A FIRE MANAGEMENT PLAN FOR LORNA GLEN (MATUWA) AND EARAHEEDY (KARARA KARARA) 2011-2015

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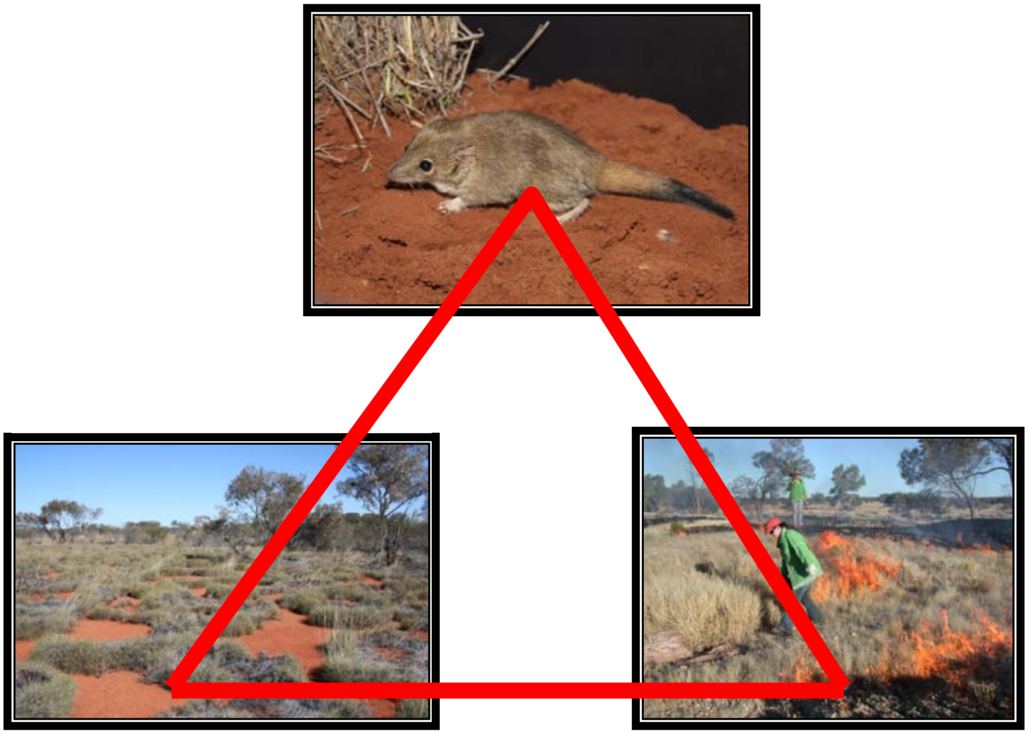

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1. Introduction

1.1. Planning context

This plan replaces the ‘Fire Management Plan 2006-2010 Lorna Glen / Earaheedy’ (Muller 2005), which focussed on the installation of fuel reduced buffers to limit the spread and damage of bushfires. This plan (2011-2015) has a two-pronged approach; i) fuel reduced buffers for bushfire damage mitigation and to assist with containing ecological patch-burning, and ii) ecological patch-burning to create and maintain a fine grain habitat mosaic to benefit biodiversity. The plan is a continuation of the 2006-2010 plan and is aligned with the Goldfields Regional Nature Conservation Service Plan (DEC 2007a), the Goldfields Regional Fire Management Plan (DEC 2008) and the Rangelands Restoration Project Plan (DEC 2010).

Because of scientific uncertainty about fire behaviour and ecological responses in these ecosystems, the plan will be implemented in an adaptive management framework (see DEC 2010 for details). The various assumptions and associated management activities will be monitored and evaluated, and if necessary, management adjusted in light of new information. Additional biodiversity monitoring (BioMonitoring) sites have been installed in the flammable Bullimore Landsystem (spinifex-dominated communities) on Lorna Glen to accommodate this (see DEC 2010 for BioMonitoring protocol).

1.2 Background

Highly flammable vegetation and long periods of hot, dry weather have ensured that hummock grassland (spinifex) ecosystems have had a long association with fire (Jones 1969; Kimber 1983, Allen and Griffin 1986, Allen and Southgate 2002). These ecosystems are not only flammable, but they are fire maintained, with plants and animals displaying a variety of physical and behavioural traits that enable them to persist with, and in many cases, depend upon a range of fire regimes. Fires have been caused by both lightning and people, but since Aborigines occupied these landscapes some 40,000 years ago (Jones 1969; Flood 1983), people have been by far the greatest source of ignitions (see Plate 1). Aboriginal people have, and in some places, continue to use fire for a variety of purposes, but mostly as a tool to acquire food and to “clean up country” (Burrows *et al*. 2006).

There is compelling evidence that fire regimes in spinifex-dominated ecosystems changed when Aboriginal people discontinued traditional burning practices (Burrows and Christensen 1990; Burrows *et al*. 2006). In a relatively short time, the regime changed from a fine grain mosaic made up of numerous burnt patches at different times since fire (seral states or fuel ages) to a coarse grain mosaic of fewer seral states. The grain size of the mosaic, or the burnt patch size, increased by several orders of magnitude following the cessation of Aboriginal burning. This pattern is consistent with that observed in other flammable landscapes around the world following a reduction in fire frequency – usually due to the departure of people, the abandonment of traditional management practices that shaped these ecosystems or partially effective suppression activity. In almost all situations where this has occurred, there are fewer fires, but the fires are larger, more intense, habitat homogenising and damaging.

This pattern may have been modified on pastoral leases, where pastoralists may have introduced fire to promote forage for sheep and cattle, or grazing may have reduced fuel loads and fire severity. For the most part, the fine scale habitat mosaic maintained by traditional Aboriginal burning over millennia has been obliterated and replaced with fewer, much larger and more intense fires.

Plate 1: Fire scars from Aboriginal burning in the Great Sandy Desert west of Lake McKay. Photo: RAAF 1953.

Altered fire regimes have been implicated in the decline of arid zone fauna over the last 60-80 years or so, with medium-size mammals and some bird species most severely affected (Saxon 1984; Burbidge and McKenzie 1989). While predation by introduced predators is most likely the primary cause of declines, this will have been exacerbated by highly altered fire regimes, and where it was practiced, pastoralism - processes that have simplified habitats and reduced vegetation cover over large areas, diminishing habitat quality and exposing native fauna to predation (Burbidge and McKenzie 1989, Letnic 2005).

As has been the case for the past 40,000 years, people are integral to fire management in these landscapes and today fire management is integral to ecosystem management and biodiversity conservation. Managing fire for the conservation of biodiversity *per se*, is a laudable but nebulous objective. Fire is one of a number of environmental factors acting alone or together with other factors that influences biodiversity and ecosystem condition (see DEC 2010). While fire can kill and injure plants and animals, it also stimulates regeneration and rejuvenates ecosystem processes such as nutrient cycling. Fire acts on ecosystems and species primarily through its action on the vegetation, or the habitat, at a variety of temporal and spatial scales. At both landscape and patch scales, fire, together with rainfall, alters the structure, composition and biomass of vegetation in space and time.

Vegetation is important in its own right and plants are also the primary producers (first trophic level) in terrestrial ecosystems, providing food and shelter (habitat) for other organisms. Vegetation provides the energy to drive ecosystems and to drive fire. For these reasons, the conceptual approach taken by this plan is to focus on the role of fire in managing the vegetation which is crucial as habitat. Good fire management will maintain a variety of seral (post-fire) states, hence diverse habitats, at appropriate scales based on the premise that diverse habitats benefit biodiversity.

2. The Physical Fire Environment

2.1 Climate and fire weather

The region experiences an arid (desert) climate (Beard 1969). Rainfall is low and unreliable with most falling in summer – the long term (1940-2009) annual average for Lorna Glen is ~250 mm (Figure 1). The summers are hot with maximum temperatures often in excess of 40°C (Figure 2) and minimum relative humidities (RH) <25%. Winters are cool to cold with sub-zero minima and pre-dawn frosts are not uncommon. In addition to cyclones and rain-bearing depressions, local summer thunderstorms can produce heavy downpours. Because of the high evaporation rates, summer rainfall can have an ephemeral effect on fuel moisture content.

Wind speed is the most important weather variable influencing fire behaviour in spinifex fuels. Wind roses (speed and direction by month) extracted from the Bureau of Meteorology (BoM) web site are provided by Muller (2005). Seasonally, spring and summer are the 'windiest' (Figure 3). Long term weather records for Wiluna show that winds are predominantly from NE to SE in summer and autumn; W to NW in spring; and light and variable in winter.

Wind speed, temperature and RH vary seasonally and diurnally. Diurnal changes of temperature and RH are predictable but wind speed is less so. Temperature increases from sunrise, peaking about mid-afternoon, then decreases reaching a minimum just before sunrise - RH trend is the reverse of this. As part of understanding the fire weather, it will be important to understand and document diurnal wind speed patterns, which, together with other weather and fuel variables, can be used to control the burn patch sizes.

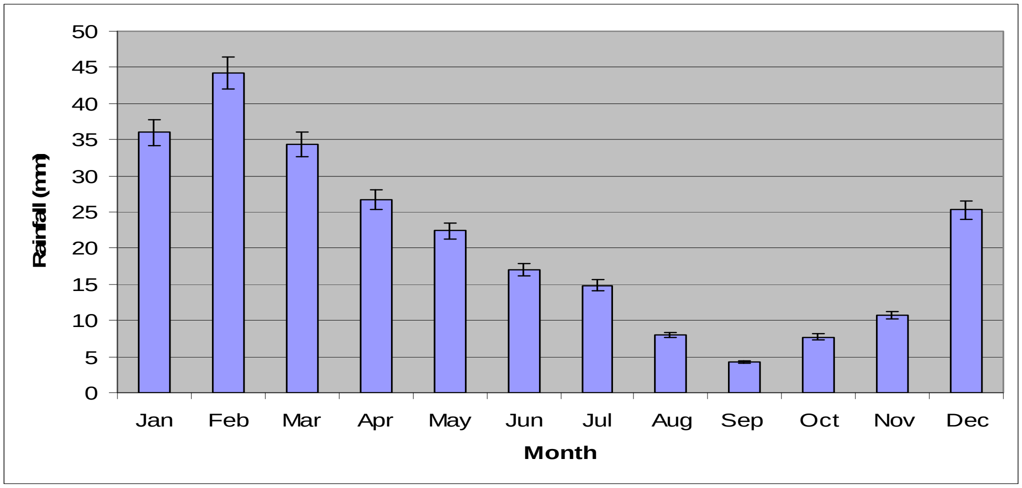

Figure 1: Mean monthly rainfall for Lorna Glen (1940-2009) showing a summer bias

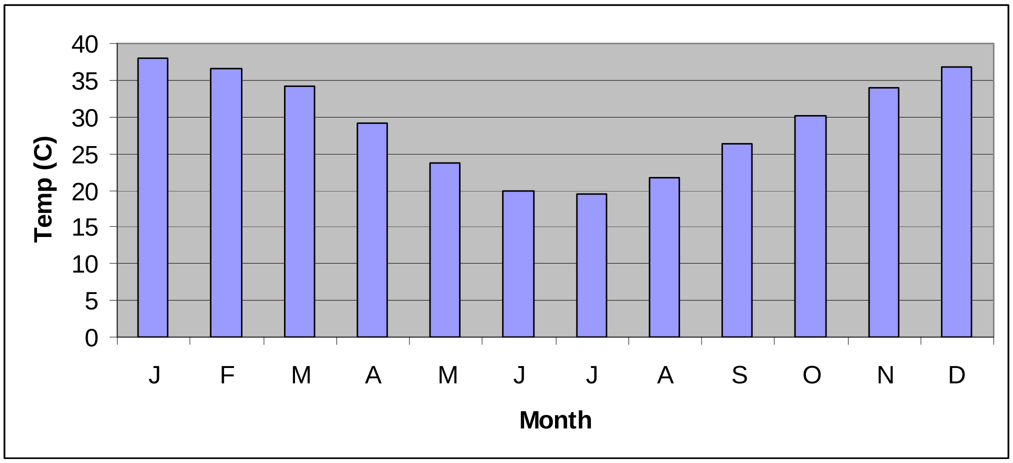

Figure 2: Mean monthly maximum temperatures for Wiluna (1902-2009)

Limited studies of diurnal wind speed patterns in the Gibson Desert (Burrows and van Didden 1991), supported by data from the Giles Meteorological Station, show that during September and October, wind speed usually increases during the day as the land surface warms, reaching a maximum soon after midday and abating as the land cools into the evening. For this reason, and the relatively mild temperatures at this time of year, 'unbounded patch-burning' has been carried out over these months with the expectation that fires would self extinguish with falling wind speed, falling temperature and rising RH (Burrows and van Didden 1991). Local knowledge, studying synoptic charts and obtaining spot forecasts will be an important part of prescribed (Rx) burning.

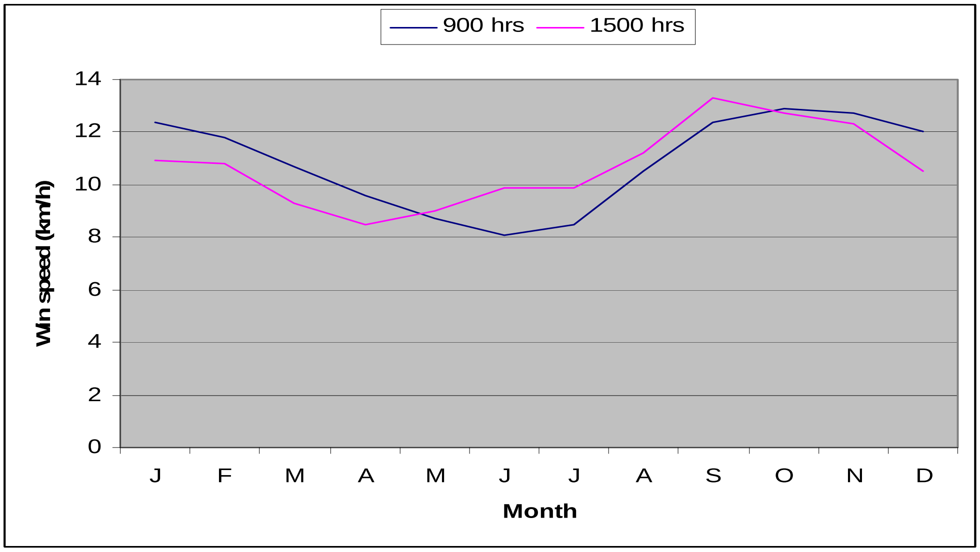

Figure 3: Mean monthly 0900 hrs and 1500 hrs wind speeds for Wiluna (1957-2009) showing wind is generally strongest over spring –summer (source: BoM).

2.2 Vegetation and fuels

While the planning area contains a diverse mosaic of landform systems and associated vegetation types, the Bullimore Landsystem on the Lorna Glen Lease Landsystem map is the most flammable on a perennial basis (see Appendix 1). For Earaheedy, substantial tracts of flammable spinifex occur within the Sandplain, Sandiman and Byro Landsystems. The flammable components of these systems are characterised by *Triodia* (spinifex) as the dominant ground cover and the keystone species, commonly growing on red sandy loam soil in sand plain / sand dune landforms or on pisolitic or lateritic stony plains (NE Earaheedy). When mature, some 15 years post-fire, spinifex cover is generally 35-45% with the cover of a variety of other trees and woody shrubs usually <15%. Soft grasses and short-lived herbs (fire ephemerals) can proliferate in the early seral (post-fire) states, especially following rain. There are at least three species of spinifex with *T. basedowii* and *T. melvillei* being most common on the red sandy-loam soils, and *T. lanigera* being restricted to the less common Cunyu Landsystem characterised by gypsum soils around lake systems. These landforms provide some shelter from fire, allowing the plants to grow to a considerable age and size.

Spinifex does occur in other landform systems such as those in the NE portion of Lorna Glen where it often grows in association with mulga and other fire sensitive plants. However, its occurrence and continuity is patchy, making these landscapes considerably less flammable than the large contiguous tracts that characterise most of the Bullimore Landsystem. That fire is an infrequent visitor to these landsystems is evidenced by the occurrence of fire sensitive taxa and the lack of evidence of previous fires. Therefore, no proactive fire management is required in these systems, at least for the life of this plan; available resources should focus on the more flammable landsystems characterised by large, contiguous tracts of spinifex.

While the spinifex-dominated landsystems could be further classified according to plant species assemblages and overstorey characteristics (if present), their fire-proneness and fire behaviour characteristics (or ‘pyrobotany’), are similar largely because of the dominance of spinifex. That is, fire interprets the landscape according to weather, topography and fuel characteristics rather than species composition *per se*. So pyrobotanically, the spinifex-dominated landsystems are relatively homogenous notwithstanding variation associated with seral state. It is logical to assume that historical fire regimes, fire response patterns and fire ecology within these spinifex-dominated, flammable landsystems will also be similar, despite some variability in species assemblages. Based on this assumption, and for the purpose of this plan, these landsystems will be treated as a single ‘fire ecosystem’. An apparent conundrum within this fire ecosystem is the co-occurrence of fire sensitive mulga (*Acacia anuera*) groves within a matrix of flammable spinifex (see also Muller 2005). This will be dealt with later.

Descriptions of spinifex as a fuel are provided by Burrows *et al.* (1991) and Burrows *et al*. (2008) so will not be presented in detail here. Briefly, the spinifex plant is highly flammable due to its physical structure, and in the case of resinous species, its chemical composition. Burrows *et al*. (1991) have described it as an “almost perfect” bushfire fuel.

As with so-called ‘resurrection plants’ the perennial spinifex plant has the remarkable ability to survive under conditions of extreme moisture stress. Rather than having a substantial root system that accesses soil moisture at depth (as is the case with many woody plants in these environments), when under moisture stress, spinifex gradually shuts down photosynthesis and growth, withdraws chlorophyll from its leaves, maintains cell structure and integrity (i.e. does not wilt) through a complex and poorly understood physiological pathway and ‘suspends’ metabolism. Under severe water stress, the plant is straw-coloured, and has the ‘cured’ appearance of an annual grass. The moisture content of ‘living’ parts of the plant (root, stem and leaf) can fall as low as 10% and plants can remain partly desiccated for at least 2 years, beyond which they will eventually start dying (N. Burrows pers. comm.). During prolonged dry spells, some plants will actually shed foliage to conserve water, giving clumps a sparsely foliaged appearance.

Following sufficient rainfall (at least 10 mm – N. Burrows pers. comm.), within a short time, the plant imbibes soil moisture, mobilises chlorophyll and commences metabolism - photosynthesis and growth - including production of new foliage, flowering and stolon growth. When the soil is wet, the foliage is very green with the moisture content of live components reaching as high as 70-80% and the moisture content of the whole plant profile, including live and dead components, reaching 40-45%.

After regeneration, usually from seed following fire and rain, the spinifex plant develops through a variety of structural or architectural forms, starting as a small dome-shaped clump, and with age, taking on a ’donut’ or crescent-shaped structure as stolons grow more-or-less radially, and older parts of the plant die. Dead spinifex is black and can persist behind the ‘active growing front’ of the plant for several years. Not only does the structure of the plant change with age, but so does the proportion of dead material in the hummock. Dead spinifex can make a significant contribution to the plant’s fuel properties mainly because it remains super dry (<6%) for long periods on account of the very low relative humidity normally experienced in desert environments. The dynamic structure of spinifex and its associated fuel properties is currently the topic of further investigation with the aim of improving an understanding of fuel dynamics and fire behaviour.

The spinifex plants form a dominant, simplex, discontinuous fuel layer with flammable elements separated by bare patches of varying dimensions. Once the cover of spinifex exceeds about 30% and its biomass exceeds about 3-4 t/ha, it has the potential to sustain fire spread. For continuous fuels such as forest litter fuels, moisture content of extinction is the only threshold to fire spread. Because of its discontinuity, or patchiness, mature spinifex fuels have at least two fire spread thresholds - the first is fuel moisture content – when wet and fully ‘green’ fire spread will be difficult (but not impossible!) to sustain (a rare condition in these environments). However, the main threshold (for mature fuels) is wind speed. The wind speed threshold varies according to cover, moisture content and fuel load, but is usually in the vicinity of 10-15 km hr^{-1} @ 2 m above ground. Guides to predicting spinifex spread are provided by Burrows *et al*. 2008. Fire in spinifex fuels is capable of spreading between 250 – 10,000 m hr^{-1} generating intensities up to 30,000 kWm^{-1}.

Other landsystems in the Lorna Glen- Earaheedy complex that are not dominated by spinifex (>30% cover when mature) and therefore never, or rarely, accumulate sufficient fuel to burn, can be charactersied as fire independent, meaning fire plays little or no role in their maintenance, and in fact, can be damaging to these ecosystems. On some sites, a cover of herbs and soft grasses can develop following successive seasons of good rainfall and will carry fire.

2.3 Topography

Spinifex dominated landsystems are characterised by sandy and stony plains and dune fields, so topography plays a minor role in fire behaviour. However, sand dune ridges are often sparsely covered with spinifex and under mild burning conditions, can be used as natural fire barriers, especially for containing flank or back fires. Under more severe burning conditions however, sand dunes are no barrier to fire spread. Obviously, other less flammable, or non-flammable landsystems are barriers to fire spread.

2.4 Fire history

Muller (2005) provides a fire history map for the planning area up to 2005 so will not be repeated here. Typical of contemporary fire regimes in these landscapes, large areas of the Bullimore Landsystem were burnt by bushfires in 1985, 2002 (~60,000 ha in a single fire event of which ~40,000 ha was on Lorna Glen) and smaller areas (several thousand ha) burnt in 2003 and 2005. As a consequence of successive bushfires, there is very little intermediate and late seral state spinifex (<5%). It will be necessary to up-date fire history in order to implement this fire plan (see below) and for annual monitoring, evaluation and reporting purposes.

3. Biological and Physical Assets

A comprehensive, adequate, representative and resilient conservation reserve system is one of the State’s key biodiversity conservation strategies and one of DEC’s primary goals (DEC 2007b). At the regional scale, the Lorna Glen / Earaheedy complex forms an important part of the nature conservation reserve network, representing geologies, landforms and vegetation types that are either not represented in the reserve system or are poorly represented. At the local scale, the complex has a very rich reptile fauna, rated as one of the world’s reptile diversity hotspots. Other extant significant fauna include a variety of small mammals such as mulgara (*Dasycercus cristicaudata*), kultar (*Antechinomys laniger*) and long-tailed dunnart (*Sminthopsis longicaudata*), an extensive bird list including mallee fowl (*Leipoa ocellata*), Australian bustard (*Ardeotis australis*), peregrine falcon (*Falco peregrinus*) and princess parrot (*Polytelis alexandrae*). There are no Declared Rare Flora (DRF) listed but there are 13 Priority species including 2 cryptogams (see Table 1).

As can be seen from Table 1 below, with the exception of *Chthonocephalus* species, none of the Priority taxa occur in flammable habitats of the Bullimore and similar landsystems. The *Chthonocephalus* species are annual herbs, so are unlikely to be adversely impacted by fire at 10-40 year intervals.

Table 1: Priority flora species for Lorna Glen / Earaheedy (source: NatureMap grid search)

Species	**Conservation status**	**Habitat**	**Habitat flammability**	**Fire management issues**
Chthonocephalus oldfieldianus	P1	Annual herb in hummock grassland	High	No Annual herb
Goodenia gibbosa	P1	Woody shrub in mulga woodland	Very Low	Non-flammable habitat
Chthonocephalus muellerianus	P2	Annual herb in hummock grassland.	High	No Annual herb
Goodenia virgata	P2	Woody shrub on banded ironstone	Very low	Non-flammable habitat
Eremophila micrantha	P3	Woody shrub Ironstone / quartzite plains and slopes	Very low	Non-flammable habitat
Frankenia georgei	P3	Salt lake margins, breakaways	Very low	Non-flammable habitat
Acacia burrowsiana	P3	Small tree on calcareous soils near lake margins	Low-Moderate	May require infrequent fire (50+yrs) for regeneration
Mimulus repens	P3	Lake margins	Very low	Non-flammable habitat
Tecticornia cymbiformis	P3	Samphire flats	Very low	Non-flammable habitat
Xanthoparmelia dayiana	P3	Lichen on bare rock and exposed habitats	Very low	Non-flammable habitat
Xanthoparmelia nashii	P3	As above	As above	As above
Eremophila pungens	P4	Woody shrub on ironstone gravels	Very low	Non-flammable habitat
Baeckea sp. Melita	P4	Woody shrub on banded ironstones / breakaways	Very low	Non-flammable habitat

In addition to extant biodiversity, Lorna Glen has become important for the restoration of mammals species that were once widespread in the semi-arid and arid zones but are now locally extinct. The Rangelands Restoration project (DEC 2010) is a fauna conservation project of global importance as the aim is to reintroduce 11 mostly threatened species by the year 2020 - four mammal species have already been reintroduced. As part of the reintroduction and restoration program, a 1,100 ha predatorproof compound has been constructed on Lorna Glen (Bode *et al.* in prep.). Currently, the compound houses reintroduced boodies, golden bandicoots and brushtail possums; other species will be reintroduced in the near future (see DEC 2010).

The acclimatisation compound is a high value asset, not only in monetary terms but also because of its crucial role in the fauna reconstruction program. Therefore, the compound and its contents, must be protected from damage by bushfire as a matter of high priority. Outside the compound, special attention will need to be given to fire management where animals have been, or are planned to be re-introduced. Initially, this is likely to require the exclusion of fire and the prevention of damaging bushfires in these habitats at least until the animals are well established, probably some 2-3 years after reintroduction.

Considerable expenditure has been incurred constructing an electrified boundary fence on Lorna Glen (incomplete) to deter stock and large feral herbivores such as camels. Sections of the fence run through flammable spinifex vegetation so it will be important to reduce the risk of bushfires damaging the fence. It will also be important to reduce the likelihood of bushfires crossing boundaries – either entering or leaving Lorna Glen / Earaheedy.

Other key infrastructure that requires protection from bushfires includes the dwellings and other buildings around the homestead precinct.

4. Fire Ecology & Fire Regimes

Scientific knowledge of the ways in which spinifex ecosystems and species respond to fire is incomplete. Consistent with an adaptive management approach, this plan draws on best available science, Indigenous knowledge, and experience to provide best possible fire management outcomes aligned with the objectives of the Goldfields Regional Nature Conservation Plan, the Goldfields Regional Fire Management Plan and the Rangelands Restoration project plan. Rather than attempting to review and summarise all of the scientific literature on fire ecology in spinifex ecosystems (see Saxon 1984; Allan and Southgate 2002), available scientific knowledge, together with some knowledge of traditional Aboriginal burning practices, has been summarised into a set of principles to guide fire management. These are at Appendix 2.

In desert ecosystems there are key feed-back loops involving fire, vegetation, biome productivity and rainfall. Antecedent rainfall drives vegetation growth, which results in increased fuel levels and increased potential for large and intense fires (Griffin and Friedel 1984a). Generally, periods of above average rainfall are followed by extensive fires due to the build-up of flammable fuel. Primarily through its influence on vegetation, rainfall also determines the quality of habitat available for animals, including cover, food and water resources, and nesting / breeding sites. On average, spinifex fuel re-accumulates at ~0.6 t/ha/annum for ~18 years before stabilising at around 11-12 t/ha. This equates to ~400 mm of accumulated rain being needed to produce 1 t/ha of fuel.

Season of the fire and post-fire rainfall will determine the composition, structure, biomass and speed of recovery of the vegetation (habitat) and its associated fauna. For example, Griffin and Friedel (1984a;1984b) working near Alice Springs found that winter fires favoured forbes and caused less physical damage to woody shrubs and trees than summer fires, which favoured grasses and stimulated better regeneration of some woody species. Southgate and Carthew (2007) working in the Tanami reported that seed from post-fire ephemeral plants like *Yakirra australiense* are an important component of the diet of the bilby and that the season and amount of rainfall and time since fire were most important in determining regeneration of *Yakirra*.

Unlike sclerophyllous vegetation that dominates much of southern Australia, spinifex-dominated ecosystems tend to follow a *pseudo-classical* succession post-fire. In the early period, annual and biennial herbs and soft grasses often dominate cover and biomass, with spinifex and woody shrubs present as either very small seedlings or as re-sprouts. With time, and depending on rainfall, the herbfield gives way to spinifex and a scattering of woody trees and shrubs, with spinifex eventually dominating the ground cover. The rate at which these ecosystems develop following fire is largely dependent on rainfall, which is unreliable and highly variable from year-to-year. This makes predicting post-fire response and fuel accumulation imprecise and indicative only (see Burrows *et al*. 2008).

At various stages of post-fire development (seral states), the floristic composition and structure of the vegetation provides different habitat opportunities for a variety of organisms. Data gathered either retrospectively or longitudinally for a variety of terrestrial fauna (vertebrates and invertebrates) show a consistent pattern – that there is no specific or optimal seral state, or time after fire, that suits *all* organisms (see Guiding Principles – Appendix 2). Some functional groups prefer the early seral states, others the later seral states and some species occur in all seral states. This fundamental ecological principle of niche partitioning associated with diverse fire-induced habitats is the ecological basis for the fine scale mosaic or patch burning strategy promoted by this plan.

Pianka (1996), writing about the incredible richness of lizards in Australian deserts noted that;

"*One of the most important factors contributing to this is fire, which generates a patchwork of habitats at different states of recover, each of which favours a different subset of lizard species. Habitat specialised species can go locally extinct within a given habitat patch (fire scar) but persist in the overall system by periodic reinvasions from adjacent or nearby patches of suitable habitat of a different age. Such spatial-temporal regional processes facilitate local diversity".*

Masters (1996) reported that a higher number of reptile species were trapped in mature spinifex and that fire mosaics maximise reptile diversity because of the preference by some species for earlier seral states. She also made the observation that recently burnt areas act as fire breaks and ensure that mature spinifex patches are always present. Langlands *et al.* (in prep.) studying the relationship between fire and spiders on Lorna Glen reported similar findings – that different spider assemblages preferred different post-fire states with about 50% of species restricted to a particular state. Similarly, Haydon *et al.* (2000) concluded that the patch-work of habitats at different stages of post-fire recovery (seral states) played a vital role in the conservation of biodiversity in desert landscapes. Smith and Morton (1990) studying scorpions in the Tanami Desert, found that one species (*Lychas alexanddrinus*) was caught most frequently 2-3 years after fire.

The relationship between patch-burning and small mammals is similar, but perhaps not as pronounced. Masters (1993) found that patch-burning spinifex grasslands to create a diversity of seral states maximised the species diversity of small mammals by ensuring that suitable successional states were always present. She concluded that this was particularly important for species that are restricted in their distribution such as mulgara (*Dasycercus cristicaudata)*. Letnic and Dickman (2005) working in the Simpson Desert found that while some species preferred long unburnt spinifex and others preferred regenerating spinifex, the greatest capture rates were made at sites that received most rainfall. Like Masters (1996), they concluded that recently burnt patches were an important part of the mosaic because they reduced the extent of bushfires. Partridge (2008) working in the Purnululu National Park concluded that small scale patchy spinifex fires were very important for *Pseudomys desertor* and *P. nanus*, which utilised long-unburnt patches for food and shelter.

Interactions between fire and introduced predation can lead to dubious conclusions about habitat preference. For example, it was thought that the mulgara was *only* found in long unburnt spinifex. However, recent monitoring at Lorna Glen has shown that this species will inhabit recently burnt spinifex with low vegetation cover once introduced predators are reduced or eliminated, suggesting that the cover provided by longer unburnt spinifex is vital when predators are present.

As mentioned, the co-occurrence of fire sensitive mulga and flammable spinifex in parts of the Bullimore Landsystem is an apparent contradiction. Muller (2005) referred to this as a “conundrum” and suggested that the co-occurrence of old, mature mulga and younger spinifex was as a result of either a) spinifex recruiting in the absence of fire or b) low intensity fires that did not kill the mulga. It is also possible that grazing by sheep and cattle in the past may have reduced fuel flammability, helping to exclude fires from these areas and allowing mulga to reach an old age (50+ years).

Nicholas *et al.* (2009) working in the Tanami Desert reported that soil properties (heavier soils and a cryptogamic soil crust) and fire frequency defined the partitioning of mulga groves. Where relatively dense groves of mulga form on soils with slightly higher clay content (5-6%), the spinifex is noticeably suppressed; its ground cover is lower and therefore less likely to carry intense fire. Thus, a fuel flammability differential exists between mulga groves and the surrounding hummock grasslands on lighter soils. This flammability differential operates best under marginal or mild burning conditions, but dissipates under more severe burning conditions when fire is able to overcome fuel discontinuity and burn the mulga groves. Therefore, the groves are able to persist for periods longer than the fire interval in the surrounding landscape only if landscape fires are relatively small and low intensity rather than infrequent, large and intense.

It is neither desirable nor possible to exclude fire for very long periods (80+ years) in Bullimore landscapes where groves of mulga occur. Rather than attempting fire exclusion, or attempting to burn around the plethora of groves with convoluted boundaries, an alternative strategy to protect the groves is to reduce the likelihood of frequent, large, intense bushfires burning into them by creating and maintaining a ‘bushfire buffered’ landscape comprising a patchwork of spinifex at different seral states / fuel ages. This is best achieved by a strategy of landscape-scale low intensity patch-burning under mild weather conditions. This will not prevent bushfires, but it will significantly reduce their damage potential.

The occurrence of inter-grove mulga, or scattered trees over a higher cover of spinifex, is more ephemeral and dynamic – it’s a pulsing phenomenon, in time, appearing and disappearing across the landscape depending on inter-fire periods, regeneration success and subsequent rainfall.

Occasionally, embedded in the Bullimore and other landsystems, flammable spinifex co-occurs in what is essentially an acacia shrubland, comprising fire sensitive species such as mulga, sandalwood and others. These patches are relatively small (usually < 100 ha) and are scattered throughout the landscape, depending on soil properties. Although small, they are quite numerous and an important part of the biodiversity of the region. On closer inspection, while there may be occasional dense spinifex patches beneath fire sensitive plants, it is mostly scattered clumps of heavier fuel separated by large bare soil patches. It would be difficult for fire to spread through these landscapes except under the most severe fuel and weather conditions. Even then, because of the patchy nature of the fuel, the fire is likely to be patchy. These ecosystems require very long intervals between fires, and may even be fire independent. Rx fire should be excluded from them - if some burn in a bushfire, so be it. As part of the monitoring protocol, mulga groves in the Bullimore Landsystem should be targeted to ensure that this fire management plan does in fact protect these groves from damaging fire. Occasional low level aerial photography (perhaps done in association with aerial baiting) with some ground-truthing may be the most cost-effect method.

5. Developing Ecological Fire Regimes

While the principles at Appendix 2 guide fire management, the development of specific, operational fire regimes for biodiversity conservation in these landscapes is challenging but necessary. The most critical elements of fire regime and mosaic metrics for spinifex-dominated ecosystems are:

- Minimum and maximum intervals between fires.
- Fire size and patchiness.
- Proportion (% area) of the landscape at various seral (post-fire) states and how these patches are distributed in the landscape.
- Seasonal timing of fires in relation to events that drive plant and animal reproduction / productivity.

5.1 Minimum & maximum fire intervals

This regime element is important, primarily because it influences ecosystem resilience, or capacity of the vegetation to recover / regenerate following fire. Generally, the post-fire response of other species will be determined by the recovery pathway of the vegetation. Fundamentally, fire interval determines the size and viability of seed banks, phytomass, structure, floristic composition and the energy reserves of storage tissue used by re-sprouters such as lignotubers, bulbs, corms and epicormic shoots. It also affects potential fire behaviour.

Plant vital attributes and life histories can be used to guide the range of appropriate fire intervals (Tolhurst 1999; Tolhurst 2000). This involves identifying the vital attributes of key ‘fire response species’, which could be fire sensitive (umbrella species), keystone species or threatened species. Key fire response species are those that are most sensitive to fire because they are most likely to be disadvantaged by excessively short or long fire intervals. Having identified the key species it is possible to determine the time interval between fires required to conserve species, i.e. the maximum and minimum intervals between lethal fires (Friend 1999; Tolhurst 1999; Burrows *et al*. 2008).

Time to first flowering after fire (juvenile period) is an important vital attribute as it indicates maturation and seed production (Burrows *et al*. 2008). Muller (2005) provides information on post-fire regeneration strategies and juvenile periods for a range of arid zone plants, based on observations of largely Pilbara flora provided by Stephen Van Leeuwen (DEC Science Division). From this, it is clear that a) most species in these environments depend on seed for regeneration following fire, b) a number of tree-form (arborescent) acacias such as mulga, have juvenile periods >10 yrs, c) all other species have juvenile periods <10 yrs with most <5 yrs. There are at least two taxa for which information about juvenile period and longevity is important – 1) spinifex – because it's a keystone species in these landscapes, and 2) mulga – an umbrella fire sensitive species that sometimes co-occurs with spinifex in the Bullimore Landsystem (see above).

Following average or better rainfall, precocious spinifex plants have been observed to flower within 2 years of fire. However, a more realistic time period for at least 50% of the population to reach maturity, and assuming average rainfall conditions over that period, is 4-5 years. Burrows and Wardell-Johnson (2008) provide a rule of thumb of allowing a minimum inter-fire period of at least twice the juvenile period for post-fire recovery of seedbanks. For spinifex ecosystems, a conservative minimum fire interval is 8-10 years. While spinifex ecosystems could probably recover from an occasional shorter fire interval, 8-10 years is considered a safer interval under average rainfall conditions over the period. It is unlikely that fuel would be such that fires could be sustained in spinifex at an earlier age – the exception being a sequence of above average wet seasons and consequent in-filling by herbs and soft grasses. There have been observations in desert biomes where two fires in 2 years following good seasons have transformed once spinifex dominated communities to simplified soft grass (*Eragrostsis* sp.) and herb communities (N. Burrows pers. comm.).

If the juvenile period of mulga was to be used to set minimum fire interval, then the conservative interval would be about 20-30 years – given that the juvenile period of mulga is 10-15 years depending on rainfall. As outlined above, it is neither appropriate nor practical to use the vital attributes of mulga to apply to the broader Bullimore Landsystem because appropriate fire management based on the flammable and keystone species (spinifex) will also protect mulga groves from fire for 40+ years. That is, the introduction of low intensity patch-burns under mild burning conditions (Fire Spread Index <2) is unlikely to burn or significantly damage mulga groves (as distinct from inter-grove mulga) because of the flammability differential, and once the fine scale landscape mosaic is established, it will provide a higher level of protection to mulga groves against damaging high intensity bushfires.

There are few biological indicators of the maximum interval between fires in the spinifex dominated landsystems (Bullimore, Sandplain etc.) One of these is the biomass, structure and vitality of spinifex plants. Clearly, it is desirable for a fire to occur before ageing spinifex plants (and other species) loose their vitality, seed production potential and their seed banks. The vigour of spinifex begins to decline from the time the plant centres die (Griffin 1984). While spinifex will recruit between fires, the combination of fire and rain provides conditions for a mass recruitment event, which is why many spinifex communities appear even-aged – although it is not uncommon for late seral state populations to be multi-aged suggesting several inter-fire recruitment events –

possibly stimulated by exceptional rainfall. From field observations, spinifex biomass declines and plants appear to break down and senesce around 40-50 years after fire. Not only does this reflect a reduction in productivity and possible decline of seed banks, but the fuel can reduce to a point where fire spread cannot be sustained. As fire and its associated by-products (heat, smoke, ash) are vital to cueing seedling germination of many species, including spinifex, this is undesirable.

As a rule of thumb based on biomass accumulation, height and cover of spinifex, the maximum interval between fires in the Bullimore Landform is 40 years - until there is better information, or an identified need to alter this period such as retaining a long unburnt fire reference area for scientific purposes. This figure (40 years) is consistent with Griffin (1984) who suggests that optimum maturity is reached after 8,000 -10,000 mm of (accumulative) rainfall. Assuming an annual average rainfall of 250 mm, this equates to about 36 years. It is likely and desirable for mulga groves and other less flammable habitats that *escape* regular low intensity, patchy fires in these landscapes to remain unburnt for 80+ years. The vitality of mulga groves will decline when canopy closure occurs, and at some stage prior to this, these groves will benefit from infrequent fire to stimulate seedling regeneration.

5.2 Fire size and patchiness

Fire size and patchiness is a factor that is more relevant to animals than plants, although it may be applicable to seed dispersal of some species such as wind-borne grass seeds or propagules relying on animals for dispersal. When large areas of a landscape are subjected to a single, homogenous disturbance such as a large, intense fire, then this will diminish habitat diversity and threaten fauna that depend on a variety of habitats, or seral states (Miller 1982, Saxon 1984). Fire size determines the patch size of the various fire-induced habitat types (seral states), therefore the juxta-position of various habitats in the landscape. For fauna that have specific habitat requirements with respect to seral state, they are more likely to find suitable habitats and refugia in a landscape where patch sizes are ‘small’ rather than ‘large’. Such a landscape facilitates recolonisation and the functioning of meta-populations – i.e. migration and the functioning of sources and sinks. The assumption is that smaller patches make the landscape more ‘permeable’ to fauna.

There are no sound biological indicators or evidence of the optimum scale of fires in spinifex ecosystems. From first principles (see Appendix 2), small fires / patches make better ecological sense than large fires for the reasons given above. While there is inherent patchiness in large and intense bushfires, unburnt patches within bushfires, as important as they are, are usually small and scattered compared with the size of burnt patches.

Table 2 below summarises burnt patch metrics for a remote Great Sandy Desert landscape studied by Burrows and Christensen (1990) and Burrows *et al*. (2006). The table is a summary of burnt patches mapped from 1953 aerial photography in a remote desert location that was under a regime of traditional Aboriginal (Pintupi and Martu) burning at the time of the photography, providing a rare insight into the fire landscape. Gill (2000) cautions that large tracts of central Australia may have been unoccupied by Aboriginal people, so subjected to lightning ignitions only.

Table 2: Recently burnt patch statistics for a desert landscape under traditional Aboriginal burning.

Source	**Area sampled (ha)**	**No. of recently burnt patches**	**Mean patch size (ha)**	**Median patch size (ha)**	**Range (ha)**
Burrows & Christensen (1990)	53,483	372	34	5	0.5 -1,744
Burrows *et al.* (2006)	241,219	846	64	6	0.5 – 6,005

While these statistics are interesting and provide some information about patch size under traditional Aboriginal burning, they do not reveal the full picture – the proportion of the landscape affected by various fire size classes. That is, while small patches were most numerous, the larger patches, although fewer, made up most of the burnt landscape. This pattern is demonstrated in Figures 4 and 5 below.

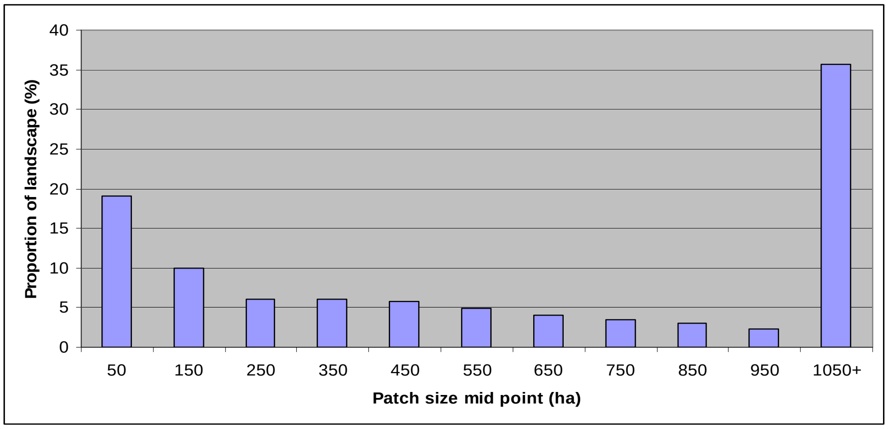

Figure 4: Size class distribution of recently burnt patches in a landscape influenced by traditional Aboriginal burning (source: Burrows et al. 2006).

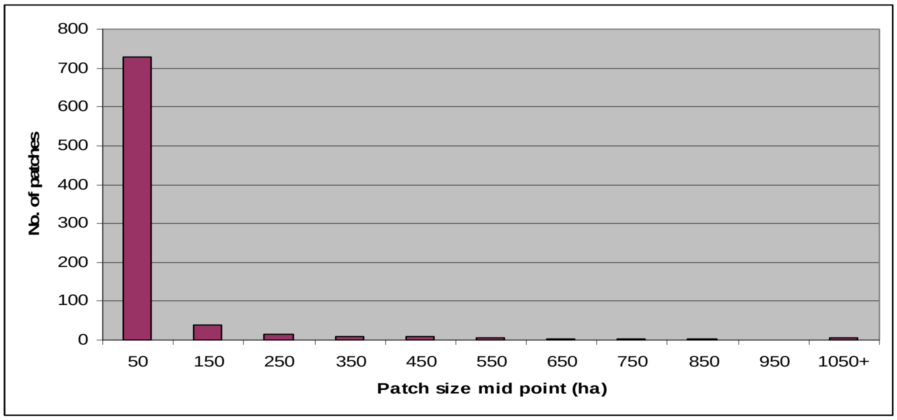

Figure 5: The number and size of recently burnt patches in a landscape influenced by traditional Aboriginal burning (source: Burrows et al. 2006).

While the means and maxima varied between the two studies (Table 1), the median patch size was about the same (5 ha & 6 ha). The authors concluded that such small patch sizes were achieved by purposeful and frequent introduction of fire into the landscape. However, within several decades of the cessation of Aboriginal burning, the mean, median and maximum patch sizes had increased to 4,970 ha, 390 ha and 71,346 ha respectively. This dramatic change in fire regime may have been modified to some extent on pastoral lands.

Griffin and Allen (1984) recommend some eleven different patch sizes for a variety of land units in the Uluru National Park, ranging from 1-5 ha patches within mulga groves, to 400-500 ha patches within sandplains. In the absence of better information, this plan will aim to reproduce the scale of traditional Aboriginal patch-burning, as reported by Burrows and Christensen (1990) and Burrows *et al*. (2006). Because the shape, size, number and distribution of burnt patches cannot be precisely controlled, the aim will be to keep the mean burnt patch size < 100 ha with the median patch size <10 ha, accepting that larger fires will inadvertently occur (up to 6,000 ha - see Table 2) and noting that under traditional Aboriginal burning, some 70% of the landscape was burnt by patches >100 ha.

This plan will aim to keep bushfires <6,000 ha. This upper limit for bushfire size is based on a) the maximum burnt patch size mapped by Burrows *et al.* (2006) under a regime of traditional Aboriginal burning and b) it is a realistic figure in this environment once the mosaic Rx burning program is in place and given that the average size of the Fire Management Units (FMUs) is about 6,000 ha (see Appendix 1).

5.3 Proportion and distribution of seral states

In flammable ecosystems such as hummock grasslands, and in the absence of suppression activity, the form of the relationship of the proportion of the landscape at various seral state / fuel age classes will approximate a negative exponential (Tolhurst 1999; Tolhurst 2000; Wouters *et al.* 2000). That is, a greater proportion of the landscape will compromise early and intermediate seral states, or younger fuel ages. The reverse of this, i.e., the majority of the landscape being of late or very late seral state, or old fuels, is unstable and impossible to maintain in the longer term in the absence of a supreme suppression effort. The shape of the negative exponential will depend on several factors, including fire frequency, or the number of ignitions in the landscape, and the assumption that all parts of the landscape have the same probability of ignition.

The shape of the negative exponential for particular vegetation types can be theoretically / mathematically derived by various plant life history attributes such as juvenile period and longevity of key fire response species, and this shape used as a basis for determining the *theoretically* ideal proportion of the landscape at various seral states / fuel ages (Tolhurst 2000; Tolhurst and Friend 2001). A parameter that must be defined to calculate the idealised age class distribution is the fire cycle. This is the time period within which the total area of a vegetation type, or landsystem, will be burnt (excluding ‘no plan burn’ areas etc.). The length of the fire cycle can be estimated as being about the midpoint between the upper and lower tolerable inter-fire periods. The shape of the theoretical negative exponential describing the fuel age class distribution is defined by the starting and finishing areas in the distribution and then using an exponential regression model to determine the parameters for joining these limits. The methodology is explained in detail by Tolhurst (2000).

Using this methodology, Muller (2005) provided a variety of theoretical negative exponential curves in the 2006-2010 Fire Management Plan based on various vital attributes of plants in different ecosystems. However, assigning multiple distributions to a single fire ecosystem is too complex and unnecessary, so it is appropriate to use a single idealised fire age class distribution for the Bullimore, Sandplain and other spinifex-dominated Landsystems based on the vital attributes and fire cycle of spinifex, the keystone species in these systems. This is shown in Figure 6 and is the same as Muller's (2005) Figure 2.

Annual mosaic burning programs can be prepared by comparing the actual seral state / fuel age distribution to the theoretical idealised age distribution to identify age classes that are over or under represented in the landscape (see Appendix 3). These can then be assessed for burning if over represented, or exclusion from burning if under represented.

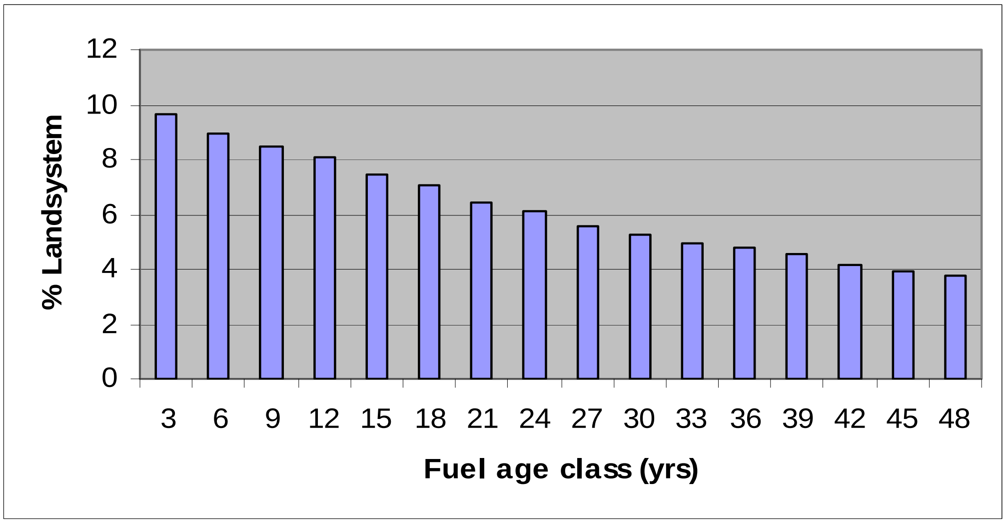

Figure 6: Theoretical ideal fuel age class distribution for Bullimore and Sandplain Landsystems based on vital attributes of keystone species T. basedowii and T melvillei.

Another related approach, one that is more biologically meaningful in these ecosystems of unreliable rainfall, and more practical to implement, is to determine the desired proportion of the landsystem at various seral states, or functional habitats, where a functional habitat is a combination of fuel age classes and reflects the state of the vegetation as habitat (structure, cover, biomass etc.) rather than its specific age since fire – see below. This also helps to 'even out' year-to-year variability in rainfall and consequent biomass productivity.

- Very early seral state: fuel age <=6 yrs or 1500mm accumulated rain
- Early seral state: 6 yrs < fuel age<=12 yrs or 1500mm<accumulated rain<=3000mm
- Intermediate seral state: 12 yrs< fuel age <=24 yrs or 6000mm<accumulated rain<=6000mm
- Late seral state: 24 yrs < fuel age <= 36 yrs or 6000mm<accumulated rain<=9000mm
- Very late seral state: fuel age > 36 yrs or >9000mm accumulated rain

The above classes are loosely based on the developmental stages of spinifex (cover, structure, biomass), although the class boundaries are somewhat arbitrary. The accumulated rainfall figures are a reminder that post-fire development is dependent on rainfall rather than time since fire *per se*, so the times may alter depending on rainfall. Using these seral state classifications and the proportions (%) shown in Figure 6, the theoretical ideal distribution of seral states / functional habitats in the Bullimore and Sandplain Landsystems is as summarised in Table 3 below. Due to the constraints of Rx burning and unknowns such as bushfires, it will be difficult, if not impossible to precisely meet the theoretically ideal seral state distribution, but it provides guidance and a target for fire management.

Table 3: Theoretical idealised proportion of functional habitats (seral states) for the Bullimore and Sandplain Landsystems based on vital attributes of keystone species (Triodia spp.).

Seral state	Very Early (<=6 yrs)	Early (6-12 yrs)	Intermediate (12-24 yrs)	Late (24-36 yrs)	Very Late 36+ yrs
% Landscape	19.4%	17.4%	26.3%	20.5%	16.4%

Seral states should be a scattered (rather than clumped) in the landscape to maximise habitat boundary, edge effect and the total distance of boundaries between different seral states. Each fire management unit (FMU – see below under heading ‘Strategies’) should contain at least three of the five seral states described above.

5.4 Seasonality of fires

There are several factors that influence when to burn. Probably the most ecologically significant of these is the timing of fire in relation to rainfall, which will strongly influence the early post-fire recovery rate and regeneration success. Because rainfall is unreliable and difficult to predict, the timing of burning can only be planned around those times of the year when statistically, burning is most likely to be followed by rainfall within several months. From Figure 1 above, burning during the period September to December increases the likelihood of follow-up rainfall within several months to stimulate regeneration.

Based on interviews with Aboriginal people, Burrows *et al.* found that fires were set throughout the year, but especially from about the time when reptiles were becoming active (around September). While there may be requirements for ‘cold burns’ (burning under conditions when fire won’t spread – i.e. lighting individual clumps) or ‘cool burns’ (when fires will *just* spread) over the autumn - winter months (April-August), most ecological burning should take place from September to December inclusive if feasible and safe to do so. Southgate and Carthew (2007) also recommended burning in late spring – early summer to optimise the chances of *Yakirra* regeneration, an ephemeral post-fire herb that is an important food resource for the bilby.

The other important factor determining ‘when to burn’ is the fire danger rating, or the ease of controlling or managing fire spread and fire size, which is primarily a function of wind speed. The combination of warm dry weather and relatively high wind speeds over the spring – early summer period (September to December) increases the fire danger rating and the potential for fast-spreading, large fires, compared to the autumn – winter period when wind speeds and ambient temperatures are lower.

For burn security and during the early stages of re-establishing a fine scale patch-burn mosaic, it will be prudent to establish a network of low fuel buffers along roads and tracks that form the perimeter of FMUs. To reduce the likelihood of large fires developing within or across FMUs, perimeter and boundary buffers should be complimented by a network of internal low fuel strips and patches installed during the period when wind speeds are likely to be low (April – August) or after significant rainfall (>10 mm) when fuel and soil moisture content will be higher. Mosaic ecological patch-burning should be carried out within these buffers over September – December. Burning conditions (weather) can be quite severe over the summer months with the potential for very fast spreading fires, so necessary precautions will need to be taken (see below).

In addition to providing a level of burn security and fire scale containment, buffer and strip burning under marginal burning conditions will also add to the fire diversity of the mosaic.

6. Specific Fire Management Objectives

6.1 Objective 1: Ecological patch- burning to support biodiversity conservation

The conservation of biodiversity is the key management goal for the Lorna Glen – Earaheedy complex. Along with other management activities, ecologically appropriate fire management is essential to achieving this goal, especially in the spinifex-dominated, flammable Landsystems such as Bullimore, Sandplain and others. Proactive fire management is necessary to create and maintain suitable habitats and to reduce the adverse impacts of bushfires on biodiversity and other values. Because of the variability of weather, burning conditions, unplanned fires etc. it will be difficult to precisely meet the following targets, but they provide a guide and something to aim for. The specific, quantifiable fire management objective to support biodiversity conservation is:

- To create and maintain a fine scale mosaic of diverse seral states and functional habitats with the following characteristics and metrics:
    - Fire intervals 10-40 yrs (80+ years for mulga groves)
    - Burnt patch size:
        - Mean ~100 ha
        - Median ~10 ha
    - Acceptable limits:
        - 35% of landscape: patches < 250 ha;
        - 35% of landscape: patches 250 ha -700 ha
        - 30% of landscape: patches 700-1,000 ha
    - Contain bushfires to <6,000 ha.
    - Proportion of seral states (rounded from Table 3 above):
        - Very early ~ 20%;
        - Early ~ 20%;
        - Intermediate ~ 25%;
        - Late ~ 20%;
        - Very late ~ 15%

- Landscape distribution of seral states: Scattered - each FMU to contain at least three of the five seral states; optimise habitat boundary.
- Season of fires:
  - Ecological (patch) burns: September to December
  - Fuel management (buffer / edge / strip) burns: April – August or when appropriate, such as after significant rainfall when fuel moisture content has increased. The tactic is to burn under marginal burning conditions such that fires will just spread.

6.2 Objective 2: Protection of other assets

There are significant other assets that require protection from fire damage, including:

- the acclimatisation compound - habitat, animals and fence
- habitat occupied by recently reintroduced animals
- boundary fence
- 'no planned burn' areas and scientific reference areas
- neighbouring properties (from fires leaving Lorna Glen / Earaheedy)
- buildings around the homestead precinct at Lorna Glen

7. Strategies & Tactics

7.1 Objective1: Ecological burning to support biodiversity conservation

An example of how to determine the annual Rx burn program from fuel age plans is shown at Appendix 3. The example does not go beyond several cycles because subsequent cycles of Rx burning will depend on what was burnt (Rx and bushfires) in the previous cycle, and this can be variable. Determining the annual burning program involves the following steps.

1. Identify / map Fire Management Units (FMUs) in the Bullimore, Sandplain and other large tracts of spinifex-dominated landsystems on Lorna Glen and Earaheedy, ignoring the non-spinifex dominated landsystems. In general terms, this means the Bullimore in the SW of Lorna Glen and the patch in the NE. On Earaheedy, this means only the large tracts of spinifex plains on the NE and S boundaries. These form the basic fire management units rationalised to existing roads and tracks and will vary in size, depending on track layout. The average size of FMUs will be ~6,000 ha (see Appendix 1).
2. Collate fire history and map current fuel ages from satellite imagery. Determine the area of each fuel age and the area of non-flammable vegetation for a) the entire Bullimore, Sandplain and other flammable landsystems and b) for each FMU.
3. From 2 above, calculate the area of the various seral states / functional habitats (Very early, Early, Intermediate, Late, Very late) for a) entire Bullimore, Sandplain and other flammable landsystems and b) each FMU. Express as a per cent of total flammable component of the landsystem. That is, exclude non-flammable elements within the landsystems.
4. Compare the existing actual proportions of the various seral states / functional habitats with the theoretical ideal proportions (see Objective above).

5. Identify which seral states / functional habitats are under-represented and which are over-represented i.e., determine the difference between actual and ideal proportions for the Bullimore, Sandplain and other flammable landsystems.
6. Develop an annual Rx burning program (including internal and external buffers and patch-burning) for the life of this plan for relevant FMUs with the aim being to work towards creating the theoretical ideal distribution of seral states / functional habitats for the Bullimore, Sandplain and other flammable landsystems by correcting over and under representation of seral states, or to maintain the mosaic if it approximates the ideal situation. As far as it is practical / feasible to do so, Rx burning should comply with the objectives (rules) above in relation to burn intervals, patch sizes, patch distributions, season of burning etc.
7. Prepare generic prescriptions for each type of burn objective, i.e., i) edge and buffer burning from breaks / tracks, ii) internal, unbounded buffer / strip burning and iii) unbounded ecological patch-burning, ensuring consistency with rule sets / objectives above and using existing spinifex fire behaviour guides. This may require:
    a. Autumn-winter (April-August): Fire Spread Index (SI) = 0-1: 'Cold' or 'cool' burning to create 50-100 m deep edges and internal buffers around and within FMUs. Consideration should be given to trialling the helitorch and vehicle-mounted flame thrower as well as using ground crews for creating edges and internal buffers. Mechanical fuel treatment should also be considered, provided it does not compromise soil or other values.
    b. Burning after significant rainfall (>10 mm) when fuel moisture content (hummock profile) is >20% to create edges and internal buffers (as above).
    c. Spring-autumn (September – December): Fire Spread Index = 1-2: Ecological patch- burning over spring / early summer, depending on fuel condition. Having established edging and internal and external buffers to contain and restrain fire, implement ecological patch-burning within designated FMUs that aims to meet the patch size specifications described above. This will require burning under conditions such that fires self-extinguish either due to falling hazard / diurnal fire weather conditions (sub-threshold wind speed, temperature and RH) or by running into low fuel areas - previous burns, buffers, natural barriers – this is where helicopter ignition could be very effective.
8. Document process – including fire behaviour, weather conditions, fuels, outcomes with respect to burn objective (see Appendix 4 – Rx Burn Report Form).
9. Review and revise annually – update fuel age plan, seral states, commence planning cycle for next season.
10. Analyse data from the biodiversity monitoring sites in the Bullimore Landsystem to track biodiversity response to fire management (see Rangelands Restoration project document). Adjust management on the basis of monitoring and evaluation of these data, or discovery of new information.

GIS will be necessary to compile and analyse fuel ages / seral states for the Bullimore Landsystem and for each of the FMUs, and for recording fire history including Rx fire and bushfires. Rx burning will need some iteration and some calculation for forward projection of seral states - GIS may be helpful in projecting seral states into the future given various Rx burning scenarios.

7.2 Objective: Protection of other assets

There will be a requirement to carry out Rx burning to reduce fuel flammability to protect specific assets from damaging bushfires. These assets are identified and the recommended fuel management / response strategies are described below.

Asset description	Protection objective	Protection strategy
Acclimatisation compound -	Protect fence and habitat within the compound from bushfire damage	50 - 100 m burnt buffer in flammable fuels on outside perimeter of compound. Maintain buffer in a low fuel condition such that it will not carry fire even under extreme weather conditions. Declared “Red Action” - immediate suppression response to fire inside the compound (by appropriately trained personnel). Suggest establishment of a water point inside or near the compound. Prepare a suppression response plan. All personnel working at LG should be at least L1 fire trained.
Boundary fence	Prevent fires crossing the boundary with neighbouring properties	50 - 100 m burnt buffer in flammable fuels on the outside perimeter of the compound. Maintain buffer in a low fuel condition such that it will not carry fire even under extreme weather conditions.
Homestead precinct	Prevent bushfire damage to infrastructure	Maintain lawns in a green state. Keep gutters clean. Maintain surrounds in a low fuel state. Maintain pressurised water supply for fire suppression.
Late seral state *Triodia lenigera*	Fire exclusion (no planned burning)	Relatively small patches of late seral state *T. Lenigera* exists in fire-shadow habitats on gypsum soils on lake margins. No planned burning.

8. Bushfire Response

In addition to carrying out Rx burning there will be a requirement to suppress bushfires in some circumstances. The Acclimatisation Compound and the fauna within represent a major investment by DEC. A detailed bushfire response plan must be developed and communicated to reduce the risk of bushfire damage to this asset (table see above). Staff on-site must be appropriately trained and equipped before responding to bushfires.

9. Key Performance Indicators

KPIs are based around the plan objectives (above for metrics):

- Burnt patch size
- Proportion of the landscape at various burnt patch sizes
- Proportion of seral states
- Distribution of seral states
- Area and location of unplanned fire (bushfire)
- Asset protection
- Biological diversity (baseline ex BioMoniotirng sites)

10. Responsibility for Plan Delivery

Regional Manager, Goldfields Region

11. Acknowledgments

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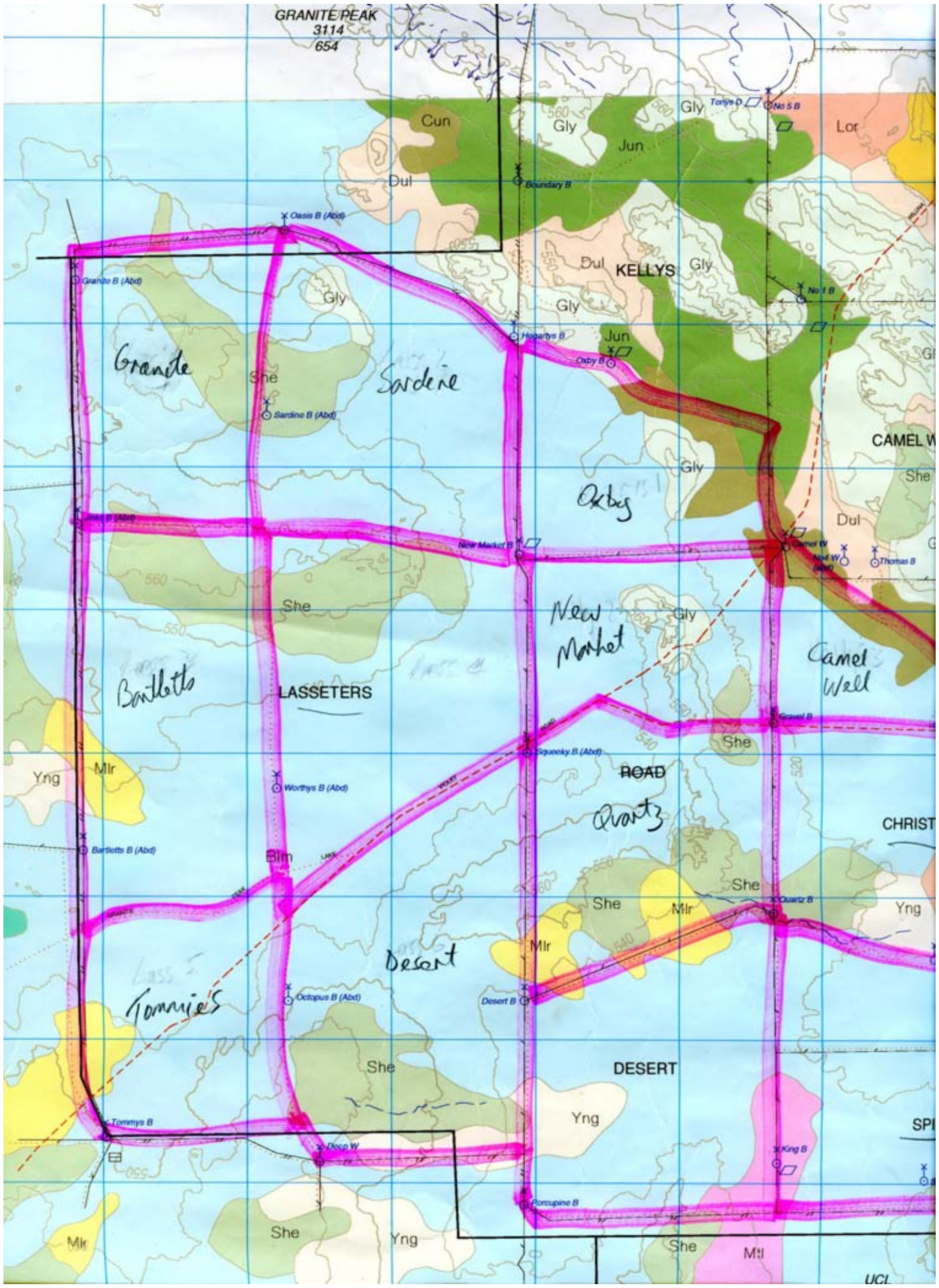
Appendix 1

An example of Fire Management Units (FMUs), Bullimore Landsystem, Lorna Glen



Appendix 2:

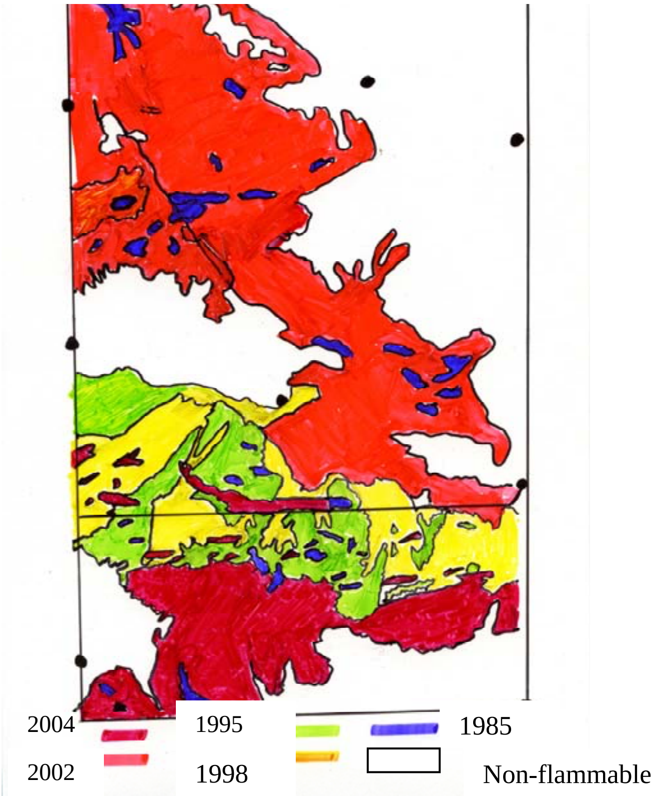
Guiding Principles for Ecological Fire Management in Hummock Grasslands

1. Climate and vegetation make landscapes dominated by spinifex grasslands highly prone to fire. For thousands of years, lightning and human ignitions have ensured that fire is an environmental factor that has influenced the structure, function and biodiversity of spinifex grasslands.
2. Species and communities vary in their adaptations to, and reliance on fire. Knowledge of the ways in which species and communities respond to fire, and of the temporal and spatial scales of fires in relation to life histories of organisms or communities, underpins the use of fire.
3. Rainfall is a primary driver of the rate of fuel accumulation and subsequent flammability of spinifex grasslands and large, extensive bushfires are usually preceded by several seasons of above average rainfall.
4. The response of species and communities to fire will be influenced by the subsequent rainfall and by the scale and patchiness of fire, which can drive systems towards a new transient state with respect to species composition and structure.
5. Fire management is required primarily to conserve biodiversity. In some circumstances, it may be necessary to manage fire to protect property, infrastructure and cultural values.
6. Fire management should be both precautionary and adaptive, considering the requirements of both fire sensitive (habitat specific) and fire maintained communities and species in order to optimize biodiversity conservation outcomes.
7. Landscapes dominated by spinifex grasslands are often vast, remote and difficult to access. Fire management resources are scarce, so active fire management including fire suppression and prescribed (Rx) burning, should focus on areas of high conservation value and on high value built and cultural assets. On much of the spinifex grasslands, passive management, including allowing unplanned fires to burn, is a realistic and acceptable management option.
8. Fire diversity can support biodiversity both at landscape and local scales. At the landscape scale, a fine grain mosaic of patches of vegetation representing a range of interlocking seral (post-fire) states will provide diversity of habitats for organisms that are mobile and can move through the landscape. At the local scale, appropriate intervals between fire, based on vital attributes of key species, are necessary to ensure the persistence of sessile or less mobile organisms.
9. Avoid applying the same fire regime (frequency, interval, season and scale) over large areas for long periods and avoid seral and structural homogenization by not treating large areas with extreme regimes such as sustained frequent burning or infrequent burning.
10. The scale or grain size of the mosaic should a) enable natal dispersal, b) optimize boundary habitat (boundary between two or more seral states), and c) optimize connectivity (ability of key species to migrate between seral states).
11. A sequence of 2-3 years or more of above average rainfall will result in rapid growth of spinifex and flammable soft grasses, predisposing landscapes to large bushfires capable of burning through fire mosaics. While such events are infrequent, strategically located low fuel buffers 500-1000 m wide may be required to contain bushfires under these conditions.
12. All available knowledge including scientific, local and indigenous knowledge should be utilized to develop ecologically appropriate fire management.

13. Consultation and partnerships with neighbours, including traditional owners, is an effective way of managing fire for mutual benefit.
14. Fire management should be planned and implemented in an adaptive management framework. Use of tools including remote sensing and aircraft, will be essential for planning and implementing fire use and for mapping and monitoring fire mosaics and fire history.
15. As part of an adaptive management framework, biodiversity monitoring should focus on; 1) threatened species and communities, 2) fire sensitive species and communities and 3) the remaining biota. Threats such as introduced plants and animals, and abiotic processes including weather (rainfall) and fire history, must be monitored/recorded in order to help interpret changes in biodiversity.
16. Where spinifex grasslands have been invaded by flammable weed species such as buffel grass, which is capable of adversely altering the frequency and intensity of fire, Rx fire should be used conservatively and strategically to break up the run of major bushfires.

Appendix 3.

Example of fuel age mapping and determination of prescribed burning program (Rx)



- Total Area of Spinifex, Christmas Creek and Camel Well FMUs ~ 27,408 ha
- Flammable area = 17,140 ha (from 2006 Landsat imagery)

Seral State	Very early (<=6 yrs)	Early (6-12 yrs)	Intermediate (12-24 yrs)	Late (24-36 yrs)	Very late (36+ yrs)
Actual (2010)	23% 6yo=3,948ha	61% 8=8,636ha 12= 1,972ha	10% 15=1,768ha	5% 25-816ha	0%
Desirable	**20%**	**20%**	**21%**	**20%**	**15%**
Rx burn 2011-2013	No burn	Rx burn 3,581ha	No Burn	No burn	No Burn
Actual 2013	21% 1yo=3581ha	20% 9yo=3428ha	31% 14yo=3599ha 18yo=1768ha	5% 28yo=1768ha	0%
Rx burn 2013-2016	No burn	No burn	No burn	No burn	No burn
Actual 2016	21% 4yo=3581ha	20% 12yo=3428ha	31% 17yo=3599ha 21yo=1768ha	5% 31yo=1768	0%
Rx burn 2016-2019	No burn	No burn	Rx burn 3,500ha	No burn	No burn
Actual 2019	**21%** 1yo=3500ha	**22%** 7yo=3581ha	**36%** 15yo=3428ha 20yo=2599ha	**21%** 24=1768ha 34=1768ha	**0%**

Appendix 4

Prescribed (Rx) Burn Report

Date:……………………Locaton:………………..…………Burn Manager:…………………………

Ignition time:…………………….……Burn-out time:……………………………………

Burn Objectives:

a) Edging / buffer burn…………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………

b) Ecological patch-burn……………………………………………………………..
………………………………………………………………………………………………
………………………………………………………………………………………………

Fuels

Age:……………Cover (%)……………Load (t/ha)…..………Fuel Code (see App. 4)……………..

Clump thick:……………Curing code ……………..…PMC (%):………Dead FMC(%)……………

Weather

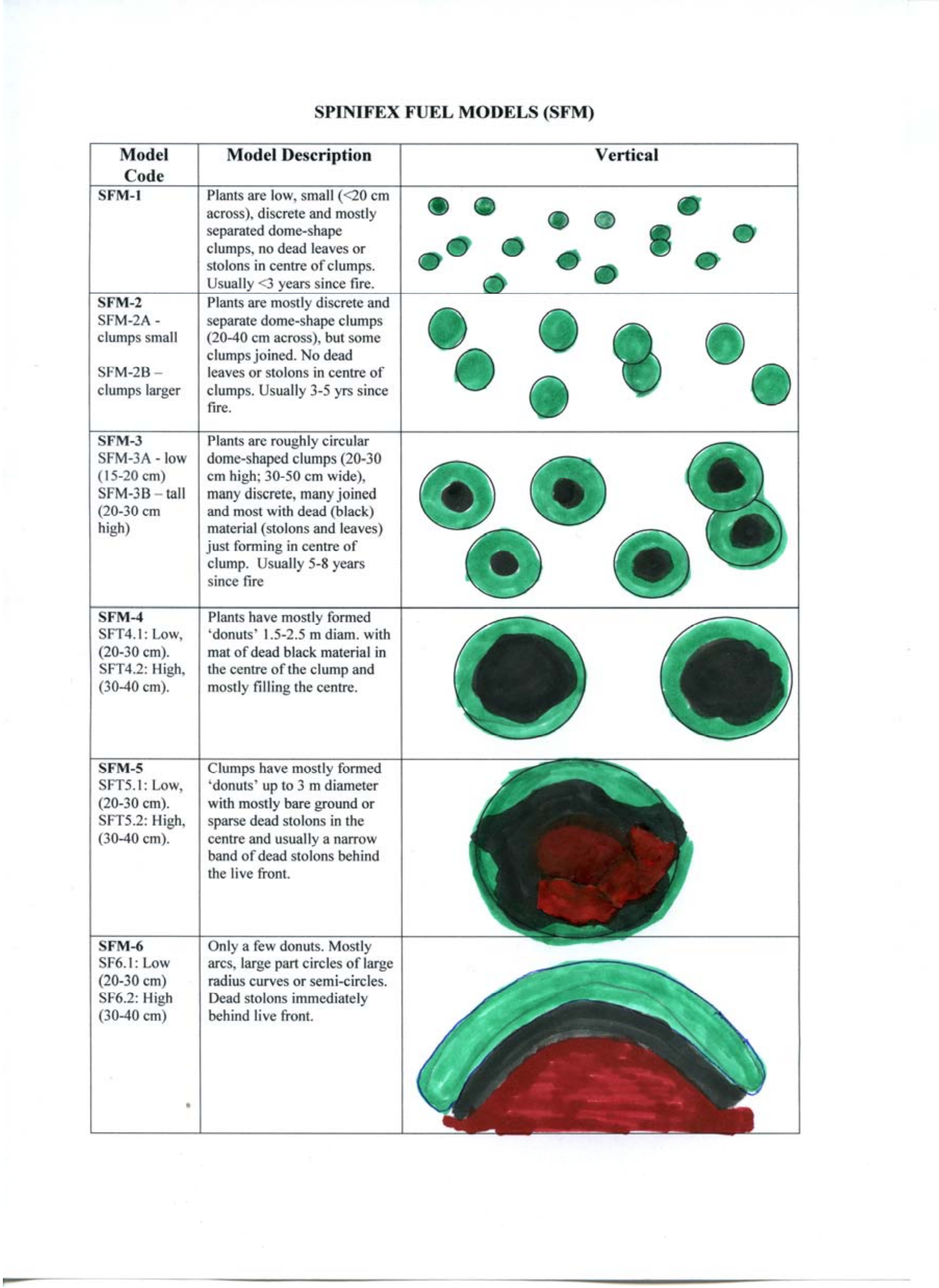
	Start		Finish	
Temp (oC)				
RH (%)				
Dew Point (oC)				
Wind speed (kph) and direction @ 2m (10 min. mean)	Time:	Time:	Time:	Time:
Wind speed max gusts @ 2m	Time:	Time:	Time:	Time:

Fire Behaviour

Fire Spread Index (SI):………………………....Predicted ROS:……………………………..
Ignition method/pattern……………………………………………………………………………….
Ignition: Good (>50% of line/spots):………Fair: (25-50%)…………Poor (5-25%). ………Nil……..
Fire spread sustained?(Y/N)...........................Burn / spread duration (mins):……………………..
Ave. HFROS (m/h)…………………………Ave flame ht (m)………………Spotting (m)...........……
Comments:

Appendix 5

Proposed spinifex fuel models (to be validated)



SPINIFEX FUEL MODELS (SFM)

Model Code	Model Description	Vertical
SFM-1	Plants are low, small (<20 cm across), discrete and mostly separated dome-shape clumps, no dead leaves or stolons in centre of clumps. Usually <3 years since fire.	
SFM-2 SFM-2A - clumps small SFM-2B – clumps larger	Plants are mostly discrete and separate dome-shape clumps (20-40 cm across), but some clumps joined. No dead leaves or stolons in centre of clumps. Usually 3-5 yrs since fire.	
SFM-3 SFM-3A - low (15-20 cm) SFM-3B – tall (20-30 cm high)	Plants are roughly circular dome-shaped clumps (20-30 cm high; 30-50 cm wide), many discrete, many joined and most with dead (black) material (stolons and leaves) just forming in centre of clump. Usually 5-8 years since fire	
SFM-4 SFT4.1: Low, (20-30 cm). SFT4.2: High, (30-40 cm).	Plants have mostly formed 'donuts' 1.5-2.5 m diam. with mat of dead black material in the centre of the clump and mostly filling the centre.	
SFM-5 SFT5.1: Low, (20-30 cm). SFT5.2: High, (30-40 cm).	Clumps have mostly formed 'donuts' up to 3 m diameter with mostly bare ground or sparse dead stolons in the centre and usually a narrow band of dead stolons behind the live front.	
SFM-6 SF6.1: Low (20-30 cm) SF6.2: High (30-40 cm)	Only a few donuts. Mostly arcs, large part circles of large radius curves or semi-circles. Dead stolons immediately behind live front.	