing asset)	<ul style="list-style-type: none"> Realign, redesign and/or reconstruct as required and as possible in response to verified climate change as part of existing maintenance regime or project upgrades. Future verified climate changes will be captured in investigatory criteria of audits. 	<ul style="list-style-type: none"> Moderate upfront costs expected. Further climate changes will force redesign. Higher costs to adapt asset in long term. Maintains level of service. 	<ul style="list-style-type: none"> Bridge is designed and constructed in such a way that adaptation responses, such as the height of the deck, can be elevated and can be undertaken as part of maintenance work or based on increased risk or opportunity such as upgrade works being planned. Road alignment is changed such that bridge over waterway is no longer required and can be decommissioned.

Source: Main Roads Western Australia (2019), *Guidelines Climate Change Risk Assessment Version 2*, Main Roads Western Australia, Perth, WA.

4.7.2 Road Design Strategies

Management objective: When selecting road design strategies, consideration should be given to the risk assessment that has been undertaken for the bushfire-prone area. Available guidelines for public and property access roads should be followed to ensure that emergency vehicles have adequate access and emergency egress for all road users.

Note: The type and geometry of the road that is likely to be designed should be taken into account. For example, there will be a difference in the risk associated with a flatter road corridor with grassed clear zones, compared with a narrower road corridor with steep batters, crash barriers and nearby trees.

An assessment of whether these requirements align with current road design practices will need to be considered. Current practices, as well as best practice references, are provided in Appendix A.

When designing a road, consideration needs to be given to access opportunities for emergency vehicles. The aim is to maximise the efficient travel of emergency vehicles via arterial road networks. Methods to achieve this are:

- Where a centre median is not provided along an arterial road, emergency vehicles need to have the ability, even when the road is congested, to divide the traffic lanes to make their way through the traffic.
- Emergency vehicles need to be able to straddle the centre median and carriageway to enable travel along a congested road.
- Gates and tracks may be able to be constructed that allow emergency vehicles to exit the road and drive along adjacent pedestrian and cycle paths, where these paths have been built to a high, road-like paving standard.
- Where only a single lane is provided along a road or car parking occupies the left-hand lane, emergency vehicles should have permission to travel along the opposite side of the road.
- In the instance of a centre median being provided along an arterial road where no provision is made for emergency vehicles to cross to the opposite side or it is not considered to be appropriate, then an emergency vehicle lane or paved shoulder could be provided along the left-hand edge of the carriageway.


Note 1: A freeway operating under all lane running conditions may not be able to meet this requirement, due to the absolute minimum shoulder width (e.g. 1.0 m). In this instance, overhead lane use management signs could be used. The traffic control centre could close a lane via the variable message signs, to allow emergency vehicle access.

Note 2: Notwithstanding the above, there was a lack of geometric road design considerations identified in the literature, and this is considered a significant gap in the knowledge of how the road network can reduce the risks associated with bushfires. As a result, a first principles approach has been applied to identify potential areas where the design of the road may influence the risks associated with bushfires. It should be emphasised this is based on judgement and should be considered as a potential area of future research as opposed to specific items for inclusion in the framework.

Potential geometric road design aspects which may influence bushfire risk are presented in Table 4.2 and Figure 4.5. Figure 4.5 provides a representation of the definition provided in Table 4.2. This figure is not intended to be a design drawing, and not all recommendations need to be used together, or in a specific location. They need to be considered on a case-by-case basis.

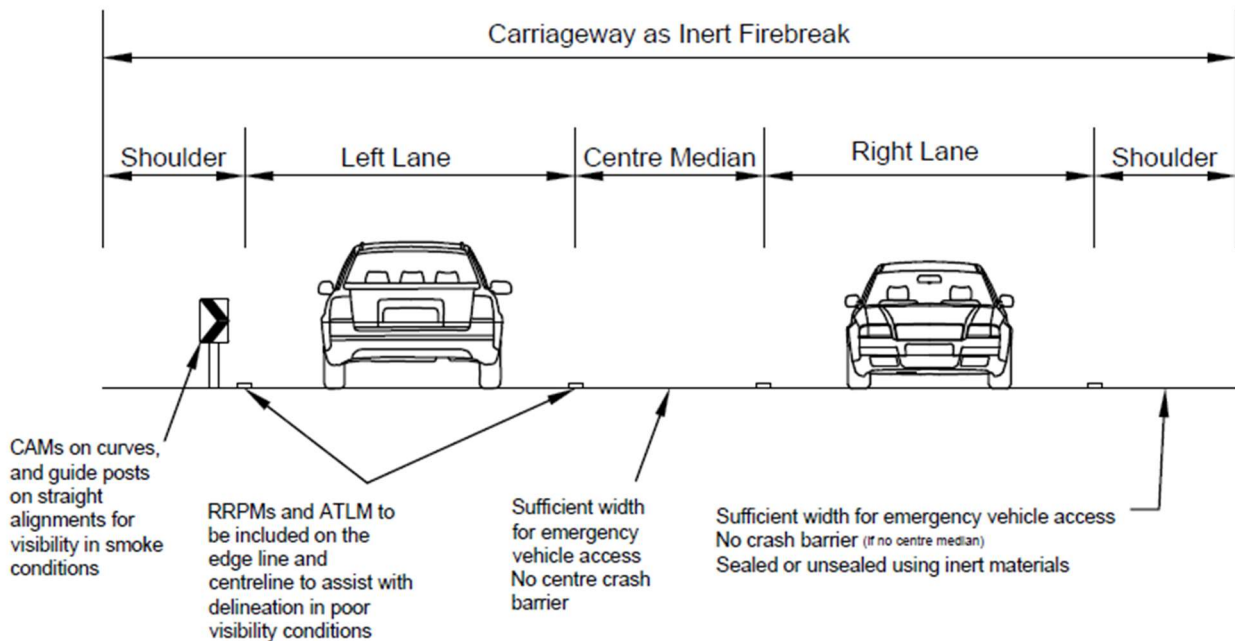
Table 4.2: Potential geometric design road cross-section for bushfire-prone areas

Geometric design aspect	Potential impact on bushfire risk
Alternative routes	<ul style="list-style-type: none"> When designing a road, consideration should be given to whether an alternative route will be available for community evacuation and emergency vehicle access or if this new road will provide additional access.
Alignment	<ul style="list-style-type: none"> Roads can be potential ignition sources of bushfires due to interactions with the general population and other factors such as powerlines in the corridor. If it is possible that an alignment can avoid an area of identified high bushfire risk, this option should be explored. Roads facilitate access to emergency vehicles. Aligning the road with likely critical access locations for emergency vehicles in a bushfire scenario should be considered. The chosen alignment of a new road may assist with achieving other bushfire prevention methods outlined in the framework, such as the use of horizontal and vertical firebreaks. For instance, it was identified that negative grades in the roadside (i.e. roads aligned with the top of a crest) had a positive effect on reducing the spread of fire, whereas positive grades (i.e. roads aligned with the bottom of a sag) increased the risk of bushfire spread. <p>It is emphasised that each of the above points would need to be considered within the broader context and objectives of the road alignment.</p>
Emergency airstrip	<ul style="list-style-type: none"> In remote, bushfire-prone areas, especially where access by road may become restricted in a fire scenario, ensuring there is an accessible emergency aircraft runway strip is important. See <i>Austrroads Guide to Road Design Part 3: Geometric Design</i>, Appendix C.
Carriageway width and trafficable lanes	<ul style="list-style-type: none"> In the event of an emergency egress situation, where a significant number of vehicles are attempting to leave an area at the same time, a wider carriageway can provide increased capacity. However, this needs to be considered in a road safety risk situation and managed accordingly. Localised widening may be considered (with or without shoulders) with delineation and may assist in limited horizontal or vertical sight distance constraints i.e. curves and crests. A wider carriageway may allow for avoidance of fallen debris by using adjacent travel lanes. A wider lane also provides increased space for vehicles to traverse around stopped vehicles, including large vehicles, which may be required during an emergency. The carriageway can act as an inert-material firebreak. A wider carriageway may provide enhanced access for emergency vehicles allowing them to pass hazards or manoeuvring opportunities if safe to do so.
Sealed and unsealed shoulder width	<ul style="list-style-type: none"> Use of the shoulder as a breakdown area to avoid restricting the use of the main carriageway. Use of the shoulder to avoid obstructions on the roadway. Use of the shoulder as an inert-material firebreak. The use of wider, enhanced access for emergency vehicles allowing them to navigate around debris, etc.
Clear zones and vegetation-free zones	<ul style="list-style-type: none"> The latest update to the <i>Austrroads Guide to Road Design Part 6: Roadside Design, Safety and Barriers</i> recognises the limitations of clear zones in preventing fatal and serious injury run-off-road crashes. More recently, road safety barriers have become a more common treatment. This change in approach may result in offsets between the traffic lanes and adjacent foliage becoming smaller and can provide an opportunity to limit the spread of large fires and can serve as a firebreak. As each location has its own constraints, the barrier may be located 4–6 m away from a traffic lane to allow for a vehicle to stop alongside the barrier. See vegetation free zones in Section 4.7.5, Table 4.5.
Roadside embankment (slope and batter) improvements	<ul style="list-style-type: none"> Reducing the steepness of roadside embankment slopes will allow a greater chance for drivers to regain control of their vehicle and avoid obstacles including the embankment and vehicle rollover. Smoke can provide limited visibility of the road alignment during a bushfire and flatter embankments may allow vehicles to regain control onto the carriageway. Flattening slopes means to reduce the steepness of embankment slopes to less than 1:6, which is generally considered drivable.
Use of untraversable medians (raised median, centre barrier, etc.)	<ul style="list-style-type: none"> An untraversable centre median may limit both emergency vehicle access and the ability for general traffic to avoid obstructions (i.e. falling trees) in an emergency egress situation. Regular access points (breaks in barrier, traversable sections, etc.) should be provided for access including maintenance vehicles i.e. lawn mowing and vegetation activities.

Geometric design aspect	Potential impact on bushfire risk
Use of enhanced delineation	<ul style="list-style-type: none"> • The use of raised reflective pavement markers and guideposts fitted with reflectors give the road user a visual cue of the alignment of the road ahead. They are useful at horizontal and vertical-alignment curves and can provide enhanced delineation in poor visibility conditions. • The use of audio-tactile line markings both on the centreline and road edge can assist with lane safety when delineation is obstructed due to poor visibility conditions. • The use of static warning signs provides drivers with early indications of changing circumstances, including an approaching intersection, a change in horizontal and vertical alignment or approaches to narrow bridges and structures to allow time for the driver to react and adjust driving behaviour, particularly in poor visibility conditions. • During the Black Summer bushfires of 2020, there were reports of drivers evacuating affected areas in smoky conditions and relying on enhanced delineation such as chevron alignment markers (CAMs) (Figure 4.4) to navigate. This may suggest that more common use of CAMs may assist in bushfire scenarios. CAMs, however, are a specific type of signage placed on the edge of the roadway, generally on the outside of curves. They consist of a chevron with the point placed towards the sweep of the curve. CAMs allow drivers to appreciate the geometry of the road by delineating curves, providing a visual reference which can be used to make decisions about the speed and trajectory of the vehicle. CAMs are used as a treatment on substandard horizontal curves, and they should be considered if the advisory speed of the curve is at least 15 km/h less than the 85th percentile speed of the departure side of the road. <p>Figure 4.4: Chevron alignment markers (CAMs)</p>  <p>Source: Road Traffic Signs, https://www.roadtrafficsigns.com/chevron-road-signs, viewed 24/02/22.</p>

Note: Consideration needs to be given to the standards and jurisdiction specifications and the scope of works when implementing the measures described above.

Figure 4.5: Potential geometric design of a road cross-section for bushfire-prone areas



Note:

- CAMs (chevron alignment markers), raised reflective pavement markers (RRPMs), audio-tactile line markings (ATLM).

The road design features shown in the figure are intended to be individual examples of potential solutions. This is not a diagram of the ideal road design in a bushfire prone area. All strategies need to be considered on a case-by-case basis and should be developed in collaboration with local authorities.

4.7.3 Structures Design Strategies

Management objective: New structures in areas of known bushfire risk should incorporate the fire design requirements stipulated in the current Australian Standard bridge code, AS 5100 *Bridge Design*. The approach detailed in this standard requires consideration of an applicable design time-temperature curve. Where it is known, a curve that aligns with suspected bushfire behaviour should be provided to the designer.

Where possible, the road agency representative should identify elements of a structure design which may be flammable or susceptible to extreme heat and explore if there are alternatives to reduce potential damage during an event. Where elements are unable to be substituted, required recovery activities should be clearly understood to streamline maintenance work plans.

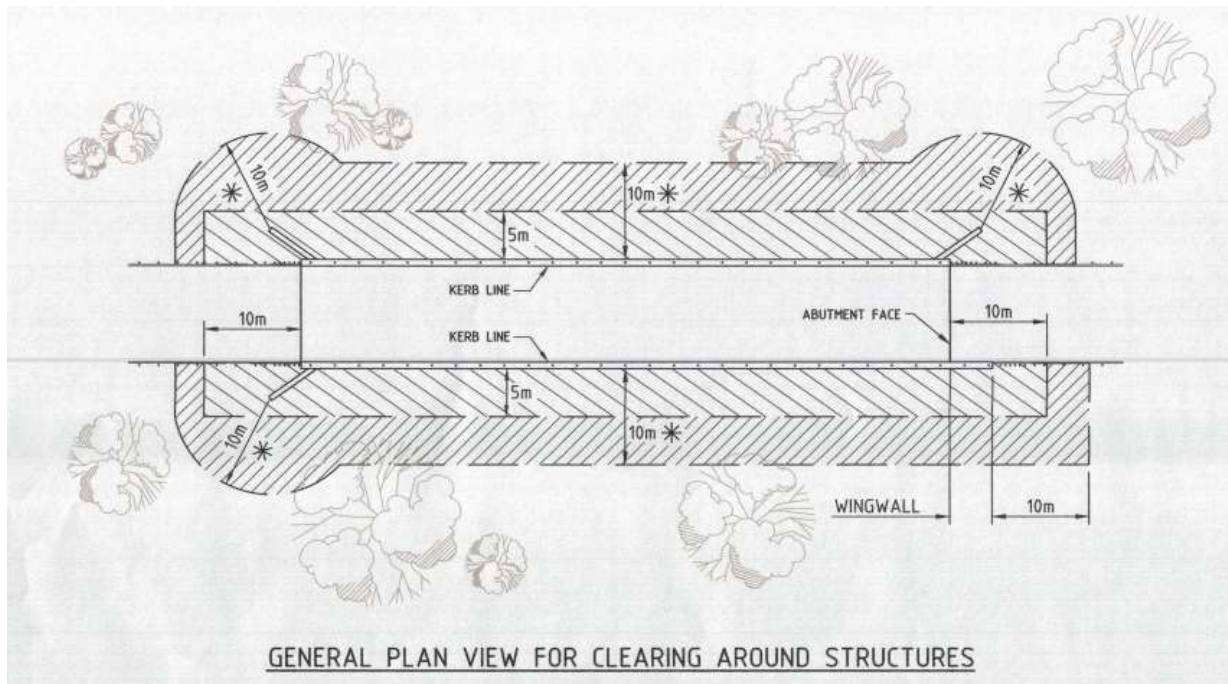
The road agency representative should also undertake routine maintenance of structures including the clearance of vegetation and reduction of natural fuel load encroaching the structure to help minimise heat effects.

The most effective preventative strategy for bushfire impacts on structures is ensuring that the fire passes structures quickly to prevent the generation of significant heat energy which may damage critical members or components. This requires the removal of flammable elements wherever possible throughout the structure and the surrounding environment.

The structure exclusion zone is shown in Figure 4.6. It shows the general plan view for clearing vegetation around structures.

It must be noted that bare earth is not required within the structure exclusion zone – the focus should be to remove the main risks, which are (i) weeds and fine fuels, and (ii) foliage that is overhanging or within 2–3 m of the structure.

Figure 4.6: Structure exclusion zone



Source: Main Roads Vegetation Clearance Envelopes (Drawing no. 201928-0027).

4.7.4 Material Selection

Management objective: Where possible, the road agency representative should ensure that when selecting materials in bushfire-prone areas, consideration is given to the use of non-flammable and non-combustible materials to minimise the intensity of a bushfire and reduce the required recovery activities. Where appropriate materials are unable to be used, the required recovery activities should be clearly understood to streamline maintenance work plans.

Note: This framework is focused on the responsibilities of the road agency, and the assets managed by it. The road agency should consider liaising with other infrastructure managers in the road corridor, such as utilities providers, regarding the types of materials they are selecting for their assets in bushfire-prone areas.

There is currently limited literature on the impact that bushfires would have on specific road materials and how this would affect the overall structure. Advice on material selection is provided in Table 4.3; however, further research into the impacts of bushfire on road infrastructure materials and overall structures is required in order to give recommendations on what materials are the most bushfire resilient.

Table 4.3: Material selection advice

Material use	Advice
Pavement materials	<ul style="list-style-type: none"> • Fire can have varying impacts on pavement materials, most notably on bituminous wearing courses. • Bitumen binder will oxidise and become hard and brittle when heated to high temperatures and can even burn if the temperature it is exposed to is significantly high. • While the bituminous materials cannot be substituted, it should be noted that a change in ongoing maintenance treatment periods and treatment types may be required preceding a bushfire, depending on the potential damage to the pavement. • An example of damage to pavement materials due to bushfires is shown in Figure 4.7.
Slope stabilisation	<ul style="list-style-type: none"> • Slope stabilisation refers to any implemented technique that aims to stabilise an unstable or inadequately stable slope. This type of treatment is important if loss of vegetation on a slope site due to a bushfire would be detrimental to overall slope stability. • The use of geosynthetic fibres or plastic netting for slope stabilisation is a potential option; however, these materials may not be suitable in high fire-risk areas as they may be at risk of damage from heat. • The use of rock armouring and other inert material for slope stabilisation can also be considered for areas where fire risk is considered too high for other engineered materials. • Many slope stabilisation materials can be damaged due to regular exposure to the elements. An example of this is shown in Figure 4.8. These show turf reinforced matting that is crumbling as a result of exposure to the elements. If regular exposure does this, then bushfire damage is going to be even worse. • Designing slopes to be less reliant on stabilisation methods such as vegetation is one method of risk mitigation.
Timber in structures	<ul style="list-style-type: none"> • When designing bridges or upgrading structures, use of flammable materials should be minimised – most critically, timber, rubber and plastic products. • In bushfire-prone areas, concrete and steel structural elements should be prioritised to enable a functioning structure and road corridor is maintained. • Fire damage to a timber bridge is shown in Figure 4.9.
Steel in structures	<ul style="list-style-type: none"> • Some coatings such as intumescent coatings, which act as insulating layers to protect the steel when exposed to a fire, can be used to improve the resilience of steel structures.
Pipe and culvert materials	<ul style="list-style-type: none"> • Fire resistance of pipe and culvert materials (especially those buried) is important to consider. Anecdotal evidence has suggested that culverts made from high-density-polyethylene (HDPE) can burn when exposed to a bushfire and then subsequently collapse under the road, leaving a severe road safety hazard. • For the design of new culverts in bushfire-prone areas, consideration should be given to more fire-resistant materials such as corrugated metal pipe or concrete. • Consider using metal or concrete culverts instead of plastic liners, because these liners are difficult to extinguish when ignited. • Only use HDPE pipe if it is buried underground and has metal end sections.

Material use	Advice
Other ancillary structures	<p>Consideration should be given to the use of non-flammable and non-combustible materials such as concrete and metal instead of plastic or rubber for all ancillary structures including, but not limited to:</p> <ul style="list-style-type: none"> • noise walls • crash barriers • guideposts • signage and ITS housings • wildlife crossings • turf reinforcement etc. • roadside furniture • rest area structures.

It should be noted that there may be trade-offs in terms of selecting non-flammable materials. For example, the use of recycled materials in road infrastructure is increasing. However, in certain circumstances and uses, these materials may not be fire-resistant. Table 4.4 provides a general summary of how some materials are affected by the heat of a typical bushfire. A bushfire temperature range of 600 °C (tip of the fire) to 1,100 °C (base of the fire) has been assumed.

Potential side-effects of a material catching alight should also be considered such as toxic fumes or micro-plastics. Conversely, substituting non-flammable materials or low-impact materials may have a cost impact. It is, therefore, up to the discretion of the road agency on how the material selection advice is implemented.

It may not be possible to 'engineer out' all high-risk materials and therefore it is important to understand the general impact of a fire on different material components and features. This will allow the potential consequences and impacts to be considered and accounted for in the planning, design and future maintenance phases. It is also important to note that fire will impact materials differently depending on their application.

Table 4.4: Effect of bushfire on materials

Material	Impact of bushfire
Metals	<ul style="list-style-type: none"> • Potential deterioration of mechanical properties depending on fire temperature and exposure time. • Heat from fire and subsequent cooling may cause buckling of metal.
Plastics	<ul style="list-style-type: none"> • Plastics will melt and burn in a bushfire setting; however, they should extinguish easily once heat source is removed.
Rubber	<ul style="list-style-type: none"> • Rubber will melt and burn in a bushfire setting. Once rubber starts to burn it is hard to extinguish.
Glass	<ul style="list-style-type: none"> • Glass should not melt in a bushfire setting. Therefore, recycled crushed glass used in pavements or for drainage should not be directly impacted by the fire. • Glass used for windows, doors, etc. may break due to non-uniform heating.
Timber	<ul style="list-style-type: none"> • Timber or other wooden structures will burn in a bushfire setting (Figure 4.9).
Concrete	<ul style="list-style-type: none"> • Mechanical and physical deterioration such as cracking, loss of strength, colour change. • Concrete can start honeycombing and become porous, causing spalling. • Concrete in reinforced structures may see loss of bond between concrete and steel due to differences in thermal expansion properties and thermal conductivity.
Bitumen	<ul style="list-style-type: none"> • Bitumen binder will oxidise and become hard and brittle when heated to high temperatures and can even burn if the temperature it is exposed to is significantly high. • Aggregates may dislodge from road surfaces (Figure 4.7).

Figure 4.7: Damage to pavement materials from bushfires (left image: asphalt; right image: sprayed seal,)



Source: ARRB.

Figure 4.8: Turf reinforced matting crumbling as a result of exposure to the elements



Source: TMR.

Figure 4.9: Bushfire damage to timber bridge



Source: ABC News, <https://www.abc.net.au/news/2020-02-21/burnt-bridge-at-tunbridge-1/11987646?nw=0> , VicRoads, <https://www.vicroads.vic.gov.au/-/media/files/technical-documents-new/technical-notes/technical-note-tn-102--fire-damaged-concrete.ashx>.

4.7.5 Roadside Design Strategies

Management objective: The road agency representative should provide design policies, guidance and specifications to ensure roadside design is undertaken with an appropriate level of bushfire consideration.

In the context of this framework, roadside design refers to all materials present between the edge of the trafficked road and the bordering land boundary lines. Further guidance on the typical road design for a clear zone from the edge of the trafficked way is provided in Appendix A.

Effective bushfire roadside design strategies should consider the following objectives:

- Prevent fires from starting on roadsides.
- Contain roadside fires and slow the spread if they occur.
- Manage the safety of road users.
- Provide control line options.
- Ensure preservation of infrastructure to a condition that allows swift restoration and recovery after the fire.

The designer's capacity to influence and achieve the above objectives is limited and generally restricted by the site constraints and context including topography, geography and capacity to prescribe vegetation. The site-specific context will influence the designs and decision-making process. Table 4.5 provides design suggestions that could be implemented as part of an overall effort to improve bushfire resilience within the roadside environment. These suggestions are depicted in Figure 4.10.

Table 4.5: Roadside design prevention strategies

Strategy	Design action	Justification
Protection zone	<ul style="list-style-type: none"> • Implement a protection zone around structures and zones that have been identified as critical, for example, timber bridges which have been defined as part of a critical route for disaster evacuation. • Design for a minimum gap (based on road agency standards) between trees and critical structures. • Create a firebreak to interrupt the continuity of vegetation and litter. • Ensure there is a gap between shrubs and trees and that they are not clumped together. 	The aim of the protection zone is to reduce the fuel that can burn, to ensure that there will be no direct flame contact from a bushfire, and to reduce the risk of ember attacks.
Vegetation-free zones	Implement vegetation-free zones along roadsides. <i>Where clear zones or maintenance zones are in place, specific vegetation-free zones may not be required.</i>	Vegetation-free zones allow for containment of localised fires that may have started on the roadside. Furthermore, this provides regions where vehicles can safely stop without creating the risk of grass fire through exhaust and heat. These insertions in the roadside environment may also assist in establishing firebreaks in the event of a bushfire.
Specifying plant material in roadside and verge design	Ensure appropriate plant types are selected for roadside verges if the area is known to be bushfire prone.	Vegetation fuel load varies by plant species. Therefore, in bushfire-prone areas it is advantageous to specify plant matter that is associated with lower overall fuel load.
Inert material firebreaks	Inert materials should be used in conjunction with vegetation-free zones to create a firebreak between the road and the landscape in high-risk areas.	Similar to vegetation-free zones, but with the incorporation of an inert material adding an additional level of resilience. While this may increase the cost of construction, it may reduce the overall maintenance requirement as vegetation will not grow and require treatment in these regions. This may be particularly beneficial in remote areas that have a cost of access when implementing other maintenance practices.

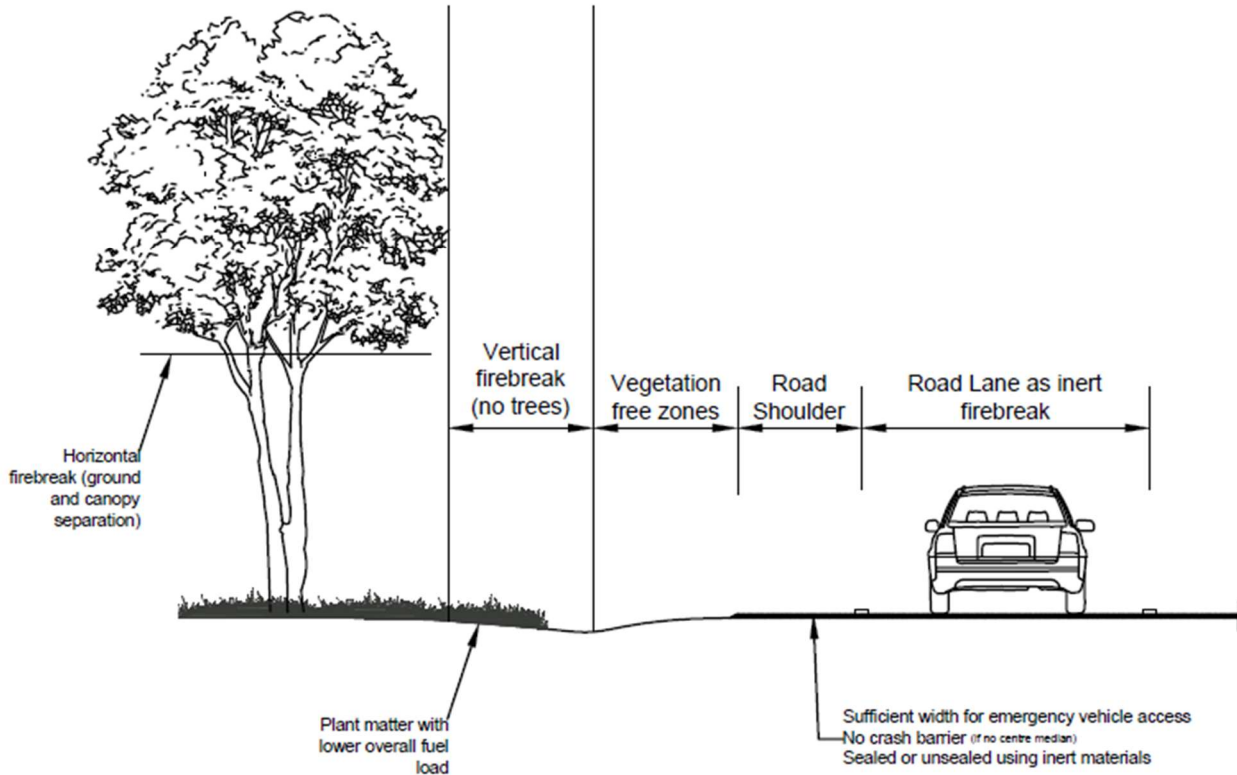
Strategy	Design action	Justification
Vertical & Horizontal firebreaks	<p>Where possible, vegetation heights should be reduced close to the road as a vertical firebreak. This includes large trees and flammable materials used for roadside furniture.</p> <p>Horizontal firebreaks can be defined as separating ground fuels from the canopy i.e. mowing, slashing, trimming and clearing shrubs or mid-storey, and under-pruning i.e. removing low tree branches. Vertical firebreaks should be considered in conjunction with other roadside design strategies.</p>	<p>Tall trees provide a means of fire transfer between adjacent sides of the road. In addition, large trees can fall on the road creating obstacles in evacuation. Removal of low tree branches reduces the risk of fire on the ground from reaching the canopy.</p> <p>Stakeholder engagement remains a powerful tool in the consideration of firebreak locations. Where practical, seeking the opinion of fire authorities may add benefit in determining optimal locations, as this will be the primary organisation capitalising on this design strategy.</p>
Reducing slope of the batter	<p>Where possible, if batter slopes can be reduced, this may prevent the speed at which fire can spread in a road corridor.</p>	<p>This would need to be considered with trade-offs in land management, road safety, etc.</p> <p>From a road safety perspective, reducing the steepness of roadside embankment slopes to less than 1:6 will allow a greater chance for drivers to regain control of their vehicle in the event that smoke has reduced the visibility of the road alignment.</p>

Notes:

- How these strategies are implemented (i.e. for critical assets) is at the discretion of the road agency.
- Not all of these preventative activities will be undertaken directly by the road agency. However, they should be considered as potential opportunities for roadside management.
- Where works are not undertaken by the road agency (i.e. landowners and farmers undertaking grazing), this advice may be subject to road corridor permits.
- In specific circumstances, such as on slopes, the use of fire-resistant materials rather than vegetation on the roadside should be considered.
- Suitable fire-resistant materials are outlined in Section 4.7.4.

In addition to the strategies listed in the table, while not always a factor that infrastructure designers have control over, consideration should be given to the sloping terrain around the roadside. Surfaces sloping upwards on a positive grade increase the relative spread of a bushfire, and vice versa, where a negative grade will reduce the spread. This consideration may be of relevance on a higher level, when undertaking evaluation of new road alignments and the effects on the surrounding environment.

Figure 4.10: Illustration of roadside design prevention strategies



4.7.6 Roadside Furniture Design Strategies

Management objective: The road agency representative should ensure that bushfire risk is integrated into the design and maintenance strategies for roadside furniture.

Roadside furniture design strategies to be considered for bushfire prevention include:

- removing vegetation growth around roadside furniture
- using non-flammable materials, such as metal for posts (rather than timber), as combustible materials are more likely to be damaged in a bushfire .

An example of a roadside that has been affected by a bushfire is shown in Figure 4.11. The left-hand image shows vegetation close to the road and timber guideposts, the right-hand image shows how this was damaged by a bushfire. All flammable materials have been damaged .

Figure 4.11: Bushfire damage to roadsides



Source: Google Maps (2022), 'Victoria', map data, Google, California, USA.

Further, consideration should be given to how roadside furniture can assist with disaster prevention, preparedness, response and recovery. This includes:

- Intelligent transport systems (ITS) that can be used for the communication of hazards, road closures and alternative routes. The location of ITS at key decision points along the network is essential so that road users can be notified and diverted if there is danger or road closures.
- Truck stops and rest areas that may have infrastructure such as signage, picnic tables and toilet blocks. When planning, designing and constructing roadside stopping areas in bushfire-prone areas, response and preventative strategies should be considered. Where evacuation facilities are not available, any part of the road reserve, such as a roadside stopping area, may be used as an evacuation facility or to allow heavy vehicles to turn around before reaching a fire zone, especially those carrying livestock or flammable, dangerous cargo.
- Potential inclusion of positional indicators in high-risk regional or isolated areas to aid with targeted emergency response or evacuation requirements.

All roadside furniture design strategies should be implemented in accordance with road agency standards, specifications and guidelines as detailed in Appendix A. In addition, stakeholders, as identified in Section 3.3, should be consulted to ensure any roadside furniture not owned by the road agency has been considered in bushfire prevention and preparedness.

4.8 Construction

Management objective: All construction activities should be undertaken with consideration of bushfire risk and working in a high-risk setting. Construction activities should not impede emergency service access to other areas, or impact planned community evacuation routes.

Construction is defined as an action to provide a new pavement, structure, or roadside asset or to increase either the strength or capacity or both of an existing asset, beyond the initial as-constructed values.

4.8.1 Working in a High-risk Setting

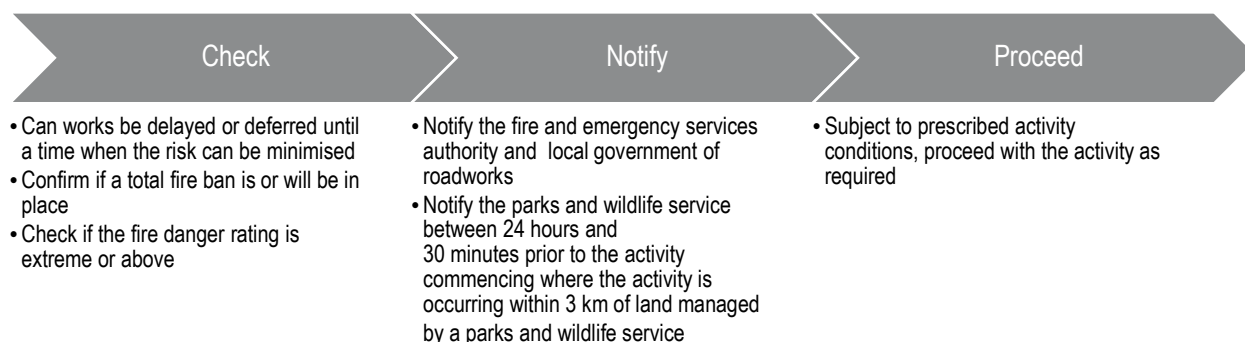
Management objective: When undertaking road construction (and maintenance, see Section 4.9.1), the road agency representative needs to ensure that all emergency advice is monitored and followed. This includes what works can be undertaken during a total fire ban. If possible, deferring high-risk work to a time when the risk setting is lower should be considered.

Roadwork should only be carried out by (or on behalf of) a public authority.

A risk matrix should be developed as part of the planning process for construction or other activities undertaken in the road reserve on days where bushfires are considered a high risk or when a total fire ban is in place. This risk assessment should include specific procedures for activities that may be considered high risk. This may involve restriction of some equipment and additional control measures for equipment that produces sparks, open flame or excessive exhaust. As a minimum, a contractor should be required to identify these risks, and enforce appropriate mitigation techniques.

Figure 4.12 provides a simple set of steps to follow in the instance of road construction and maintenance in a high-risk location. This process should be implemented in conjunction with any required permits or exemptions and include the requirements outlined in the project contract and/or specification documents.

Figure 4.12: Steps to follow for roadwork in high-risk settings



Note: This process should be adapted by the relevant authority in the jurisdiction where it is being implemented.

When undertaking construction in a bushfire-prone area, consideration needs to be given to:

- risk reduction activities to continue work (e.g. understanding and planning mitigation)
- site tidiness and storage of flammable materials
- smoking restrictions and other restricted areas
- access to water for both drinking and firefighting purposes
- availability of fire extinguishers, fire blankets, water tanks and water trucks
- maintenance of plant and equipment to avoid fuel or oil leaks
- the use of spark arresters and other fire prevention methods on plant equipment.

If an emergency does occur within the construction site, early warning to all operating crews is imperative. In addition, planned evacuation routes from the site should be established and, therefore, consideration should also be given to the accessibility of the construction site if an emergency occurs.

4.8.2 Establishing Vegetation

Management objective: When establishing vegetation, the road agency representative should develop a work plan to identify the location of works to be completed, the roadside management objective being managed, and the type of treatment being carried out – for all selected and prioritised treatments. The roadside treatment selection process is outlined in Section 4.6.3.

Vegetation refers to the cover of plants suited to the location and involves:

- preparation of finished soil surfaces, e.g. by ripping or tilling the soil surface and resspreading site topsoil and chipped vegetation, to assist regeneration to occur naturally
- generation of vegetation:
 - through the seed existing within the site topsoil if this is stripped, and resspread during the earthworks or
 - from the seed that is carried in the cleared site vegetation that is chipped and resspread over the soil
- seeding by direct broadcast by hand or machine onto the prepared soil surface
- planting of nursery-grown plants in pots or small tubes by hand or machine
- landscaping including grassing and irrigated planting beds, feature paving, etc; undertaken for functional and amenity objectives, for example at key locations along urban roads and town entries.

The selection of vegetation techniques should be based on the value of the asset needing protection and the risk of bushfire in the area where the asset is located. In order to designate a treatment, the cost should be weighed against the value of the asset and the potential success that the treatment will have in the area. The vegetation treatment selection process is outlined in Section 4.6.3.

Vegetation planning and establishment needs to have regard to future fire hazards created by the plantings, based on the risk to the road and its function and criticality during a bushfire.

Vegetation placement should consider the provision of unplanted fire access tracks, trafficable to fire-fighting vehicles, along road reserve boundaries where verges are wide and adjacent to sensitive land uses such as residences.

4.9 Maintenance

Management objective: Roadside maintenance should be undertaken to prevent or minimise the impacts of a bushfire on the road corridor. Well-maintained roadsides also ensure safe, efficient, and effective access during an emergency response.

Maintenance is defined as all actions necessary for retaining an asset as near as practicable to its original condition, or for reducing its rate of deterioration.

4.9.1 Working in a High-risk Setting

Management objective: When undertaking road maintenance in preparation for a bushfire season, the road agency representative needs to consider whether there are regulations in place or rules that need to be followed for projects undertaken in high bushfire risk areas.

Roadwork, as part of road maintenance, should only be undertaken in accordance with Section 4.8.1.

4.9.2 Developing a Works Plan

Management objective: When developing a works plan for maintenance activities, the road agency representative should give priority to key risk areas and critical infrastructure.

Works plans are used to identify, prioritise and implement prevention and maintenance programs. There are five major categories of works to be considered in a bushfire recovery works plan:

- **Maintenance:** Regular ongoing day-to-day work necessary to keep assets operational, e.g. road patching, line marking upgrades, road sign maintenance, removal of flammable hazards including oil build-up from traffic, litter and drainage maintenance.
- **Operations:** Regular activities to provide public health, safety and amenities, e.g. street sweeping, grass mowing, street lighting and tree trimming.
- **Renewal/refurbishment:** Restores, rehabilitates, replaces the existing asset to its original capacity, e.g. gravel resheeting of unsealed road infrastructure – to restore to the same level of service.
- **Upgrades/improvements:** Enhances the existing asset to provide higher levels of service, e.g. reseal, sealing of unsealed roads and widen seal (verge sealing).
- **New/expansion of assets:** Creation of a new asset to meet additional service level requirements, e.g. new building or new service.

As discussed in Section 3.1.2, developing a list of critical infrastructure assets will help identify key safety infrastructure to be inspected and determine if it should be repaired, replaced or removed. The road agency representative should identify potential controls for areas where key infrastructure elements are impacted. These controls may include detouring, changes in operational speed and installation of temporary signage.

Further, a works plan should consider whether those involved have received adequate training in bushfire risk management and what to do in the event of an emergency.

4.9.3 Management of Tree Hazards

Management objective: The road agency representative should ensure that tree hazards along the roadside are effectively managed during disaster response to ensure critical routes remain open to the

community for evacuations and emergency response. This will need to be managed and coordinated on a case-by-case basis by the responsible authorities.

Readiness and response activities should be undertaken in the immediate lead-up to and during an emergency. A key activity is ensuring that organisations, the community and individuals are informed and ready to respond (e.g. readiness activities). This phase extends to response, relief and initial recovery activities which include:

- If there are routes that have been assessed and identified with tree hazards, these areas should be prioritised for crew deployment in the event of an emergency (if it is safe to do so). This will ensure that the roads do not become blocked or if blockages occur, they can be promptly removed.
- Ensuring incoming emergency response teams or community members evacuating are notified about any tree hazard identified on or around the incident either on the ground or on access routes.
- Prior to commencement of emergency response operations, the responsible authority should ensure a tree hazard assessment is undertaken for the operational area (the operational area includes escape routes and safety zones, and these should be identified and assessed as soon as practical).
- Ensuring incoming emergency response teams withdraw from and establish an exclusion zone where a tree hazard has been identified, especially in high-risk conditions (such as periods of high wind).
- Ensuring incoming emergency response teams activate traffic management procedures to minimise the risk from tree hazards, if it is safe to do so.
- Ensuring incoming emergency response teams move to abandon control lines in areas with high volumes of tree hazards.
- If possible and if safe to do so, emergency response teams should remove trees to create a path for evacuation and emergency access (for example, a dozer could be used to push trees aside to reinstate access; then, following the event, these trees will be removed).

Examples of tree hazards are shown in Figure 4.13. These images show where tree branches have fallen on the road during or after a bushfire. The tree hazards can create unsafe driving conditions, or can block the road entirely causing issues with accessibility.

Figure 4.13: Tree hazards



Source: Australian Institute for Disaster Resilience Knowledge Hub, <https://knowledge.aidr.org.au/resources/black-summer-bushfires-qld-2019/>, viewed 01/09/2021; ABC News, <https://www.abc.net.au/news/2020-01-12/fire-hit-roads-have-army-crews-remove-killer-trees-in-victoria/11860638>, viewed 24/02/22.

4.9.4 Undertaking Roadside Vegetation Maintenance

Management objective: The road agency representative should develop a work plan, identifying the location of works to be completed, the roadside management objective being managed, and the type of treatment being carried out – for all selected and prioritised treatments. This should be undertaken in accordance with the roadside treatment selection process outlined in Section 4.6.3.

The road agency representative should develop a dataset/mapping tool to identify when areas have been managed with prevention activities or when these areas are due to be managed, relative to their vegetation type and category.

As a wider strategy, the road agency representative should investigate the development of a risk-based maintenance prioritisation strategy utilising a series of vegetation and fuel reduction techniques.

Note: Areas of environmental significance will require permits to undertake vegetation clearing. These areas should also be noted when updating a maintenance tracking database.

Roadside vegetation management strategies can be used to reduce bushfire risk and prevent bushfire impacts during the maintenance phase of the road infrastructure project life cycle. This includes fuel reduction activities, which can be undertaken in conjunction with road maintenance. In addition, as part of road maintenance, all strategies implemented as part of roadside design need to be maintained (i.e. vegetation-free zones). Specific strategies, including recurring maintenance periods, should be developed for high-risk areas or vulnerable network locations.

It is of key importance where road maintenance strategies have been implemented that these are adequately reported and communicated within the road agency (i.e. in maintenance records) and with stakeholders. This will ensure that resources can be effectively prioritised in terms of areas that have had their bushfire risk managed and areas that have not. The following process should be undertaken when considering vegetation removal:

- Use the risk assessment undertaken to identify priority roads for fire mitigation treatments (as outlined in Section 3.1.1).
- Undertake a roadside treatment selection process through collaboration with other agencies.
- Develop a plan to document the works to be undertaken and their objective .

Potential roadside mitigation strategies for bushfire risk, that can be undertaken during maintenance, are presented in Table 4.6.

Table 4.6: Roadside vegetation mitigation strategies in maintenance

Strategy	Recommended road agency representative action	Justification
Fuel reduction, prescribed and planned burning	<ul style="list-style-type: none"> • Prescribed burning should be undertaken in collaboration with the fire service or land manager to reduce fuel loads along roadsides, particularly along roads which are critical access and evacuation points. • Effectiveness of treatment may be enhanced by conducting burning in adjacent land to achieve a wider treatment zone. • Ensure effective and periodic drainage maintenance to prevent overgrowth of vegetation or concentrated collection of fuel loads. 	<ul style="list-style-type: none"> • Reduces the overall fuel load or hazard in the area, thus reducing the localised intensity of bushfires that may occur.
Cultural burning	<ul style="list-style-type: none"> • Collaboration with local Indigenous Australian communities should take place to understand the landscape and cultural burning practices. 	<ul style="list-style-type: none"> • Increasing engagement between traditional owners and other land managers in building an understanding of the nuances and the opportunities to improve fire management practices through a partnership approach.

Strategy	Recommended road agency representative action	Justification
Slashing, mowing and baling	<ul style="list-style-type: none"> • Clear accessible grass within the road corridor. • If baling is undertaken, remove the bales from areas identified as medium to high risk of a bushfire occurring. 	<ul style="list-style-type: none"> • Reduces the overall fuel load in the area, thus reducing the intensity of bushfires that may occur. • Reduces the height of fuels, thus reducing aeration of fuels and increasing the separation of ground fuels from canopies.
Herbicide treatment	<ul style="list-style-type: none"> • Spray road verges with herbicide. • Monitor and treat as required recently burnt areas. 	<ul style="list-style-type: none"> • Aids in the management of invasive plants. • Reduces the overall fuel load in the area, thus reducing the intensity of bushfires that may occur. • This approach should be undertaken cautiously as in the short-term herbicide may increase fuel load as plant matter dries out. • Reduces the height of fuels, thus reducing aeration of fuels and increasing the separation of ground fuels from canopies. • Burning can promote the growth of weeds and re-establishment of fuels, and this must be controlled.
Grazing	<ul style="list-style-type: none"> • Establish agreements with farmers in rural regions to access roadside areas and maintain through livestock grazing. 	<ul style="list-style-type: none"> • Reduces the overall fuel load in the area, thus reducing the intensity of bushfires that may occur within the region. • This approach may be particularly advantageous in rural settings, where it is not convenient to transport slashing, mowing and baling equipment. • Provides an opportunity to educate farmers on maintaining their property when directly adjacent to a roadside.
Tree management ⁽¹⁾	<ul style="list-style-type: none"> • Separation of tree crowns where trees are located close together. • Under-pruning of trees to allow for increased canopy separation from ground vegetation. • Removal of tree branches overhanging structures and fences. • Removal of dead trees unless there are specific circumstances where these provide habitat (consideration of environmental trade-off). 	<ul style="list-style-type: none"> • Assists with the implementation and maintenance of vertical firebreaks.
Scrub rolling	<ul style="list-style-type: none"> • Undertake scrub rolling in areas with minimal ground cover and high levels of aerated fuels. • The most common and cost-effective form of landscape-level scrub rolling involves dragging a large 'chain' between two bulldozers to create a fuel-reduced strip up to 100 m wide, subsequently burnt under prescribed conditions. • An alternative method is blade-up rolling, which involves using a bulldozer with a slightly elevated blade to push over vegetation. This produces a similar result but is only cost-effective for treatment areas (strips) up to about 20 m wide. 	<ul style="list-style-type: none"> • Scrub rolling is a form of mechanical fuel reduction commonly undertaken in vegetation communities with minimal ground cover and high levels of aerated fuels. • The aim is to 'lay over' vegetation to create a modified fuel zone or strip strategically across the landscape to assist with both mitigation and suppression activities. These may be either permanent or temporary. • Scrub rolling is only considered a cost-effective fuel reduction treatment when there is a commitment to ongoing management and maintenance to maintain risk reduction benefits over time.

1. Tree management is explored further in Section 4.9.3.

As maintenance activities are often associated with limited budgets and resources, risk-based prioritisation is necessary to ensure the frequency and treatment standard applied is proportional to the relative risk of a bushfire occurring. Risk should not be the only factor taken into consideration; location, practicality, economic and physical factors also need to be considered.

Table 4.7 provides an outline of treatment standards which could be derived from a risk assessment.

Table 4.7: Roadside vegetation management criteria and treatment standards

Priority rating and risk	Treatment type	Treatment standard
High	Permanent	Permanently treated roads are managed to the current maintenance standards specified in maintenance contracts plus identified annual fire mitigation treatments which may include removal of hazardous trees or limbs that are likely to fall on a road in high winds plus any other treatment as agreed to by all agencies involved in integrated fire management planning.
Medium	Periodic	Periodically treated roads are managed to the current maintenance standards specified in maintenance contracts plus identified annual fire mitigation treatments which may include removal of hazardous trees or limbs that are likely to fall on a road in high winds.
Low	Routine	Routinely treated roads are managed to the current maintenance standards specified in maintenance contracts.

The approach to maintenance should be dynamic as bushfires occur seasonally. This will typically mean a greater allocation of resources in the months approaching and throughout the bushfire season. Consideration should also be given to regions that have previously experienced a bushfire, as typically the fuel load will have burnt off in these regions and may not represent as great a risk as modelling may indicate.

Although it has been identified that many of the vegetation maintenance strategies suggested may not reduce the rate at which a fire may spread within the road corridor, they do reduce the intensity of the fires and decrease the fuel available to support bushfire ignition. Failure to undertake appropriate levels of maintenance may not only expose a region to bushfire risk but may reverse efforts undertaken in design as encroaching vegetation compromises areas designated as firebreaks and clearance zones.

Routine or periodic maintenance of roadsides should not be reserved for major roads. Periodic maintenance of fire-access tracks, to ensure the availability of these during an emergency, should also be considered.

An example of excessive vegetation is shown in Figure 4.14. The vegetation is overgrown with the underside of the structure barely visible. In a bushfire, this would create fuel close to the structure, increasing the likelihood of severe damage to the structure.

Figure 4.14: Excessive vegetation encroaching structure



Source: ARRB.

4.9.5 Undertaking Pavement Maintenance

Management objective: Undertake pavement maintenance activities as required based on an assessment of bushfire damage. Where the opportunity arises to make improvements or undertake preventative maintenance, this should be implemented in conjunction with recovery maintenance activities. This approach is known as 'build-back-better'.

In order to identify the impacts of a bushfire on a pavement to enable maintenance works planning, visual, condition and structural assessments should be undertaken once it is safe to do so.

Visual assessment

When bitumen binders are subjected to heat from a bushfire, evidence has shown that the bitumen binder will oxidise and become hard and brittle. The bitumen may also burn if the temperature it is exposed to is significantly high. The exact temperature at which damage will occur will depend on the type of bitumen used in the construction of the seal.





When oxidisation has occurred and a seal has become brittle, remedial treatments need to be undertaken in order to preserve the pavement surface and ensure additional deterioration does not occur. Signs that binder oxidisation has occurred include the stripping of aggregate from the seal or cracking of the seal.

Sections where the seal has been lost completely due to fire should be replaced with a treatment appropriate to the size of the area affected. All cracks should be sealed to prevent moisture ingress into the underlying pavement material.

Although the damage from a bushfire may not pose an immediate serviceability issue for the road, it is likely that without treatment accelerated deterioration of the surface (and hence overall pavement) will occur. All roads known to have been damaged by a fire should be monitored for further deterioration on a six-monthly basis and repairs prioritised as a part of a broader pavement maintenance program.

Examples of the types of damage to seals to look for when undertaking visual assessments are provided in Figure 4.15.

Figure 4.15: Damage to investigate in visual assessment

	<p>Fire damage – vitrified binder and loss of aggregate</p> <ul style="list-style-type: none"> • Fire damaged area of spray seal close to the edge of the carriageway. • Bitumen binder appears black and glassy (almost vitrified in appearance). Seal was noted to be more brittle than adjacent unburnt area. • Localised loss of coarse aggregate from matrix of seal is apparent in burnt area.
	<p>Damage from falling debris</p> <ul style="list-style-type: none"> • Serious damage to spray seal most likely due to falling tree branch. Bitumen appears friable. Coarse aggregate has been lost from seal and is apparent on the surface of the pavement.
	<p>Wheel-path damage from radiant heat</p> <ul style="list-style-type: none"> • Photograph shows close-up of flushed and excess bitumen on surface of asphalt in vehicle wheel paths. • The key serviceability issue for the road surface is reduced wet-weather skid resistance.
	<p>Fire damage on asphalt</p> <ul style="list-style-type: none"> • Photograph shows damage to asphalt. Bitumen was noted to be friable and coarse aggregate was observed to have been lost from the asphalt matrix.

Source: ARRB.

Condition assessment

For a condition assessment, a pavement condition index (PCI) analysis should be undertaken.

The process for undertaking this analysis is:

1. automated collection of network data
2. calculation of the PCI
3. identification of changes using a dilapidation or comparison technique with previous network condition assessments (or through visual surveys in priority locations).

For a PCI assessment methodology, refer to Appendix A. An example of a PCI assessment for a road network is shown in Figure 4.16.

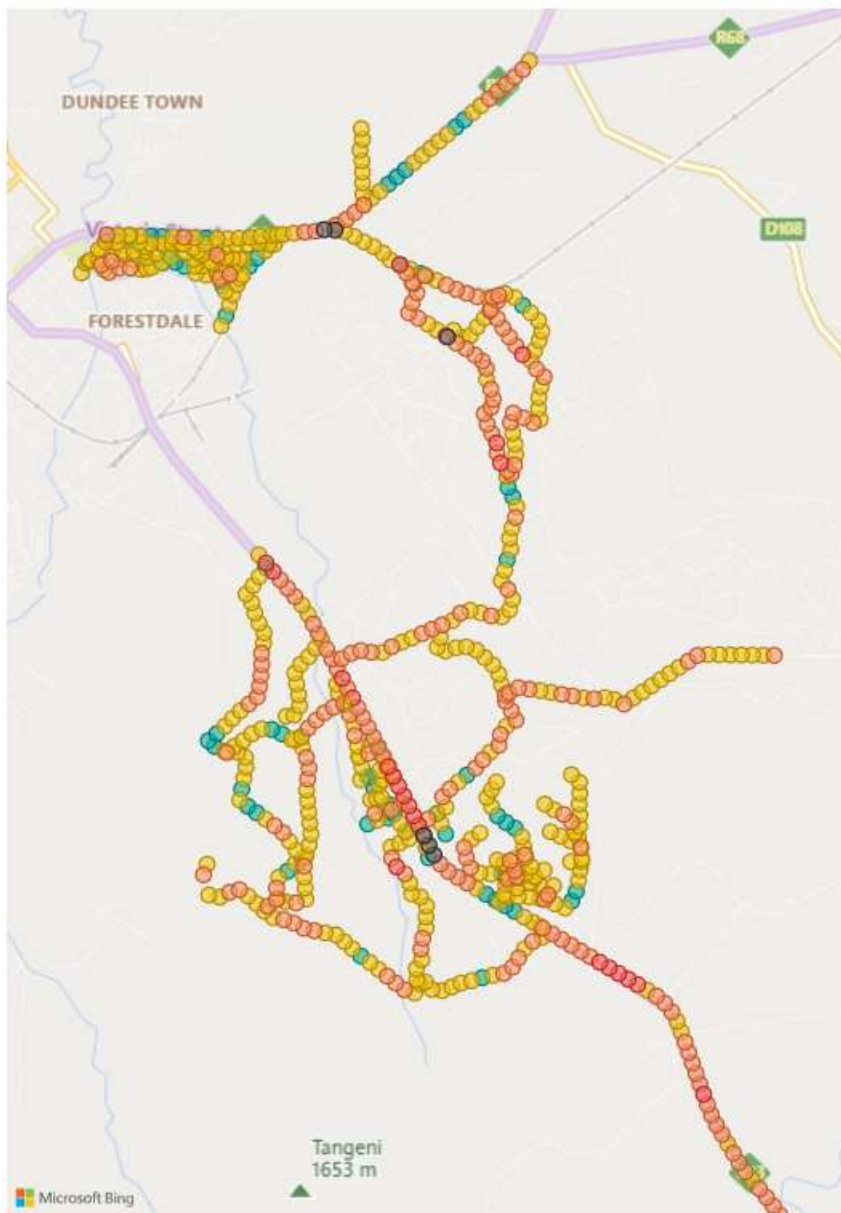
It is recommended that road agencies have a clear understanding of the condition of their road network. This will mean that if a condition survey is undertaken after a fire, there will be baseline data available for comparison allowing the agency to understand exactly what damage has occurred as a result of the fire. Quantifying this damage may also help in selecting the most appropriate treatments for pavements in high-risk fire areas to lessen the impact of a future fire.

The outcomes of this assessment will assist the road agency with identifying maintenance needs. This maintenance can be on an as-needed basis or the scheduled routine maintenance could be brought forward.

Figure 4.16: Example of PCI assessment for a road network, 100 m road segments

Pavement Condition Index

Condition 1 - VERY GOOD 2 - GOOD 3 - FAIR 4 - POOR 5 - VERY POOR



Note: This is not actual data.

Structural assessment

A structural assessment will provide information on pavement distress which may not be visible. A structural assessment can be undertaken using pavement deflection data collected with a traffic speed deflectometer or a falling weight deflectometer.

Structural assessments are useful as they can provide information on the remaining useful life of a pavement structure. Again, a comparison with baseline data can be undertaken to determine how the bushfire and associated fire traffic has affected pavement life. This can then be costed as a percentage of the value of the asset.

For remaining useful life-assessment methodology, refer to Appendix A.

4.9.6 Undertaking Inspections and Maintenance of Structures

Management objective: The road agency representative should ensure that the appropriate levels of inspections are undertaken on structures after a bushfire and the corresponding administrative controls are enforced.

The road agency representative should ensure that there is specific guidance available in relation to bushfires when it comes to vulnerable structures, such as timber bridges. This may include additional documentation, research, and specifications relative to standard practice.

Inspections of structures after a bushfire are necessary to determine damage to or deterioration of condition. At a minimum, a visual inspection (Level 1) should be undertaken after a bushfire has occurred. Examples of damage to inspect are shown in Figure 4.17. A further explanation of the effects of fire damage on structural materials such as steel, timber and concrete is provided in Table 4.4.

Figure 4.17: Fire damage to structures



Source: ABC News, <https://www.abc.net.au/news/2020-02-21/burnt-bridge-at-tunbridge-1/11987646?nw=0> , VicRoads, <https://www.vicroads.vic.gov.au/-/media/files/technical-documents-new/technical-notes/technical-note-tn-102--fire-damaged-concrete.ashx>.

The inspection should be flagged as specialised (not considered part of the routine inspection program) and focus on damage associated with a fire. The scope of the inspection should include review of existing asset records prior to the bushfire so that damage can be differentiated from historic wear.

Defects or evidence of significant fire exposure should prompt further tiers of inspection (Level 2) or engineering investigations (Level 3), as required. Destructive and non-destructive techniques should be utilised to assess the remaining strength properties of materials, as strength loss after a fire cannot always be perceived through visual methods.

In the short term, assessment outcomes should be used to determine the level of controls enforced. This may range from no action required, administrative controls such as load limiting and lane restrictions (lane restrictions can be utilised if only particular elements of the structure have been damaged, e.g. the edge stringers), speed restrictions and in a worst-case scenario, closure of the roadway. In the long term, this inspection may influence maintenance budget allocations or an options analysis considering replacement and strengthening solutions.

Special consideration should be given to timber structures, where a coordinated response directly after a fire may be beneficial for early intervention as the bridge may have caught fire in a small section but not progressed to full engulfment of the structure. Furthermore, methods of improving the resilience of timber bridges to bushfires should be considered and implemented as part of a broader asset management strategy.

For existing structures, targeted maintenance of components that have been previously identified as contributory to poor fire performance such as timber deck planks particularly with exposed ends, splitting timber pile and timber wingwalls, may decrease the likelihood of serious damage to the overall structure in a

bushfire. Together with identified geographical risk areas, this approach could assist in the prioritisation of repairs as part of the overall asset management process.

Where practical, design strategies for bushfire-resilient structures discussed in Section 4.7.3 could be incorporated into maintenance works, thereby improving bushfire resilience of the structure in the process of undertaking necessary works. This plays into a wider strategy, by which any upgrade or repairs to structures should not degrade the fire performance to any extent. Fire resistance should be either unchanged or improved by any works undertaken.

4.9.7 Revegetation

Management objective: The road agency representative should ensure revegetation is undertaken within an appropriate period of time to prevent soil erosion from rainfall impact and surface water flows where the land is now bare due to bushfire destruction. Immediate cover should be prioritised in high-risk areas such as steep slopes and areas where water movement is likely to occur.

Revegetation refers to the re-establishment of a cover of vegetation suited to the location. The roadside vegetation process is outlined in Section 4.6.3.

4.9.8 Asset Upgrades

Management objective: In order to ensure the future resilience of infrastructure following a bushfire, asset upgrades should be made, where possible. This includes the implementation of the prevention strategies defined for road design, roadside design and structural design.

Critical-route analysis can be used to determine locations where asset upgrades may be beneficial. Critical-route analysis is outlined in Section 4.6.1.

4.10 Operations

Management objective: All road operations activities should be undertaken with consideration for the bushfire risk in the area. If an emergency occurs, all road operations responses should be coordinated with stakeholders.

Operations refers to the activities undertaken to monitor, manage, and respond to alerts on the road network to maintain the expected level of service. Road operations before, during and after a bushfire require a multi-agency approach. All relevant stakeholders, as outlined in Section 3.3 should be consulted as part of road operations activities.

4.10.1 Monitoring of Implemented Bushfire Management Strategies

Management objective: The road agency representative should ensure that a monitoring plan has been developed and implemented to assess the ongoing effectiveness of bushfire prevention strategies.

This monitoring will identify changes to prevention strategies based on how well they perform in future events. This may involve routine internal audits based on compliance and targets set as part of the overall strategy. It is critical that outcomes and lessons learnt be factored into the following year's priorities to ensure efficient use of the program budget.

4.10.2 Defining Key Access and Egress Roads and Fire Control Lines

Management objective: The road agency representative should employ a prioritisation system for characterising key access and egress roads.

Key access and egress roads are those which are critical in disaster response for either the evacuation of a community or use by emergency service vehicles. Priority should be given to these roads when undertaking bushfire prevention and preparedness activities, and controls should be in place to ensure that the roads can remain open during response activities.

Key access and egress roads should be categorised as outlined in Table 4.8.

Table 4.8: Road prioritisation categories

Road classification	Description	Bushfire management requirements
Priority 1 roads, structures and/or routes	Key access and egress roads for communities and the travelling public via major link roads.	<ul style="list-style-type: none"> Implementation of techniques for ignition control, dangerous trees treatment, critical infrastructure protection, emergency services access and emergency services turning areas are critical.
Priority 2 roads, structures and/or routes	Critical access and egress for high bushfire risk communities. (These are key roads that provide access for sections of high-risk communities to travel to Priority 1 roads).	<ul style="list-style-type: none"> Consider where access to and from communities is one way, or where vegetation may prohibit the function of a road during a fire. Where practicable the roadsides for Priority 2 roads should be managed to reduce hazards from vegetation.
Priority 3 roads, structures and/or routes	Emergency service roads.	<ul style="list-style-type: none"> Roads should be designed to aid in the transition of emergency vehicles to and from an incident and fire.
Fire trail and fire access track	A trail used for access with local knowledge and suitable fire agency vehicles.	<ul style="list-style-type: none"> Trails require annual pre-summer inspection, followed by identified remedial works to maintain access over this period.
Fire control line	A fire control line is an inclusive term for all constructed or natural barriers and retardant-treated fire edges used to control a fire. Roads defined as strategic fire control lines allow for a dual use in the protection of townships and population centres.	<ul style="list-style-type: none"> There are two main types of strategic fire control lines: <ul style="list-style-type: none"> Active lines: where vegetation should be modified to offer safety to emergency services and allow for firefighting activities. Passive lines: where graded or ploughed-back techniques are used during the progress of a fire. These areas may have pre-planned works done to aid the access of plant and machinery (removal of impediments, rocks, etc.).

Note: In some circumstances, there may be a need to categorise sections of roads as opposed to entire roads. For example, some long roads may have changed ratings throughout the length due to changing conditions.

4.10.3 Understanding Evacuation Plans

Management objective: The road agency representative should understand all effective emergency management plans which have been developed by the local police and fire services. The road agency representative should ensure these plans can be implemented on their network and are effectively communicated to the community through collaboration with these parties.

Evacuation planning is a critical component of bushfire response, with a shared responsibility between individuals and authorities to ensure both private and public infrastructures are suitably prepared should a bushfire occur.

Understanding evacuation routes stipulated by the local police and fire services and assessing these routes within the context of the risk assessment and the critical route analysis (refer to Section 4.6.1) will ensure functional, efficient and safe evacuation and response activities. This understanding also allows for the identification of any high-risk locations or expected areas of poor performance which can be communicated to emergency services and potentially rectified during maintenance or upgrade works.

Evacuation routes should be planned in collaboration with evacuation facilities, and other stakeholders, to ensure that the community has access to the facilities and services it may require and to identify access points from local and major roads. Where an evacuation route includes access or a detour through private property (e.g. active agricultural land, mining leases, etc.) in the event of other road closures, consideration needs to be given to access and road user implications such as access through gates which may need to be unlocked or opened, road user interaction with livestock and operating plant equipment, and other potential hazards along the route.

When developing and disseminating an evacuation plan, the road agency representative should ensure that the plan is suitable for the community that it is intended for (i.e. differences between urban, rural and remote communities).

4.10.4 Traffic Management

Management objective: The road agency representative should ensure that guidance for road closures and traffic management is well-disseminated and understood, and that these strategies are implemented effectively during disaster response.

Traffic management interventions such as traffic management points, road closures and signage play an important role in traffic management and in maintaining public safety during and after a bushfire, and they can protect health and safety or facilitate fire investigations. As an example, the use of intelligent transport systems such as variable message signs can be used to alert drivers of current or planned road closures, road obstructions (e.g. smoke hazards), evacuation routes, locations of evacuation centres, and detours.

Consideration should also be given to the impact of road closures within a bushfire-risk area. If major roads such as highways are closed in bushfire-risk areas, and the alternative is to move evacuation traffic via other minor and major roads, there may be a need to update the specifications to include the alternative routes or detours.

The interventions are determined by operational circumstances. The road agency should have processes for the implementation of traffic management points and road closures, and the coordination of the interventions with emergency services. These processes are referenced in Appendix A.

4.10.5 Consideration of Smoke Hazards

Management objective: The road agency representative should ensure smoke hazards are adequately considered as part of response efforts.

Bushfire smoke contains a mixture of water vapour, airborne particles and gases (such as carbon monoxide, carbon dioxide and nitrogen oxides).

Risk treatments for bushfire smoke hazards are difficult to identify for road design as smoke is considered amongst other hazards such as fog, dust, heavy rain and snow. All these aspects are considered in road design when it comes to features such as gradient, curvature and speed setting.

If these items have been adequately considered, smoke does not need to be considered as a standalone risk when designing roads. Acute or chronic smoke logging (smoke logging refers to the filling of a space with smoke in the event of fire) of the road corridor is best managed through operational arrangements (e.g. traffic management points, speed restrictions).

An example of smoke on the road from a bushfire is shown in Figure 4.18. The smoke is causing issues with visibility on the road, creating unsafe driving conditions.

Figure 4.18: Smoke haze over the road during a bushfire



Source: Australian Institute for Disaster Resilience Knowledge Hub, <https://knowledge.aidr.org.au/resources/black-summer-bushfires-qld-2019/>, viewed 01/09/2021.

4.10.6 Access to Water and Other Services

Management objective: The road agency representative should ensure that appropriate allowances have been made on road-agency-managed land for access to water or other services for emergency response activities. In addition, fire-fighting access to water requirements should be discussed with response agencies and considered in road design and planning.

The requirement for access to water depends on the source and/or whether that source is on private or public land.

Relevant building codes and permit conditions for properties detail a dependence on access for water. For example, if a source of water is a dedicated fire-water-tank supply erected on road agency property as a mandated requirement of the building approval process, access provisions may also be included.

5 Overarching Management Considerations

This framework provides strategies for the management of bushfire impacts in the road corridor to ensure that road assets can continue to provide safe access for the community and emergency services.

When considering the advice provided in this framework, general consideration needs to be given to:

- all bushfire management actions and works determined by the use of the framework are in alignment with legislation and regulatory frameworks
- for the case in which the strategy is being implemented
 - all design, construction, maintenance and operational procedures need to be considered in the context of location, road type, project, budgets and other factors.
- the engagement of all stakeholders who may need to be involved or who are responsible for decision making and implementation of varying strategies
- the environmental trade-offs that may become apparent when undertaking prevention activities
 - jurisdictional environmental law, regulations and management strategies need to be consulted to ensure there is no conflict
- the other assets which are present in the road corridor that may not be managed by the road agency
 - in some instances, other agencies (such as utility providers) may have their own bushfire management strategies which will need to be considered when implementing the practices presented in the framework
- the cultural heritage of the region and engaging the relevant parties in managing and protecting the area.

References

Austrroads 2022, Guide to Road Design Part 6: Roadside Design, Safety and Barriers, Austrroads, Sydney, NSW.

Catchment and Creeks Pty Ltd 2014, Advice note 10 – Turf Reinforcement Mats, <<https://www.catchmentsandcreeks.com.au/docs/TRM-1.pdf>>

Main Roads Western Australia 2019, *Guidelines Climate Change Risk Assessment Version 2*, Main Roads Western Australia, Perth, WA.

O'Connor, G, Dwyer, P, Rice, Z, Lyons, M & Cogo, K 2022, *Incorporating Bushfire Impacts into Road Design Literature Review Report*, project 016847/016920, prepared by ARRB for Queensland Department of Transport and Main Roads under the NACOE program and Main Roads Western Australia under the WARRIP.

Appendix A Documentation

Table A.1 details the guidance documentation and specifications to be read in conjunction with this framework from the Queensland Department of Transport and Main Rads (TMR) and Main Roads Western Australia (M R WA). If utilising this framework in another jurisdiction, the documentation will need to be substituted.

Table A.1: Guidance documentation and specifications

Clause no.	Framework section	Legislation/guidelines	TMR	MRWA	Incorporating Bushfire Impacts into Road Design Research Literature Review Report (O'Connor et al. 2022)	
					Section	Recommendation no.
3	Governance				Section 3.2.1 Section 3.3.1	6
3.1	Understanding Network Vulnerability	Australian Fire Danger Rating System (AFDRS)	<ul style="list-style-type: none"> Climate Change Risk and Adaption Assessment Framework for Infrastructure Projects Engineering Policy 170 – Climate Change Risk Assessment Methodology C7521 – Options Analysis C7522 – Business Case 	<ul style="list-style-type: none"> Guidelines: Climate Change Risk Assessment Risk Management Plan Business Case (External) 	Section 3.1.1	
3.1.1	Undertaking a Risk Assessment to Identify Bushfire-prone Areas		<ul style="list-style-type: none"> Roadside Bushfire Risk Assessment Model (RBRAM) <i>Note: RBRAM is designed for preventative and maintenance activities, not for project-specific assessments</i> 			3
3.1.2	Identifying Assets and Critical Links for Emergency Access				Section 3.3.3 Section 3.4.1	4 5
3.2	Legislative Requirements	See Appendix D				
3.3	Roles and Responsibilities					
3.4	Engagement Strategy Framework			<ul style="list-style-type: none"> Operational Procedure 108 – Bushfire Risk Management and Mitigation Community and Stakeholder Engagement Strategy 	Section 3.3.4 Section 3.3.5	31
3.4.1	Community Readiness				Section 3.3.4	30

Clause no.	Framework section	Legislation/guidelines	TMR	MRWA	Incorporating Bushfire Impacts into Road Design Research Literature Review Report (O'Connor et al. 2022)	
					Section	Recommendation no.
4	Implementing the PPRR Model into the Road Infrastructure Project Life Cycle				Section 3	1
4.1	Strategic Bushfire Plan			<ul style="list-style-type: none"> Operational Procedure 108 – Bushfire Risk Management and Mitigation Project Scope Identification Document Risk and Issues Register 	Section 3.1	2
4.3	Elements of the PPRR Model					
4.3.1	Prevention		<ul style="list-style-type: none"> Maintenance, Preservation and Operations Fire Risk Management Program (Element 6) 		Section 3.2	
4.3.2	Preparedness				Section 3.3	
4.3.3	Response				Section 3.4	
4.3.4	Recovery				Section 3.5	
4.4	Approach					
4.5	Methodology					
4.6	Planning					
4.6.1	Network Resilience				Section 3.3.2 Section 3.3.3	28 29
4.6.2	Consideration of Environment Law, Regulation and Management Requirements	See Appendix D	<ul style="list-style-type: none"> MRTS51 Environmental Management 	<ul style="list-style-type: none"> Specification 204 – Environmental Management 	Section 3.2.6	22
4.6.3	Roadside Treatment Selection Process				Section 3.2.8	20 21
4.7	Design		<ul style="list-style-type: none"> C7523 – Preliminary Design C7524 – Detailed Design 			
4.7.1	Consideration of Asset Resilience					

Clause no.	Framework section	Legislation/guidelines	TMR	MRWA	Incorporating Bushfire Impacts into Road Design Research Literature Review Report (O'Connor et al. 2022)	
					Section	Recommendation no.
4.7.2	Road Design Strategies	<i>Austrroads Guide to Road Design Part 3: Geometric Design</i>	<ul style="list-style-type: none"> Bruce Highway Scope Management and Design Guidelines 		Section 3.2.3	25
4.7.3	Structures Design Strategies		<ul style="list-style-type: none"> Design Criteria for Bridges and Other Structures MRTS15 – Noise Fences 	<ul style="list-style-type: none"> Structures Engineering – Bridge Branch Design Information 	Section 3.2.9	
4.7.4	Material Selection		<ul style="list-style-type: none"> Advice note 10 – Turf Reinforcement Mats (Catchment and Creeks Pty Ltd 2014) 		Section 3.2.10	26 27
4.7.5	Roadside Design Strategies		<ul style="list-style-type: none"> Supplement to Austrroads Guide to Road Design Part 6B: Roadside Environment 	<ul style="list-style-type: none"> Vegetation Placement within the Road Reserve Guideline 	Section 3.2.3	8 9 10 11 12 13 14 15
4.7.6	Roadside Furniture Design Strategies		<ul style="list-style-type: none"> MRTS14 – Road Furniture 	<ul style="list-style-type: none"> Road and Traffic Engineering Manual: Chapter 4 – Sign Structural Design Specification 601 – Signs Design of Fencing/Walls Emergency Stopping Bays and Roadside Help Phones 	Section 3.2.7	23 24
4.8	Construction		<ul style="list-style-type: none"> CAC068M Severe Weather Management Plan Engineering Policy 146 – Severe Weather Management Plans (SWMP) 			
4.8.1	Working in a High-risk Setting					
4.8.2	Establishing Vegetation					
4.9	Maintenance					

Clause no.	Framework section	Legislation/guidelines	TMR	MRWA	Incorporating Bushfire Impacts into Road Design Research Literature Review Report (O'Connor et al. 2022)	
					Section	Recommendation no.
4.9.1	Working in a High-risk Setting				Section 3.3.6	
4.9.2	Developing a Works Plan			<ul style="list-style-type: none"> Asset Management Plan Template for Bridges 	Section 3.5.1	39 40
4.9.3	Management of Tree Hazards				Section 3.4.6	37
4.9.4	Undertaking Roadside Vegetation		<ul style="list-style-type: none"> MRTS16 Landscape and Revegetation Works Road Landscape Manual – Edition 2 	<ul style="list-style-type: none"> Specification 304 – Landscaping and Revegetation 	Section 3.2.4	16 17 18 19
4.9.5	Undertaking Pavement Maintenance	<p>For undertaking a condition assessment, methodologies recommended include:</p> <ul style="list-style-type: none"> ARRB Best Practice Guide for Sealed Roads ARRB Best Practice Guide for Unsealed Roads Austrroads AP-T273-14 Good Practice in Reseal Programming <p>For remaining life assessments, methodologies recommended include:</p> <ul style="list-style-type: none"> ARRB Best Practice Guide for Sealed Roads Austrroads R649-21 Prolonging the Life of Road Assets Under Increasing Demand: A Framework and Tools for Informing the Development and 	<ul style="list-style-type: none"> Guide to the Visual Assessment of Pavements Routine Maintenance Guidelines 	<ul style="list-style-type: none"> Engineering Road Note 16 – Pavement Evaluation and Treatment Design 	Section 3.5.2	41

Clause no.	Framework section	Legislation/guidelines	TMR	MRWA	Incorporating Bushfire Impacts into Road Design Research Literature Review Report (O'Connor et al. 2022)	
					Section	Recommendation no.
		Justification of Asset Preservation and Renewal				
4.9.6	Undertaking Inspections and Maintenance of Structures		<ul style="list-style-type: none"> Structures Inspection Manual Guideline for the Preparation of Road Structure Durability Plans Timber Bridge Maintenance Manual 	<ul style="list-style-type: none"> Timber Bridge Preventive Maintenance Standards Detailed Visual Bridge Inspection Guidelines for Timber Bridges (Level 2 Inspections) Specification 850 – Timber Bridges Load Rating and Refurbishment Design Manual for Existing Timber Bridges 	Section 3.5.4	
4.9.7	Revegetation Revegetation		<ul style="list-style-type: none"> MRTS16 Landscape and Revegetation Works 	<ul style="list-style-type: none"> Revegetation Planning and Techniques Guideline Specification 304 – Landscaping and Revegetation 	Section 3.5.3	42 43
4.9.8	Asset Upgrades				Section 3.5.5	44
4.10	Operations					
4.10.1	Monitoring of Implemented Bushfire Management Strategies					
4.10.2	Defining Key Access and Egress Roads and Fire Control Lines				Section 3.4.1 Section 3.4.2	32 33 34
0	Note: In some circumstances, there may be a need to categorise sections of roads as opposed to entire roads. For example, some long roads may have changed ratings throughout the length due to changing conditions. Understanding Evacuation Plan			<ul style="list-style-type: none"> Incident Management Plan 	Section 3.4.4	35

Clause no.	Framework section	Legislation/guidelines	TMR	MRWA	Incorporating Bushfire Impacts into Road Design Research Literature Review Report (O'Connor et al. 2022)	
					Section	Recommendation no.
4.10.4	Traffic Management		<ul style="list-style-type: none"> Part 9: Traffic Operations/Transport Control Systems: Strategies and Operations 	<ul style="list-style-type: none"> Specification 202 – Traffic Traffic Management for Events Code of Practice Local Area Traffic Management 	Section 3.4.5 Section 3.4.7	36 38
4.10.5	Consideration of Smoke Hazards					
4.10.6	Access to Water and Other Services					

Appendix B Glossary of Terms

Bushfire	An unplanned vegetation fire. It is a generic term that includes grass, forest and scrub fires. Bushfires are characterised as a natural disaster or natural hazard.
Bushfire prone	An area which has been identified to have a high risk of bushfires, based on the outcomes of a risk assessment.
Climate change	Long-term shift in global or regional temperatures and weather patterns.
Construction	Defined as action to provide a new pavement, structure or roadside asset or to increase either strength or capacity or both of an existing asset, beyond the initial as-constructed values.
Design	The process of selecting and combining appropriate elements that will develop a fit-for-purpose solution. It is an iterative process that requires a designer to exercise judgement and use experience while also practically applying accepted technical guidelines and continually evaluating the design to assist in the selection of the appropriate values for the design elements.
Governance	Encompasses the systems by which the road agency operates, and the mechanisms by which it, and representatives, are held to account.
Maintenance	Defined as all actions necessary for retaining an asset as near as practicable to its original condition, or to reduce its rate of deterioration.
Operations	Refers to the activities undertaken to monitor, manage, and respond to alerts on the road network to maintain the expected level of service.
Planning	The phase of the project where the road agency representative addresses how to complete the project within a certain timeframe, through defined stages or milestones with designated resources.
Preparedness (activities)	All activities undertaken in advance of the occurrence of an incident to decrease the impact, extent, and severity of the incident and to ensure more effective response activities.
Prevention (activities)	All activities concerned with minimising the occurrence of incidents, particularly those of human origin.
Recovery (activities)	All activities undertaken after the occurrence of an incident to provide ongoing support to affected communities in the reconstruction of the physical infrastructure and restoration of emotional, social, economic and physical wellbeing.
Response (activities)	All activities undertaken immediately before, during and after an incident to ensure that its effects are minimised and that those immediately affected are given relief and support.
Road agency representative	The member of the road agency tasked with the management objective in this framework.
Road infrastructure	All infrastructure in the road corridor including the road pavement, roadside furniture, structures and other components.
Road infrastructure project life cycle	The planning, design, construction, maintenance and operations of a road project or maintenance activity.

Appendix C Forms

These forms apply to the various stages of the life cycle of the road: governance, planning, design, construction, maintenance and operations phases of the road infrastructure project life cycle or network management. The forms should be reviewed to ensure all required management objectives have been achieved in bushfire management to prevent or minimise bushfire impacts.

The responsibility for each task must be assigned to the appropriate road agency representative.

Checklists to be reviewed through the road agency delegation of authority to determine responsibility for risk management.

C.1 Governance

Framework section	Item	Management objective description	Has this been completed?	Management objective output
3.1.1	Undertaking a Risk Assessment to Identify Bushfire-prone Areas	Risk assessment undertaken.	<input type="checkbox"/>	Risk assessment documented
3.1.2	Identifying Assets and Critical Links for Emergency Access	All assets within the bushfire-prone area have been identified. The road networks and links that will be critical in disaster response and recovery have been identified.	<input type="checkbox"/>	List of assets
3.2	Legislative Requirements	Legislative requirements have been reviewed.	<input type="checkbox"/>	List of legislation reviewed
3.3	Roles and Responsibilities	The roles and responsibilities of each party are understood. Road agency bushfire-related works will be coordinated with relevant parties.	<input type="checkbox"/>	List of stakeholders
3.4	Engagement Strategy Framework	Engagement of stakeholders has been undertaken by developing a standardised and consistent engagement strategy.	<input type="checkbox"/>	Engagement strategy
3.4.1	Community Readiness	Fire service engaged to ensure that communities in bushfire-prone areas are aware of what they need to do in the event of a bushfire.	<input type="checkbox"/>	Dissemination of community engagement information
4.1	Strategic Bushfire Plan	Strategic bushfire plan developed to specify the road agency objectives in strategic asset management when considering bushfire risk.	<input type="checkbox"/>	Strategic bushfire plan
4.2	Continuous Improvement	Findings from previous bushfire recovery activities implemented in planning practices.	<input type="checkbox"/>	Document outlining lessons learnt
4.4	Approach	Overarching plan for implementing bushfire risk management into ongoing road agency practices based on the guidance provided in this framework.	<input type="checkbox"/>	

C.2 Planning

Framework section	Item	Management objective description	Has this been completed?	Management objective output
4.6.1	Network Resilience	Bushfire risk of a region has been considered when undertaking project planning.	<input type="checkbox"/>	Bushfire risk documented
	Critical Route Analysis	Approach to managing bushfires and any plans and approaches driven by a broader resilience process.	<input type="checkbox"/>	
4.6.2	Consideration of Environment Law, Regulation and Management Requirements	Environmental legislation, regulations and management guidelines have been consulted prior to implementing any bushfire prevention programs.	<input type="checkbox"/>	List of legislation and regulations reviewed
4.6.3	Roadside Treatment Selection Process	Roadside treatment selection process has been reviewed in order to determine the appropriate treatments.	<input type="checkbox"/>	

C.3 Design

Framework section	Item	Management objective description	Has this been completed?	Management objective output
4.7	Design	Fire-design requirements have been considered in bushfire-prone areas and all components have been thoroughly reviewed for a design fire event and mitigated where possible.	<input type="checkbox"/>	
4.7.2	Road Design Strategies	Risk assessment reviewed prior to selecting road design strategy. Available guidelines for public and property access roads followed to ensure that emergency vehicles have adequate access and emergency egress for all road users.	<input type="checkbox"/>	Road designs
4.7.3	Structures Design Strategies	New structures have incorporated the fire design requirements stipulated in the current Australian Standard bridge code, AS 5100 Bridge Design. Routine maintenance of structures undertaken.	<input type="checkbox"/>	Structures designs
4.7.4	Material Selection	Consideration has been given to the selection of materials to minimise the intensity of a bushfire and reduce required recovery activities.	<input type="checkbox"/>	Materials information documented
4.7.5	Roadside Design Strategies	Provision of design policies, guidance, and specifications to ensure roadside design is undertaken with an appropriate level of bushfire consideration.	<input type="checkbox"/>	Roadside designs
4.7.6	Roadside Furniture Design Strategies	Bushfire risk has been integrated into the design and maintenance strategies for roadside furniture.	<input type="checkbox"/>	Roadside furniture designs

C.4 Construction

Framework section	Item	Management objective description	Has this been completed?	Management objective output
4.8.1	Working in a High-risk Setting	All emergency advice has been monitored and followed for works undertaken during a total fire ban.	<input type="checkbox"/>	Documentation of emergency advice review
4.8.2	Establishing Vegetation	Vegetation establishment undertaken in accordance with vegetation treatment selection processes for bushfire prevention.	<input type="checkbox"/>	Vegetation establishment

C.5 Maintenance

Framework section	Item	Management objective description	Has this been completed?	Management objective output
4.9.1	Working in a High-risk Setting	Reviewed regulations for projects working in high bushfire-risk areas.	<input type="checkbox"/>	Documentation of emergency advice review
4.9.2	Developing a Works Plan	Developed a works plan for maintenance activities, given priority to key risk areas and critical infrastructure.	<input type="checkbox"/>	Works plan
4.9.3	Management of Tree Hazards	Tree hazards along the roadside managed during disaster response to ensure critical routes remain open to the community for evacuations and emergency response.	<input type="checkbox"/>	Managed tree hazards documented
4.9.4	Undertaking Roadside Vegetation Maintenance	Dataset and mapping tool developed to identify when areas have been managed with prevention activities or when these areas are due to be managed, relative to their vegetation type and category. A risk-based maintenance prioritisation strategy utilising a series of vegetation and fuel reduction techniques should also be employed.	<input type="checkbox"/>	Dataset and mapping tool of vegetation
4.9.5	Undertaking Pavement Maintenance	Pavement maintenance activities undertaken, based on an assessment of bushfire damage.	<input type="checkbox"/>	Summary of maintenance activities
4.9.6	Undertaking Inspections and Maintenance of Structures	Inspections undertaken on structures after a bushfire, and corresponding administrative controls enforced.	<input type="checkbox"/>	Summary of inspections
4.9.7	Revegetation	Revegetation undertaken within an appropriate period of time to prevent soil erosion from rainfall impact and surface water flows where the land is now bare due to bushfire destruction.	<input type="checkbox"/>	Summary of revegetation activities
4.9.8	Asset Upgrades	Asset upgrades made, where possible. This includes the implementation of the prevention strategies defined for road design, roadside design and structural design.	<input type="checkbox"/>	Summary of asset upgrades implemented

C.6 Operations

Framework section	Item	Management objective description	Has this been completed?	Management objective output
4.10.1	Monitoring of Implemented Bushfire Management Strategies	Monitoring plan has been developed and implemented to assess the ongoing effectiveness of bushfire prevention strategies.	<input type="checkbox"/>	Monitoring plan
4.10.2	Defining Key Access and Egress Roads and Fire Control Lines	Prioritisation system employed for characterising key access and egress roads.	<input type="checkbox"/>	Prioritisation system documented
4.10.3	Understanding Evacuation Plans	Emergency management plans have been developed through consultation with stakeholders.	<input type="checkbox"/>	Emergency management plans
4.10.4	Traffic Management	Guidance for road closures has been well disseminated and understood, and road closures are implemented effectively during disaster response.	<input type="checkbox"/>	Road closure guidance
4.10.5	Consideration of Smoke Hazards	Smoke hazards have been adequately considered as part of response efforts.	<input type="checkbox"/>	Documentation of how smoke hazards have been considered
4.10.6	Access to Water	Allowances have been made on road-agency-managed land for access to water for emergency services.	<input type="checkbox"/>	Access to water documented