Firebreak Location, Construction and Maintenance Guidelines

GOVERNMENT OF
WESTERN AUSTRALIA

Bush Fire and Environmental Protection Branch

FESA
Fire & Emergency Services
Authority of Western Australia

480 Hay Street, Perth, Western Australia, 6000

Author: Ralph Smith

ISBN: 978-0-9806116-6-3

GOVERNMENT OF
WESTERN AUSTRALIA

Bush Fire and Environmental Protection Branch

FESA
Fire & Emergency Services
Authority of Western Australia

Firebreak Location, Construction and Maintenance Guidelines

Purpose

The purpose of the *Firebreak Location, Construction and Maintenance Guidelines* is to provide fire and land management practitioners with a tool to assist with the location, construction and maintenance of firebreaks on any natural environment (e.g. pastoral station, farm or reserve). The *Guidelines* are designed to provide an estimation of the situation with guidance to the soil types, slope, estimations of water concentrations and volumes, and the impact of these factors on soil erosion associated with firebreak location, construction and maintenance.

Prior to undertaking any firebreak construction or maintenance work it is essential that the potential social, financial and, very importantly, the environmental costs and impacts are identified and considered against the potential fire management benefits gained by clearing vegetation from the land.

The *Guidelines* have been developed by working with very experienced land and fire managers within the pastoral industry, local government and within the Fire and Emergency Services Authority (FESA) and reference publications on firebreaks, soil management and erosion.

FESA has designed these *Guidelines* as a reference tool to assist pastoralists, land and fire managers in determining solutions for firebreak location, construction and maintenance when a management issue, such as erosion, is likely to eventuate. FESA is aware that many pastoralists, farmers and land managers have very extensive networks of firebreaks on land that suffer no erosion and therefore do not require any additional erosion mitigation works.

These *Guidelines* will assist in meeting the firebreak requirements as prescribed in the *Bush Fires Act 1954* and the local laws developed by local governments whilst limiting the potential for environmental harm.

Introduction

Firebreaks used in the natural environment are developed for a range of purposes. Each purpose will be determined by the bush fire protection needs of the individual pastoralist owner/manager, farmer or land manager. The bush fire protection needs will be determined by the combination of the soil type, slope, vegetation type and density, the risk of ignition, the fire suppression response capability and options, and the values such as infrastructure at risk.

Unless the land is actively eroding, run-off from undisturbed grazing or bush land is relatively free of suspended solids. There are several management methods available to assist in reducing sediment movement. The first is to keep the area of land that is disturbed for firebreaks, tracks and roads to a minimum and the second is to limit the amount of clean water run-off passing through disturbed areas.

Where erosion is not an issue, the practical application is achieving the desired result and additional erosion control measures are not warranted.

Firebreaks serve a number of functions. Generally they are considered to be relatively narrow man-made barriers of bare ground intended to stop bush fires[1]. Under high fuel load conditions man-made mineral earth firebreaks can only be of assistance in slowing down a bush fire rather than stopping it, because spotting will occur and no direct fire suppression attack is possible. Some firebreaks are designed to prevent the fire escaping, and others are designed to restrict entry of a fire from outside the property or area. In northern Western Australia and other locations there are very large areas protected by strategically placed aerial burnt firebreaks of between 300 and 1000 metres.

---

[1] Luke & McArthur, 1986, *Bushfire in Australia,* Australian Government Publisher, Canberra.

Firebreaks can also provide a prepared, ready to operate back-burning boundary so that valuable time is not lost establishing the boundary during fire suppression activities.

Where mineral earth firebreaks are not required as a prevention tool, they can fill a very important fire suppression role by providing access routes for fire vehicles and water supplies.

The vegetation type, density and period since last burnt are important determinants of the required firebreak width. The soil type, slope and rainfall concentrations, peak volume and long duration periods are also significant determinants in determining the soils propensity to erode.

Firebreaks associated with grassland areas with an average 4–5 t/ha[2] are effective when they are wider than where radiation and/or flame contact is expected to be less than four times the flame length in the horizontal plane.

When the Fire Danger Index (FDI) on the Grassland Fire Danger Meter is less than 2.5[3], it is recognised that the Fire Danger Rating (FDR) is low and the head fire is expected to be stopped by roads and tracks. An FDI of 7.5 recognises that the FDR is moderate and the head fire is easily attacked by water. When the FDI rises to 32, the FRD is high and the head fire attack is generally successful with water. When the FDI exceeds 32, the ability to successfully directly attack the head of the bush fire diminishes to a point to where, if the bush fire is to be attacked, it should only occur under favourable conditions. This is based on the assumption that the fuels are continuous and reasonably consistent.

The impact of burning embers on bush fire management and firebreak effectiveness must also be considered when analysing whether firebreaks will be successful in stopping the fire, providing firefighter access, or forming a secure boundary from which to undertake back-burning operations. Low intensity fires will generally have shorter spotting distances compared to very intense fires. Grasslands will generally have a shorter spotting distance than forest fuels.

In many areas, there are natural firebreaks of bare ground or areas that have been developed for other purposes (e.g. roads, transmission line clearings or land under fallow) that provide the same function. They create a discontinuous fuel area that will under many circumstances stop the bush fire or provide an area to undertake back-burning operations.

Urban/rural interface (includes towns, settlements and remote indigenous communities)

The urban/rural interface is one of the potentially most difficult areas to undertake bush fire suppression activities. The area is generally built up with homes within the vegetation. Another factor is that many of these homes have been built to the low bush fire threat as prescribed in 'Australian Standard 3959—Construction of buildings in bushfire-prone area' when the construction should have been for medium or high threat. Effectively, these homes will not have been built to the suitable standard and, consequently, firebreaks, building protection zones, and hazard separation zones are needed to ensure increased protection.

Firebreaks will be critical in ensuring that these homes are protected from fires. Firebreaks also assist in preventing bush fires entering or leaving the property and this bush fire movement through the property may also pose a threat to the neighbouring property.

---

[2] Luke & McArthur, 1986, *Bushfire in Australia,* Australian Government Publisher, Canberra.

[3] CSIRO Forestry and Forest Products Bushfire Behaviour and Management, 1997, 'CSIRO Grassland Fire Danger Meter'.

Forest firebreaks

Like grassland area firebreaks the purpose of a forest firebreak is three-fold[4]. These are to provide protection to valuable forest assets either by preventing fires entering, or to provide protection to neighbours by preventing fires from leaving the forest estate. Firebreaks also provide access into the forest and water resources. Access into the forest can be very difficult and this difficulty in travelling can add valuable time between detection and suppression actions being commenced. This increased time allows the fire to develop more fully and become more difficult to suppress.

There appears to be a need for two different types of forest firebreaks. Plantations (pine and bluegum)[5] are high value timber crops that can be adversely affected by bush fire. It is therefore considered important that boundary firebreaks be constructed quite wide (around 15 metres), and the breaks have a minimum trafficable width of 5 metres and also a vertical clearance of 5 metres between the trees. The compartment breaks need to be based on the size of the compartment: compartments up to 30 ha have a recommended width of firebreak of 6 metres; and for those of over 30 ha, a minimum width of 10 metres applies. The 5 metre trafficable surface should be retained for all firebreaks—these minor breaks require a minimum height clearance of four metres to facilitate unrestricted access and maintain an effective width of firebreak.

There are also other plantations that are of high value either as a commercial crop or for environmental health—these include mallet (tool handles), sandalwood, oil mallees and *Casuarina spp* (saline soil) plantations. Each plantation has its own soil and rainfall requirements. The rainfall belts are:

- low rainfall zone which has less than 400 mm;
- mid-rainfall zone which has between 400–600 mm; and
- high rainfall zone which has greater than 600 mm.

These high value crops require some protection from a fire entering into the area.

Forest fires that have not developed may be readily suppressed on a low forest fire danger index (FFDI) by simply running into the firebreak. Even in a more intense forest fire, the backing fire and tail end of the flank fires may be suppressed with no additional suppression effort when they run into a firebreak, particularly on a falling bush fire hazard.

Table 1. External firebreak requirements.[6]

Management Requirements	External Firebreak Requirements			
	Eucalyptus	Pines	Oil Mallee	Sandalwood
Vertical clearances	5 m			
External boundaries including, public roads and neighbouring properties	15 m (10 m minimum)	15 m	10 m	15 m
All breaks must be fuel free at time of local government firebreak notice notification.				
Dwellings[7] and valuable property[8]	100 m Hazard Separation Zone (HSZ)*	100 m HSZ	100 m HSZ	100 m HSZ
*Hazard separation zones (HSZ) to be maintained as low fuel areas less than 8 t/ha where possible[9].				

---

[4] Luke & McArthur, 1986, *Bushfire in Australia*, Australian Government Publisher, Canberra.

[5] FESA, 2001, 2nd Ed, *Guidelines for Plantation Fire Protection*, Perth.

[6] FESA, 2010, *Plantation fire guidelines* (draft), Perth.

[7] Homesteads/Houses constructed after the plantation has been established can be less than 100 m from the plantation if the house has increased construction standards in accordance with Australian Standard *AS 3959 Construction of buildings in bushfire-prone areas* and the *Planning for Bush Fire Protection* document produced by FESA and WAPC.

[8] This must be clearly identified as such during the planning process.

[9] More information on Hazard Separation Zones and related requirements available in FESA's *Planning for Bush Fire Protection*.

Pasture and non-forest lands firebreaks

Firebreaks in grassland, pasture and non-forest land have a dual purpose.[10]

1. To provide protection to valuable pasture assets either by preventing fires entering or to provide protection to neighbours by preventing fires from leaving the individual pastoral station, farming estate or other lands.
2. Firebreaks also provide access into the station, farm and other lands and also to water resources. Access into the land can be very difficult and this difficulty in travelling can add valuable time between detection and suppression actions being commenced. This increased time allows the fire to develop more fully and become more difficult to suppress.

There appears to be a need for two different types of firebreaks for the vegetation types of pasture and non-forest. Land managers can have high value pasture crops and other vegetation that can be adversely affected by bush fire, both for the current season and the next. It is therefore considered important that boundary firebreaks be constructed quite wide—possibly 10 metres for pastoral stations. The internal pastoral station paddock breaks need to recognise the importance of the area being protected, and it is recommended a narrower width of break of 6 to 10 metres is used (although this may be reduced to 3 metres where appropriate).

Firebreaks associated with grassland areas with an average 4–5 t/ha[11] are effective when they are wider than where radiation and/or flame contact can be expected to be less than four times the flame length in the horizontal plane. For example, if the flame length is expected to be one metre then the firebreak needs to be four metres wide.

When the FDI on the Grassland Fire Danger Meter is less than 2.5, it is recognised that the FDR is low and the head fire is expected to be stopped by roads and tracks of around three metres in width.

As the FDI increases, the functionality of the minimum width firebreak starts to diminish because of the increased flame length and the embers created, which are carried forward ahead of the fire. In these instances, the firebreak assumes two roles: firstly, as a fire suppression tool primarily for the flank and tail fire; and secondly, as an access track. If the firebreak is used as an access track it provides increased ease of access to water and other areas of value. It also provides an opportunity for the fire manager to conduct back-burning operations to contain the fire during suppression operations.

The impact of burning embers on bush fire management and the effectiveness of firebreaks must also be considered when analysing whether firebreaks will be successful in stopping the fire, providing firefighter access, or forming a secure boundary from which to undertake back-burning operations. Low intensity fires will generally have shorter spotting distances than very intense fires. Grasslands will generally have a shorter spotting distance than forest fuels.

In many areas, there are natural firebreaks of bare ground or areas that have been developed for other purposes (e.g. roads, transmission line clearings or land under fallow) that provide the same function. They create a discontinuous fuel area that will, under many circumstances, stop the bush fire or provide an area to undertake back-burning operations.

Bush fires that have not developed a significant head fire may be readily suppressed on a low grassland FDI by it simply running into the firebreak. Even in a more intense bush fire, the backing fire and tail end of the flank fires may be suppressed with little or no additional suppression effort when they run into a suitable width firebreak.

[10, 11] Luke & McArthur, 1986, *Bushfire in Australia*, Australian Government Publisher, Canberra.

Placement of firebreaks

Slope

Firebreaks need to be placed so that they fill all or most of the desired outcomes. As in all situations, there will be some compromise between an ideal firebreak location, soil conservation, fencing requirements, practicability and cost. The firebreak should therefore be located so that it will either stop the low intensity fire, provide a back-burning buffer from which to undertake the burning, or provide access to key infrastructure or other areas of value.

Bush fires travel faster upslope than downslope. It is therefore more desirable to place the firebreaks lower in the profile and, where possible, to place the firebreak so that it runs parallel to the contour. Where the firebreak cuts across the contour, the chance of erosion is increased and measures must be undertaken to mitigate the erosion risk.

Location

Firebreaks should be located to achieve four objectives:

1. Provide a mineral earth break or reduced fuel zone so that unplanned fires do not enter the property—i.e. a strategic external threat protection break.
2. Provide a mineral earth firebreak or reduced fuel zone so that unplanned fires do not leave the land holding—i.e. a strategic internal threat protection.
3. So that prescribed burns do not escape the prescribed burn area—i.e. a strategic burn boundary.
4. Provide access to the critical areas of the land so that fire suppression activities can be undertaken—i.e. a predetermined back-burning boundary.

Each type of firebreak has important components that must be met.

1. Provide a mineral earth break so that unplanned fires do not enter the property (i.e. a strategic external threat protection break)

These firebreaks must be located close to the boundary of the property and of sufficient width to minimise radiant heat or the chance of direct flame contact with vegetation causing the fire to ‘hop over’ the break.

In the pastoral region, particularly in the Kimberley, it is estimated that these firebreaks need to be a minimum of 12 metres wide (three grader blade width breaks), but will frequently be 16 metres wide (four grader blade width breaks). It may also be appropriate to have both sides of the boundary fence graded depending on the ownership or management of the neighbouring land.

In the pastoral regions, these breaks may be enhanced by conducting burning operations immediately adjacent to the graded break so that embers from the fire do not ‘hop over’ the break. An alternative system may be to have a series of graded firebreaks 300 metres apart and to burn out one parallel area each subsequent year. A fire would therefore run into a graded firebreak and a burnt buffer within 300 metres of the boundary.

On farms and other land not in the pastoral region, it may be possible to have effective fire management strategies that only require a firebreak width to be three metres.

2. Provide a mineral earth firebreak so that unplanned fires do not leave the property (i.e. a strategic internal threat protection)

As described in the previous section, firebreaks used for this purpose must be located close to the property boundary, be of appropriate width to minimise radiant heat and the chance of direct flame contact with vegetation causing the fire to ‘hop over’ the break.

Refer to the Objective No. 1 for specific requirements.

3. So that prescribed burns do not escape the prescribed burn area (i.e. a strategic burn boundary)

To ensure fires do not escape a prescribed burn area, firebreaks must be located close to the boundary of the burn and of sufficient width to minimise radiant heat or the possibility of direct flame contact with vegetation on the area not planned to be burned.

These breaks need to be a minimum of one metre wide—however, for burn security it is recommended that the breaks be three metres wide, particularly when the grasses are greater than 60–80 per cent cured.

Firebreaks can be very effective in bush and grassy fuels but their effectiveness diminishes when the fire is spotting.

4. Provide access to the critical areas of the land so that fire suppression activities can be undertaken (i.e. a predetermined back-burning boundary)

The provision of access is critical both for effective land management and bush fire management. If firebreaks are to be used primarily as an access track, they need to be formed and maintained so that a constant vehicle speed can be maintained and they do not become water-holding gullies for erosion to occur.

For these factors to be met, the firebreak needs to have erosion control measures implemented and maintained. One method of achieving this is to flat grade the firebreaks with windrows on the edge of the firebreak in the beginning of the summer or the dry season, and then return immediately before the onset of rain and return the windrow back across the firebreak.[12] This method may save some initial time and money but the risk of erosion from unseasonal or early heavy rainfall is very high.

Whilst this soil return process is an option, the preferred option is the establishment and maintenance of appropriate water turn-outs and firebreak banks that are created and maintained during the initial firebreak maintenance work. The establishment and maintenance of appropriate water turn-outs and firebreak banks is recommended because, with these in place, unseasonal rainfall in the midst of the dry season will not cause the firebreak to erode or degrade. The erosion control measures are built into the firebreak and will work regardless of the ability of the land manager to implement additional erosion control measures that depend on time and access.

---

[12] McGuffog, undated, *The ‘how-to’ of firebreaks and aerial burns,* Bushfire Council NT

Mineral earth firebreak construction

Mineral earth firebreaks need to be constructed and maintained so that they will assist in stopping a bush fire, either directly during the low FDI or as a tool used for fire management (e.g. as an access track or back-burning boundary), and they should not erode. In a range of slopes and soil types erosion may not be an issue and no additional erosion prevention works need to be undertaken. In other locations, however, minimal soil disturbance may cause significant erosion.

In some areas, such as the Pilbara, the soil may be held together with quick growing plants that thrive after disturbance—such as buffel grass. If this is the case, then there may not be any need for additional soil and water erosion control. If the introduction of the plants (whether by natural means or by the land manager) does not hold the soil together, then it is proposed that the following be considered and applied where appropriate.

Soil structure

The soil's structure is very important in determining the type and location of the firebreak.[13] An inappropriate firebreak can result in increased water erosion and wind erosion and the loss of the productive topsoil, termed the 'A horizon' (which is the top 10 to 15 cm of soil). The physical, chemical and biological changes in the soil resulting from changes in agricultural practices also alter the soil as a habitat for micro-organisms.

The size and stability of the soil structure directly affects the susceptibility of soils to erosion. The determining components are the texture, structure, stability, organic matter content, soil micro-organisms, salts and colloids. For most soils, their susceptibility to wind erosion is increased by the reduction of soil clod or aggregate size, organic matter content and water content (e.g. affected by ploughing, cultivating and grazing). The texture of the soil is the major factor in susceptibility to wind erosion. This also affects the soil's ability to hold moisture. More coarse textured soils are generally more susceptible to erosion than fine textured soils. Coarse soils also hold less water and drain more rapidly than finer soils, which make them more susceptible to wind erosion.

Only root material will hold soil, and this root growth and development only occurs where soils can sustain growth. Non-wetting soils are usually coarser and the grains of sand appear to form a skin that sheds water. These areas are generally leached of nutrients and consequently grow few plants. A deteriorating soil structure will result in an increase in the potential for soil erosion. Many soils in the world are renewed naturally. The Western Australian soils have probably formed more than 50 million years ago, and little deposition now occurs.[14]

Wind erosion occurs when vegetation ground cover is insufficient to protect the soils and it is exposed to wind. Soil particles start moving when wind speeds exceed 8 km/hr and it is the very important fine particles that become airborne.

Water erosion occurs when the soil is unable to cope with rainfall that falls faster than the ground can soak up the water. This inability to cope may occur because the soil is at storage capacity, surface infiltration is impeded or the hard setting nature of duplex soils restrict infiltration. All of these result in increased overland flow. The various types of water erosion all manifest themselves by transferring soil from one location and depositing it elsewhere. The site that suffers the soil loss may expose the less durable soils to further erosion problems.

[13, 14] G A Robertson, 1987, *Soil Management for Sustainable Agriculture*, Resource Management Technical Report No. 95, WA Department of Agriculture.

Soil types

Table 2. Soil types and texture.[15]

Clay: Particles less than 0.002 mm in diameter	Clays have very large surface areas compared with other inorganic fractions. As a result, clays are chemically very active and are able to hold nutrients on their surfaces. These nutrients can be released into soil water from where they can be used by plants. Like nutrients, water also attaches to the surfaces of clays but this water can be hard for plants to use.
Silt: Particles between 0.02 mm and 0.002 mm in diameter	Silt has a relatively limited surface area and little chemical activity. Soils high in silt may compact under heavy traffic and this affects the movement of air and water in the soil.
Sand: **Fine sand:** Particles between 0.2 mm and 0.02 mm in diameter **Coarse sand:** Particles less than 2 mm and greater than 0.2 mm in diameter	Quartz is the predominant mineral in the sand fraction of most soils. Sand particles have a relatively small surface area per unit weight, low water retention and little chemical activity compared with silt and clay.
Gravel: Particles greater than 2 mm in diameter and up to 7.5 cm in diameter	An unconsolidated, natural accumulation of rounded rock fragments resulting from erosion, consisting predominantly of particles larger than sand, such as rocks, cobbles, granules or any combination of these fragments.

Table 3. Infiltration rates for selected combinations of soil and ground cover.[16]

Soil categories	Infiltration rates in cm/hr
Soils with high rates (sandy soils, friable loams)	
Bare soil	1.3 – 2.5
Forest and grass	3.8 – 19.1
Close-growing crops	3.2 – 7.6
Row crops	1.7 – 3.8
Soils with intermediate rates	
Bare soil	0.3 – 1.3
Forest and grass	0.8 – 9.5
Close-growing crops	0.6 – 3.8
Row crops	0.3 – 1.9
Soils with low rates (dense clays, clay loams)	
Bare soil	0.03 – 0.3
Forest and grass	0.08 – 1.9
Close-growing crops	0.06 – 0.6
Row crops	0.02 – 0.4

---

[15] Source: http://www.dpi.vic.gov.au/dpi.

[16] Anderson, Beiswenger, Purdom, 1987, *Environmental Science,* third edition, Merrill Publishing Company, Columbus, Ohio.

Causes of soil erosion

Soil erosion—happens when the energy of moving water or air is enough to overcome the cohesive forces that bind soil particles together. Particles detach from the surface and are carried in the moving fluid (i.e. particles are suspended in the moving fluid).

Sedimentation—results when fluid flow decreases to the point where its kinetic energy is no longer sufficient to maintain the particles in suspension (i.e. where the movement of the fluid stops enough to keep the particles suspended).

Wind erosion—is mostly initiated by coarser particles moving in saltation (bouncing) across the surface as carried by wind. With each bounce, finer material comes off the surface and is carried along in the air.

Water erosion—can happen in two ways. These are:

- **Rain drop splash.** A raindrop striking an unprotected soil surface will form a small crater with particles thrown in a roughly circular pattern around the hole. A vertically falling raindrop hitting a sloping surface will throw more material to the downhill side—thereby a large amount of surface soil may move down a slope during rainfall. The energy from the raindrop impact also pulverises and compacts the soil which causes the surface to seal and reduces infiltration. Consequently this will increase the amount of rainfall that flows over the surface, contributing to a second form of erosion.
- **Gully and sheet erosion** are functions of the velocity of surface water flow and the cohesiveness or detachability of the soil particles.
    - Flow velocity is determined by the depth of flow, the angle and length of the slope and the retardance or surface roughness of the soil.
    - The cohesiveness of soil particles is affected by soil type (grain size and degree of aggregation) and by the binding effect which organic matter and plant roots have upon the soil).

Preventing water erosion

Methods of preventing water erosion include:

- Control over velocity and depth of flow can be exerted by constructing **contour furrows or contour banks** at intervals down the slope:
    - Catchment area commencing at each bank or furrow.
    - This stops the run-off from reaching a depth of flow or velocity that would cause erosion.
    - As the slope angle increases, the furrows must be spaced closer together until a point is reached where they're not longer effective.
- Contour cultivation is only useful to slopes below about five degrees (5°). On steeper slopes, the water-holding capacity of the individual plough furrows becomes limited.
- For slopes up to 10 degrees (10°) contour, deep-ripping or contour furrowing in conjunction with contour cultivation can provide a reasonable degree of erosion protection for a limited time.
    - **Contour ripping:** Ripping to a depth of 60–90 cm with conventional single or multi-type ripper (by bulldozer). For best results use two tynes spaced one metre apart with individual rip lines spaced two to six metres apart, depending on the slope angle.
    - **Contour furrowing:** Single tyne fitted with a 'mould board' attachment that lifts the soil from the furrow and forms a small bank on the downhill side which increases water-holding capacity.
    - Both rips and furrows should be constructed precisely on the contour.

- **Contour banks:** These are bigger versions of contour furrows with a proportionately greater capacity to store runoff and/or drain it to some chosen discharge point. There are three types of banks, although two or more can be used in one continuous line.
    - **True contour or level banks**—these are constructed exactly on the contour and can be discharged at either or both ends.
    - **Absorption banks**—constructed along the contour but have both ends turned uphill to a predetermined height so they pond a desired depth of water along their length.
    - **Graded banks**—constructed away from the true contour at a designed gradient so that they drain water from one part of a slope to another (e.g. to a watercourse or dam).

  As slope angle increases, the erosion control of these larger banks is reduced until—at about 12–14 degrees of slope—the need to be so close together may limit any benefit. On a steep slope, there is also a risk of gully erosion.[17]

Method of creating mineral earth firebreaks

Mineral earth fire breaks are created by ploughing, grading or other earth movement. The process involves mechanically removing the vegetation. This process is very effective but can lead to erosion if poorly managed on steep slopes or lose sands. In most instances, a plough or rake will do less damage to the soil's structure than a grader that removes the topsoil.

Figure 1. Mineral earth graded firebreak.

When a mineral earth firebreak is created, it is essential to manage the water that will run along the firebreak. Where possible, it is preferable to ensure the water is moved off the graded firebreak as soon as practical.

---

[17] Hannan J C, 1984, *Mine Rehabilitation A Handbook for the coal mining industry*, New South Wales Coal Association, Sydney.

Water turn-outs

Water turn-outs are essential on a firebreak that is in a soil type, structure or slope where there is a propensity to erode.

Gradients in the Pilbara are generally flat with some short slopes associated with ranges and isolated hills. The region is also subject to very heavy rainfall for only relatively short durations. With no vegetative cover, the consequence of very heavy rainfall, seasonal characteristics and the type of soil that is exposed is that the soil can erode very quickly. It is critical with soils that have a propensity to erode to ensure management of the water flow on the bare surface is minimised. The steeper the slopes, the more water management is required.

Table 4. Grade in degrees, percentage and gradient comparisons.[18]

Grade (degrees)	Grade (%)	Gradient
0.6	1	1 in 100
1.2	2	1 in 50
1.7	3	1 in 33.3
2.2	4	1 in 25
2.9	5	1 in 20
3.4	6	1 in 16.7
4	7	1 in 14.3
4.6	8	1 in 12.5

Figure 2. Water table turnout.

Water divergent banks on firebreaks

Where the water will run down the firebreak, it is essential to create water divergent or restraining banks—similar in structure to speed humps—across the firebreak or road.

These need to be a minimum height of 400 mm and a minimum of 500 mm wide or, if used in a high traffic area, up to double the width of the firebreak. These banks should be placed in the firebreak when it exceeds one degree (1°). At one degree there should be a bank every 150 metres and, as the slope increases, the distance between banks should reduce by 20 metres for every degree of increase of slope.

---

[18] Australian Centre for Minesite Rehabilitation Research, 1997, *Short Course on Mine Rehabilitation: principles and practice,* Kenmore, Queensland.

Figure 3. Water control banks on a firebreak.

Table 5. Bank distances as slope increases to reduce erosion.[19]

Slope (degrees)	Bank distance apart (metres)
1	150
2	130
3	110
4	90
5	70

Table 6. Culvert/turnout maximum average spacing (metres).[20]

Road gradient	Clay, silt, fine sand, ash	Sand, very fine gravel, pumice	Gravel with some sand	Clean gravel
5%	200	300	400	500
10%	100	150	200	250

Table 7. Grade in degrees and percentage and gradient comparisons.[21]

Grade (degrees)	Grade (%)	Gradient
0.6	1	1 in 100
1.2	2	1 in 50
1.7	3	1 in 33.3
2.2	4	1 in 25
2.9	5	1 in 20
3.4	6	1 in 16.7
4	7	1 in 14.3
4.6	8	1 in 12.5

Notes:

- Material differentiation is on the basis of particle size. Mixtures of materials should be assessed to provide the maximum spacing for the predominant water transportable particles.
- Maximum spacings are in metres for either culvert pipes or turn-outs.
- The maximum spacing for 300 mm pipe culverts is 185 metres. The maximum spacing for 375 mm pipe culverts is 325 metres.
- Culvert and turn out spacings (maximum average) can be calculated from the formula:
  Spacing (metres) = **factor** / road gradient (%)

---

[19] McGuffog, undated, *The 'how-to' of firebreaks and aerial burns,* Bushfires Council, Northern Territory.

[20] PNG, 1995, *Papua New Guinea Logging Code of Practice,* Department of Environment and Conservation, Boroko, Papua New Guinea.

[21] Australian Centre for Minesite Rehabilitation Research, 1997, *Short Course on Mine Rehabilitation: principles and practice,* Kenmore, Queensland.

The factors are:

Table 8. The factors to use in the spacing formulae.

Clay, silt, fine sands	1000
Sand, very fine gravel, pumice	1500
Gravel with some sand	2000
Clean gravel	2500

For example: the spacing of a water turn-out on a slope of 3 degrees is calculated for clay as $1000/3 = 333$ metres.

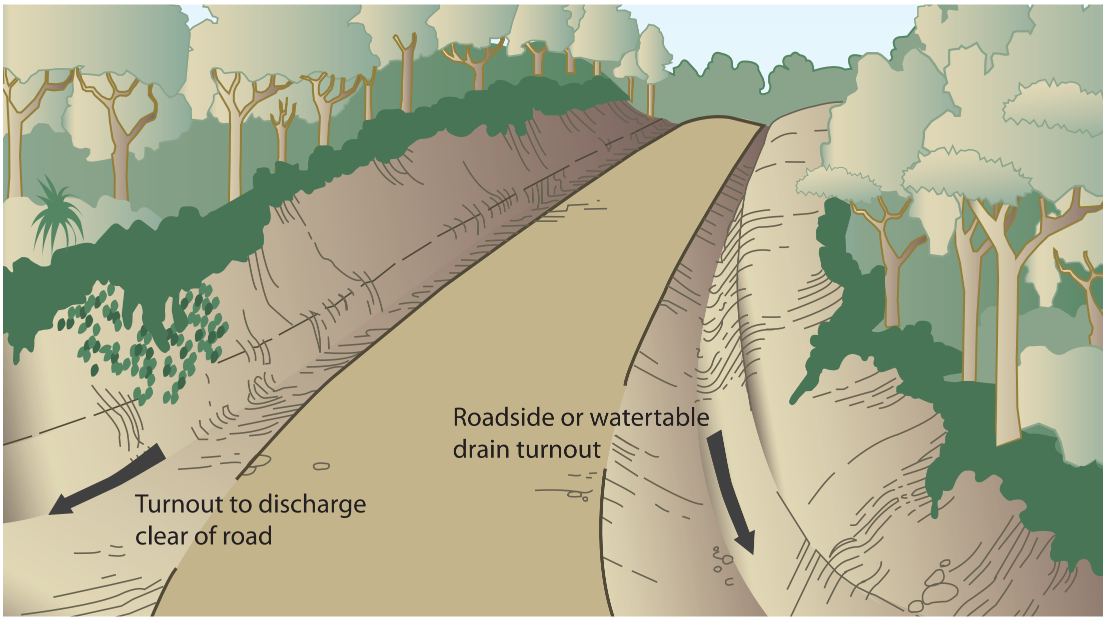

Figure 4. Diagram of the water table turnout.[22]

Road cross fall or camber

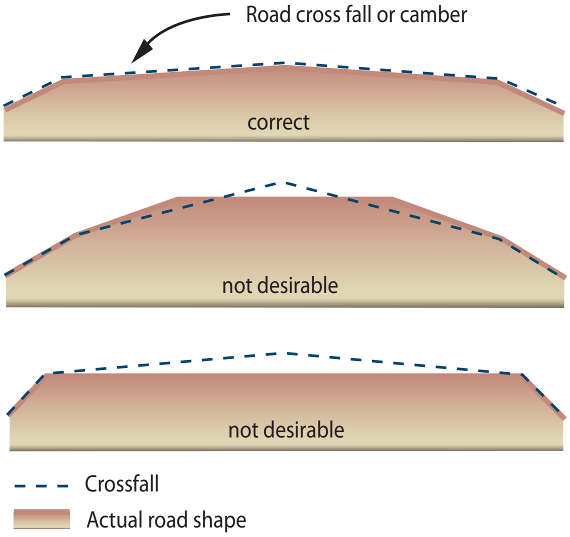

Figure 5. Road cross fall or camber required to minimise erosion.[23]

[22, 23] PNG, 1995, *Papua New Guinea Logging Code of Practice,* Department of Environment and Conservation, Boroko, Papua New Guinea.

When water erosion is likely to become an issue as a consequence of the frequency, duration or intensity of rainfall, it is very important to consider the effects this will have on the surface of the firebreak (road), and where the road will become a catchment that will contain the water and encourage it to flow down the graded surface.

It is essential to minimise the water movement down or across surfaces that have an increased propensity to erode such as a graded firebreak. The shape of the firebreak surface can lead to erosion and, where appropriate, road cross fall or camber should be built into the exposed surface.

Figure 6. Water trapped on the firebreak because of the construction and the lie of the land.

The firebreak in this instance has not lead to erosion, even though it is covered in water, which may be due in part to the amount of traffic on the firebreak.

Figure 7. A firebreak that is poorly placed and with inadequate water control measures.

Other forms of firebreaks

1. **Herbicide use:**[24] Herbicides are very effective if applied at the appropriate time for creating a mineral earth break that retains the root matter in the soil and reduces the potential for erosion.

Figure 8. Slashed and herbicide treated firebreak.

2. **Managed grazing.** Animals managed to graze the area can create appropriate reduced fuel areas, and still ensure that the grass root zone remains to hold the soil structure together and minimise erosion.

Figure 9. Grazing to keep fuels reduced.

3. **Strategic placement of aerial and hand burning.** This burning needs to create a width of between 300 and 1000 metres as not all fuels will be consumed during the burning and small, isolated pockets will remain partially burnt or unburnt. The unburnt pockets must be relatively small and not able to be linked by short distance spotting or direct flame contact.

Figure 10. Burnt firebreak.

Figure 11. Burnt firebreak starting to regenerate.

---

[24] Robertson G A, 1987, *Soil Management for Sustainable Agriculture,* Resource Management Technical Report No. 95, WA Department of Agriculture.

4. **Combination of grading and burning.** An alternative system may be to have a series of graded firebreaks 300 metres apart and to burn out one parallel area each subsequent year. A fire would therefore run into a graded firebreak and a burnt buffer within 300 metres of the boundary.

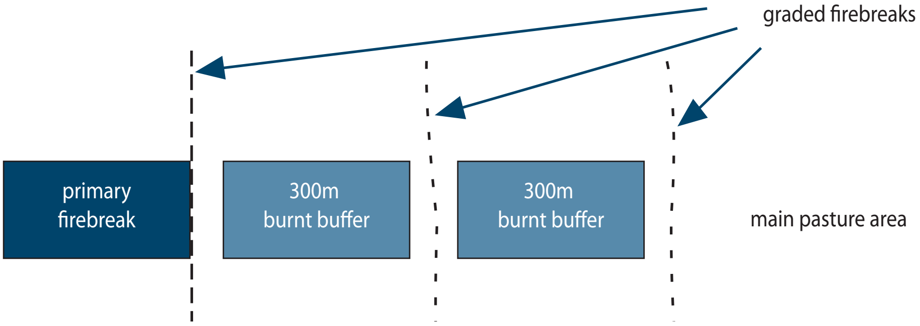

Figure 12. Alternative grading and burning strategic firebreak system.

Rainfall

As previously described, water erosion occurs when the soil is unable to cope with the rain that falls faster than the ground can soak up the water. This inability to cope may occur because the soil is at storage capacity, surface infiltration is impeded or the hard setting nature of duplex soils restrict infiltration. All of these result in increased overland flow of the water. The various types of water erosion all manifest themselves by transferring soil from one location and depositing it elsewhere. The site that suffers the soil loss may expose the less durable soils to further erosion problems.

To determine the potential sediment load in the surface water run-off the following formulae are provided. In all the examples provided they are based on a default catchment of 500 hectares. The formulae have come from J. C. Hannan's book *Mine Rehabilitation A Handbook for the coal mining industry* and are provided as a guide to assist in more finely determining individual requirements.

$$Tc = \frac{L}{27\sqrt[5]{S}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

where:

Tc = time of concentration

L = length (in metres) of the main watercourse from discharge point to the catchment boundary

S = average slope of the main watercourse in per cent

Figure 13. Time of concentration.

The above figure is the shortest time necessary for all points within a catchment to simultaneously contribute to flow past a given point in the catchment.

Example:

L = 500 metres

S = 2°

Tc = 500 / 31.0148

Tc = 16.12

$$Qp = \frac{CIA}{360}$$

where:

Qp = peak discharge in m^3/sec

C = coefficient of runoff

I = maximum rainfall intensity in mm/hr

A = catchment area in hectares

Peak discharge (maximum rate of run-off)

This is the maximum rate of runoff, expressed in cubic metres per second, which can be expected from a catchment for a particular rainfall event.

Example:

C (from the table below) = 25, 5, 10, 5 = 45
I = 75 mm/hr
A = 500

Qp = 16875 / 360
Qp = 46.88

The coefficient of run-off table is the ratio to rainfall expressed as a decimal fraction. The coefficient of run-off is affected by rainfall intensity, the infiltration capacity of the soil, by surface slope and vegetation cover and by other forms of surface storage and detention. Some interpolation is often required when using this table as some of the conditions in the various boxes need to suit particular situations.

Table 9. Determination of coefficient of run-off ('C') for various catchment conditions.

Catchment characteristics	Run-off producing characteristics							
Rainfall intensity	75-100 mm/hr	30	50–75 mm/hr	25	25-50 mm/hr	15	<25 mm/hr	5
Relief	Steep, rugged av. slopes above 20%	10	Hilly, av. slopes 10–20%	5	Rolling, av. slopes 5–10%	0	Relatively flat, av/ slopes 0–5%	0
Surface retention	Negligible, few surface depressions, watercourses steep; overland flow thin.	10	Well defined system of small watercourses.	5+	Considerable surface depressions; overland flow significant; some ponds and swamps, some s/c earthworks.	5	Poorly defined and meandering streams; large surface storage; s/c earthworks on 90% of land.	0
Infiltration	No effective soil cover; either solid rock or thin mantle.	25	Slow infiltration, e.g. solodic soil when surface sealed.	20	Loam soil or well structured clay soils, e.g. Chemozem.	10	Deep sand or well aggregated soils, e.g. Kraznozems.	5
Cover	No effective plant cover.	25	Sheet eroded native pastures; less than 10% under good pasture; clean cultivated crops.	20	50% of area with improved pasture; not more than 50% cultivation or open woodlands.	10	About 90% of area with improved pasture or forest.	5

1. To determine run-off coefficient, select the most appropriate description of each of the five characteristics and use the total of the values as a decimal fraction (e.g. a total of 75 becomes a coefficient of 0.75).
2. Reduce total by 5 for increased infiltration in hot climates (mean air temperatures above 25°C during rainfall).
3. Reduce total by 10% for rainfall interception in thick forest.

Qt = 0.2222 Tc (CIA). . . . . (3)

where:

Qt = total run-off volume in cubic metres

C = coefficient of run-off

I = peak rainfall in mm/hr

A = catchment area in hectares

Figure 14. Total discharge.

This figure is the total discharge from storms of up to two hours duration.

Example:

C = 0.45 (as previously determined)

I = 75 mm/hr

A = 500

Tc = 16.12

Qt = 0.222.(16.12)(0.45.75.500)

Qt = 3.58 (16875)

Qt = 60,412 [25]

Therefore the water management associated with firebreaks must ensure that they can handle large volumes of water over short durations.

---

[25] Hannan J C, 1984, *Mine Rehabilitation A Handbook for the coal mining industry,* New South Wales Coal Association, Sydney.

Environmental considerations

The movement of soil and water can cause significant environmental impact, particularly in areas that have a propensity to erode, areas that contain diseases such as *Phytophthora* dieback, high impact areas such as granite outcrops and areas that are protected by statutes such as declared rare flora, priority flora and rare fauna, wetlands and environmentally sensitive communities.

Phytophthora dieback

> '*Phytophthora* dieback is an introduced plant disease caused by *Phytophthora cinnamomi*. Originally *P. cinnamomi* was classified as a fungus, now it is classified as an Oomycete or water mould.
>
> *P. cinnamomi* spends its entire life in the soil and plant tissue. It attacks the roots of plants and causes them to rot. This kills the plant by limiting or stopping the uptake of water and nutrients.
>
> In sloping areas *Phytophthora* dieback spreads quickly when the microscopic spores move downwards in surface and sub-surface water flows. The disease can also spread uphill autonomously through root to root contact at approximately one metre per year.
>
> However, it is human activity that causes the most significant, rapid and widespread distribution of this pathogen. Road construction, earth moving, driving vehicles on bush roads and stock movement can all contribute significantly to the spread of *Phytophthora* dieback. Bush restoration projects may also inadvertently spread the pathogen.
>
> It is important to ensure that water does not pond or accumulate in the upslope areas as an introduction of the *Phytophthora* dieback into this environment will intensify the potential spread and downslope impact.
>
> Soil that is warm and moist provides the best conditions for *Phytophthora* dieback. These conditions allow the pathogen to produce millions of spores. These spores are attracted to the plant roots and actively swim through the soil water.' [26]

Granite outcrops

Granite outcrops form a complex part of the WA ecosystem, and therefore require protection from unnecessary disturbance.

> 'Most granite outcrops require management if their local biota is to survive. Physical degradation by rock removal, clearing, invasion by disease, weeds and feral animals, excessive grazing pressure, altered fire regime, and progressive salinisation are but some of the ongoing processes that are likely to affect the long-term survival of granite outcrops and their biota.' [27]

As a consequence of the very important ecological and social values associated with granite outcrops fire managers must wherever possible limit potential adverse fire activities (e.g. constructing firebreaks near to granite outcrops, prescribed burning at an inappropriate time or frequency or the construction of machine firelines in the vicinity of granite outcrops).

---

[26] Kilgour S, 2009, *Managing Phytophthora Dieback in Bushland A Guide for Landholders and Community Conservation Groups,* Dieback Working Group

[27] Withers P C, Overview of granite outcrops in Western Australia, *Journal of the Royal Society of Western Australia,* Volume 83, Part 3, September 2000.

Declared rare flora and priority flora

Declared rare flora (DRF) is protected under the *Wildlife Conservation Act* and must not be taken without the approval of the Minister for the Environment. These species are extremely rare and require protection.

Prior to constructing firebreaks or machine firelines the person undertaking the work must consider the location of the DRF and not disturb the flora. Ideally, locate a different firebreak route or, if that is not practical or possible, then it is a legal requirement to obtain the necessary approval 'to take' the DRF. It must not be assumed that approval 'to take' will be given automatically. There will be a requirement to justify the placement of the firebreak on that location.

Priority flora does not have the same level of legislative protection as DRF but they are still extremely vulnerable and require protection. The approval 'to take' is through the administration by the Department of Environment and Conservation. Again, it must not be assumed that approval 'to take' will be given automatically. There will be a requirement to justify the placement of the firebreak on that location.

The following list describes the declared rare and priority flora:

- **Declared Rare Flora—Extant Taxa**
  Taxa which have been adequately searched for and are deemed to be in the wild either rare, in danger of extinction, or otherwise in need of special protection, and have been gazetted as such.
- **Declared Rare Flora—Presumed Extinct Taxa**
  Taxa which have not been collected, or otherwise verified, over the past 50 years despite thorough searching, or of which all known wild populations have been destroyed more recently, and have been gazetted as such.
- **Priority One—Poorly known Taxa**
  Taxa which are known from one or a few (generally <5) populations which are under threat, either due to small population size, or being on lands under immediate threat (e.g. road verges, urban areas, farmland, active mineral leases, etc) or the plants are under threat (e.g. from disease, grazing by feral animals, etc). May include taxa with threatened populations on protected lands. Such taxa are under consideration for declaration as 'rare flora', but are in urgent need of further survey.
- **Priority Two—Poorly Known Taxa**
  Taxa which are known from one or a few (generally <5) populations, at least some of which are not believed to be under immediate threat (i.e. not currently endangered). Such taxa are under consideration for declaration as 'rare flora', but are in urgent need of further survey.
- **Priority Three—Poorly Known Taxa**
  Taxa which are known from several populations, and the taxa are not believed to be under immediate threat (i.e. not currently endangered), either due to the number of known populations (generally >5), or known populations being large, and either widespread or protected. Such taxa are under consideration for declaration as 'rare flora' but are in need of further survey.
- **Priority Four—Rare Taxa**
  Taxa which are considered to have been adequately surveyed and which, whilst being rare (in Australia), are not currently threatened by any identifiable factors. These taxa require monitoring every 5–10 years.

Wetlands

In the *Environmental Protection Act* a wetland is defined as:

(a) a wetland included in the List of Wetlands of International Importance kept under the Ramsar Convention;

(b) a nationally important wetland as defined in 'A Directory of Important Wetlands in Australia' (2001), 3rd edition, published by the Commonwealth Department of the Environment and Heritage, Canberra;

(c) a wetland designated as a conservation category wetland in the geomorphic wetland maps held by, and available from, the Water and Rivers Commission;

(d) a wetland mapped in Pen, L. 'A Systematic Overview of Environmental Values of the Wetlands, Rivers and Estuaries of the Busselton–Walpole Region' (1997), published by the Water and Rivers Commission, Perth; or

(e) a wetland mapped in V & C Semeniuk Research Group 'Mapping and Classification of Wetlands from Augusta to Walpole in the South West of Western Australia' (1997), published by the Water and Rivers Commission, Perth. [28]

These areas require protection and must not be disturbed during the creation or maintenance of a firebreak. In many instances not only will the firebreak be a disturbance to the wetland but it will not effectively serve its purpose as the organic material likely to be found in the area will burn under summer soil drought conditions.

Environmentally sensitive communities

The *Environmental Protection Act Environmental Protection (Clearing of Native Vegetation) Regulations 2004 reg (6)* also defines environmentally sensitive communities as:

(1) (a) a declared World Heritage property as defined in section 13 of the *Environment Protection and Biodiversity Conservation Act 1999* of the Commonwealth;

(b) an area that is registered on the Register of the National Estate, because of its natural values, under the *Australian Heritage Commission Act 1975* of the Commonwealth;

(c) a defined wetland and the area within 50 metres of the wetland;

(d) the area covered by vegetation within 50 metres of rare flora, to the extent to which the vegetation is continuous with the vegetation in which the rare flora is located;

(e) the area covered by a threatened ecological community;

(f) a Bush Forever site listed in 'Bush Forever' Volumes 1 and 2 (2000), published by the Western Australia Planning Commission, except to the extent to which the site may be cleared under a decision of the Western Australia Planning Commission;

(g) the areas covered by the following policies —

  (i) the *Environmental Protection (Gnangara Mound Crown Land) Policy 1992*;

  (ii) the *Environmental Protection (Western Swamp Tortoise Habitat) Policy 2002*;

(h) the areas covered by the lakes to which the *Environmental Protection (Swan Coastal Plain Lakes) Policy 1992* applies;

(i) protected wetlands as defined in the *Environmental Protection (South West Agricultural Zone Wetlands) Policy 1998*;

---

[28] *Environmental Protection Act,* 1986, *Environmental Protection (Clearing of Native Vegetation) Regulations 2004 (WA)*

(j) areas of fringing native vegetation in the policy area as defined in the *Environmental Protection (Swan and Canning Rivers) Policy 1997*.

(2) An area that would otherwise be an environmentally sensitive area because of subregulation (1) is not an environmentally sensitive area unless —

(a) the declaration, registration, listing, mapping or definition of the area, site or flora has been made public; or

(b) the owner, occupier or person responsible for the care and maintenance of the land has been informed of the declaration, registration, listing, mapping or definition of the area, site or flora.

(3) An area that would otherwise be an environmentally sensitive area because of this regulation is not an environmentally sensitive area to the extent to which the area is within the maintenance area of a stretch of road or railway.

(4) For the purposes of subregulation (1)(d), an area of vegetation is continuous with another area of vegetation if any separation between the areas is less than 5 m at one or more points.

(5) For the purposes of subregulation (1)(f), an area of a Bush Forever site may be cleared under a decision of the Western Australia Planning Commission if —

(a) the Commission has made a decision with respect to the site that, if implemented, would have the effect that the area may be cleared;

(b) that decision is not under assessment under Part IV of the *Environmental Protection Act 1986*; and

(c) where an assessment under Part IV of the *Environmental Protection Act 1986* has been made—the decision may be implemented.

(6) In determining the extent of an environmentally sensitive area in relation to the maintenance area of a stretch of road or railway, the following apply—

(a) for an area that is an environmentally sensitive area on the day on which this regulation comes into operation, the maintenance area of the stretch of road or railway is the maintenance area of the stretch of road or railway on that day;

(b) for an area that becomes an environmentally sensitive area after the day on which this regulation comes into operation, the maintenance area of the stretch of road or railway is the maintenance area of the stretch of road or railway on the day before the day on which the area becomes an environmentally sensitive area. [29]

These areas require protection and must not be disturbed during the creation or maintenance of a firebreak unless authorised by an exemption.

Weeds

What is considered a weed depends on perceptions and the context in which the term is used. In general weeds may be regarded as such when they:

1. Are an economic threat.
2. A threat to an indigenous species.
3. When they disrupt the ecosystem process.
4. Inhibit corrective land management strategies.

---

[29] *Environmental Protection Act,* 1986, *Environmental Protection (Clearing of Native Vegetation) Regulations 2004 (WA)*

For the most part it is exotic plant species that are considered weeds or undesirable species. Australian native plants when grown outside of their normal range can also become weeds.

The following summarises the effect of the declaration categories for plants under the *Agriculture and Related Resources Protection Act 1976*:

- P1—Introduction of the plant into, or movement of the plant within, an area is prohibited.
- P2—Plant to be eradicated in the area.
- P3—Plant to be controlled by reduction in number or distribution of the plant or both.
- P4—Spread of plant beyond where it currently occurs to be prevented.
- P5—Particular action to be taken on public land or land under the control of a local government.[30]

Information about requirements relating to the introduction, movement, eradication and control of declared plants is available from the Department of Agriculture and Food.

Bushland or environmental weeds may be defined as 'an unwanted plant or species growing in bushland'. Bushland weeds may be categorised according to their degree of invasiveness—that is, as:

1. Established.
2. Adventives.
3. Casual.[31]

There are several types of environmental weeds. These are:

1. Species introduced from overseas.
2. Australian species from outside Western Australia.
3. West Australian species outside their pre-European distribution.[32]

Weeds are potentially a major threat to Australia's natural environment. Soil disturbance, such as firebreak construction or maintenance, can favour weeds over local indigenous species. This provides opportunities for weeds to colonise new areas, and reduces the ability of native vegetation to compete with and suppress invading weed plant species. Weed species frequently have a regeneration advantage over local indigenous species because of the weed life cycle and seed production potential.

Firebreak construction and maintenance disturbances can facilitate weed establishment because all competition for light, nutrients, moisture and space have been removed. Machinery used during the firebreak work must be free of weed seeds prior to entry into a location.

The potential for environmental degradation as a consequence of firebreak location, construction and maintenance must be considered during the planning and implementation phases.

---

[30] *Agriculture and Related Resources Protection Act,* 1976 (WA)

[31] CALM, 1983, *Weed management,* unpublished.

[32] Carr, Yugovic *et al*, 1992, *Environmental weed invasions in Victoria*, E. Melbourne, Dept of Conservation & Environment & Ecological Horticulture Pty Ltd.

References

Agriculture and Related Resources Protection Act, 1976 (WA)

Australian Centre for Minesite Rehabilitation Research, 1997, *Short Course on Mine Rehabilitation: principles and practice*, Kenmore, Queensland.

Standards Australia 1999, *AS 3959 Construction of buildings in bushfire-prone areas*, Sydney, Australia.

Anderson, Beiswenger, Purdom, 1987, *Environmental Science* third edition, Merrill Publishing Company, Columbus, Ohio.

CALM, 1983, *Weed management,* unpublished.

Carr, Yugovic *et al*, 1992, *Environmental weed invasions in Victoria*, E. Melbourne, Dept of Conservation & Environment & Ecological Horticulture Pty Ltd.

Cheney & Sullivan, 1997, *Grassfires fuel, weather and fire behaviour*, CSIRO Publishing, Canberra.

CSIRO Forestry and Forest Products Bushfire Behaviour and Management, 1997, *CSIRO Grassland Fire Danger Meter*, CSIRO Publishing, Canberra.

Environmental Protection Act 1986 *Environmental Protection (Clearing of Native Vegetation) Regulations 2004 (WA)*

FESA, 2001, 2nd Ed, *Guidelines for Plantation Fire Protection*, Perth.

FESA, 2010, *Plantation fire guidelines (draft),* Perth.

Robertson G A, 1987, *Soil Management for Sustainable Agriculture,* Resource Management Technical Report No. 95, WA Department of Agriculture.

Hannan J C, 1984, *Mine Rehabilitation A Handbook for the coal mining industry,* New South Wales Coal Association, Sydney.

Kilgour S, 2009, *Managing Phytophthora Dieback in Bushland A Guide for Landholders and Community Conservation Groups,* Dieback Working Group

Luke & McArthur, 1986, *Bushfire in Australia,* Commonwealth of Australia, Canberra.

McGuffog, undated, *The 'how-to' of firebreaks and aerial burns,* Bushfires Council, Northern Territory.

PNG, 1995, *Papua New Guinea Logging Code of Practice,* Department of Environment and Conservation, Boroko, Papua New Guinea.

WAPC, 2001, *Planning for Bush Fire Protection,* Perth WA.

Withers P C, Overview of granite outcrops in Western Australia, *Journal of the Royal Society of Western Australia,* Volume 83, Part 3, September 2000.