NATIONAL BURNING PROJECT

Australasian Fire and Emergency Service Authorities Council (AFAC)
***and* Forest Fire Management Group (FFMG)**

National Guidelines for Prescribed Burning Operations:

Case Study 6 – Buttongrass moorland burning in Tasmania

National Burning Project: Sub-Project 4

An Australian Government Initiative

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This case study has been prepared by Paul de Mar and Adrian Pyrke (2013). It is a synthesis of buttongrass burning information documented in Buttongrass Moorland Fire-Behaviour Prediction and Management (Marsden-Smedley et al. 1999), Planned Burning in Tasmania I, II, and III (Marsden-Smedley 2011a, 2011b and 2011c), and Parks and Wildlife Service Fire Planning Policy P-055 (Department of Primary Industries, Parks, Water and Environment 2009). It incorporates burning operations planning and implementation practice information (provided by Adrian Pyrke) as well as the relevant fire science on which current procedures are founded.

1 Fuels and fire risk management context

1.1 Risk management context

Buttongrass moorlands are areas dominated by low growing sedges (the most dominant sedge being buttongrass – *Gymnoschoenus sphaerocephalus*), and heaths. They may be completely treeless or occur in a landscape mosaic with patches containing trees or scrub. They often occur in wet landscape positions with poor drainage, but also on slopes in hilly terrain, and are mostly associated with nutrient-poor substrates such as quartzite, conglomerate and granite. They are one of the most fire-adapted ecosystems to have evolved.

Tasmanian buttongrass moorlands occupy more than one million hectares, approximately one seventh of the island. It is the most common vegetation type in many parts of the west and south west of the state where annual rainfall exceeds 1000 mm. While it does occur in eastern Tasmania it is confined to creek lines and depressions. It also occurs in other areas of south eastern Australia (South Australia, Victoria, New South Wales) though it is less common there than in Tasmania (Parks and Wildlife Service Tasmania 2013).

Buttongrass plants form tussocks which over time (since the last fire) become increasingly dense. Buttongrass leaves are very fine. As growth from previous seasons dies, the very fine dead grass leaves are retained within the tussock forming what is commonly referred to as thatch. This thatch is held above the wet ground underneath. As a result, accumulations of thatch build up within the buttongrass moorland, and due to their fineness can dry very quickly after rain. Accordingly, despite occurring in relatively high rainfall areas and wet landscape positions, there are many days in the year when buttongrass moorland will burn, and they may burn even though the ground below the tussocks is waterlogged. Buttongrass can be burnt under conditions in which other types of vegetation in the landscape are too wet to burn.

Buttongrass moorland mostly occurs in areas remote from human settlements although some asset protection burning does occur in buttongrass areas around towns, buildings and infrastructure. However, most buttongrass burning is conducted for ecological and strategic landscape reasons – to induce a degree of time-since-fire heterogeneity so as to avoid damaging, large scale higher-intensity buttongrass fires that can and do occur if older growth stages are allowed to accumulate broadly across a landscape.

Figure 1 Buttongrass moorland, Tasmania

Source: David Taylor

1.2 Fuel dynamics and fire behaviour issues

Research into buttongrass fuels has identified relationships between time-since-fire and fuel load (both total fuel load and dead fuel load). The rate at which buttongrass grows and accumulates fuel varies with the productive capacity of the landscapes in which it is growing. Over any given timeframe, higher productivity sites accumulate substantially higher fuel loads than lower productivity sites. To reflect this, Marsden-Smedley *et al.* (1999) have developed a site age-fuel load relationship table which stratifies productivity into low and medium classes. Low productivity sites are those sites within western, north-western and south western Tasmania that are underlain by quartzite, conglomerate, granite and/or gravels derived from these geology types; all other buttongrass sites are classified as medium productivity where dolerite is the most common substrate in this class.

Table 1 Buttongrass fuel accumulation based on productivity of site

Age (years)	Low productivity sites		Medium productivity sites	
	Total fuel load (t/ha)	Dead fuel load (t/ha)	Total fuel load (t/ha)	Dead fuel load (t/ha)
3	3.2	0.3	5.2	0.7
5	4.8	0.7	8.3	1.9
10	7.7	2.0	15.0	5.9
20	10.3	4.6	25.0	15.7
40	11.6	7.7	36.0	30.2

Depending on the state of landscape dryness reflected by soil dryness index (SDI) and the number of days since rain, burns in buttongrass moorlands will consume different components and proportions of the buttongrass fuel profile. In very low SDI conditions and within a day or two of rain, a burn may remove only the more aerated outer parts of the tussocks, leaving denser thatch components unburnt. If conditions continue to dry out, later in the same burning season those fuels that remained unburnt may become available to burn. In some cases, sufficient fuel may be left behind after a second burn to support fire spread a third time, if ignition occurs in severe wildfire conditions.

1.3 Other issues, opportunities and constraints

In a high proportion of landscape areas where buttongrass burning is considered, roads and fire breaks are absent or only available in limited areas. Therefore, selection of fuel moisture conditions in adjacent vegetation types is used to limit fire spread. Alternatively, burning that relies on diurnal variation in fuel moisture conditions, or any overnight rain or dew fall is used, so that fire in the buttongrass self-extinguishes overnight.

Due to the remote location of many buttongrass sites, some issues such as smoke and visual amenity impact management are less constraining than for other types of burning closer to settled areas.

A key issue with burning in buttongrass areas is the potential to initiate organic soil fires in some areas, which once alight can burn underground potentially for weeks or even months, with the ability to re-surface potentially igniting surface fires in adverse conditions. This problem arises commonly at the boundaries of buttongrass moorland with forest and scrub, but also occurs within buttongrass under very dry conditions. The consequences and therefore the risk can be great. Bushfires in summer can smoulder for months, flaring up during drier warmer periods. The risk can be effectively managed through selecting burning conditions with low SDI in which organic soil/peat fires are unlikely to be initiated or sustained.

2 Burn planning approach and process

There are two key phases of planning applied to prescribed burning on Tasmanian PWS managed lands. The first is Annual Planned Burning Program (APBP) planning which is guided by the requirements of strategic fire management plans. Annual burn program planning is conducted in accordance with Tasmania PWS Fire Planning Policy (2009).

Once a burn is approved within an APBP, it progresses into the second phase of planning which is the site-specific planning, for which a *Planned Burning Form* is prepared. The purpose of the *Planned Burning Form* is to document all the operational detail necessary to ensure that a planned burn operation is conducted in a safe, reliable and accountable way.

2.1 Burning season selection

Areas of Tasmania occupied by buttongrass typically have a climate characterised as Cool Wet Temperate, with a cold winter in which the peak rainfall months occurs, and a mild summer with rainfall levels moderating over summer or early autumn to around half of the peak winter rainfall level. Buttongrass moorlands, particularly those in the western half of Tasmania, occur in some of the wettest landscape areas in south-eastern Australia.

Suitable seasonal conditions for burning buttongrass are driven principally by the SDI which should be within the 0 – 10 range and ideally greater than 5, with effective rainfall having occurred within the last 5 days, although Tasmanian buttongrass planned burning guidelines allow for up to 10 days without rain. Such conditions mostly present themselves in an autumn burning season (April – May) and a late winter/spring burning season late August to early October. Day length in winter from June to mid-August is too short to allow adequate fuel drying.

Unbounded patch burning for ecological management

For unbounded patch burning, the favoured burning season is April to May and mid-August to mid-September. During this season, periods when the SDI is in the range of 0 – 10 can be expected to occur. When such SDIs coincide with days when the period since last rain is 1 to 4 days ago, and preferably 2 – 3 days ago, conditions are optimal for low intensity patch burning. These conditions maximise the likelihood that vegetation types fringing or interspersed with buttongrass areas will be too wet to sustain fire, organic soils will not smoulder, and therefore patch-burns will self-extinguish when they reach the edge of buttongrass areas. They also are conducive to fire self-extinguishing overnight within the buttongrass when moisture absorption from the atmosphere results in fuel moisture increasing above its fire-extinction point, as long as the wind speed is low overnight.

Therefore, it is very important to closely monitor rainfall and SDI trends in the area where burning is planned to establish when conditions are coming into burning windows, so full advantage of what may be short opportunity periods can be taken.

2.2 Planning of burn area dimensions

At the planning stage, the location of mineral earth trails for use as burn boundaries, and of other fuel-reduced areas in the landscape, will be important.

For larger burns, a combination of ground operations for edge burning and aerial ignition for patch-burning the core of the planned area is usually undertaken. Large remote burns typically involve aerial ignition over one or two days with no ground crews. For smaller burns, ground operations only are normal.

Fuel reduction burning in buttongrass

The burn area dimensions for fuel reduction burns are driven principally by the location of containment features, either mineral earth boundaries or secure natural boundaries. Fuel reduction burns generally do not exceed 3,000ha in size. For burns with fuel reduction as the principal objective, it is generally desirable to reduce fuels by around 70% across 70% of the planned burn area, and this usually necessitates burning at the higher or dryer end of the prescription range. For risk management reasons, burns at the higher or dryer end of the prescription range tend to be at the smaller end of the burn size range.

Unbounded patch burning for ecological management

The principal purpose of broad area unbounded patch burning in buttongrass moorlands is to induce a degree of variability in post-fire age class distribution across a landscape. Variability in buttongrass age and structure serves to increase landscape resilience to mid-summer wildfires by reducing the extent and impact severity of unplanned fires, and provides a range of suitable habitat conditions accommodating a broad suite of species that live in or use buttongrass moorlands. Fire also serves to keep buttongrass moorlands open and inhibits invasion by scrub vegetation.

In order to have an influence on reducing the extent of unplanned fires in buttongrass and adjacent vegetation types, planned burns need to be designed so they are big enough that they can potentially affect wildfire spread patterns, but not so big that the burns themselves carry unacceptably high risks for practical implementation and/or environmental impact. They should be of sufficient size and arranged strategically so that they have a reasonable probability of being partly or wholly in the path of a subsequent unplanned fire (thus reducing unplanned fire spread). This entails consideration of recent fire history, particularly the landscape distribution of burnt areas with different fuel ages. Buttongrass fire spread simulation modelling by King *et al.* (2008) identified that in order for planned fire size to make a significant difference in reducing annual unplanned fire extent, annual buttongrass landscape burning treatment levels should be in the range of 5 to 10%.

Accordingly, buttongrass moorland burns range in size, and they include some of the largest-sized planned burns undertaken in Tasmania. At the smaller end of the scale, burns of a few hectares are undertaken in small blocks immediately adjacent to at-risk assets or communities. At the larger end burns can be up to around 5,000 hectares, incorporating landscape areas where buttongrass is interspersed with other vegetation types.

2.3 Burn timeframe and duration

Burning guidelines for buttongrass identify a burning window from 1 to 10 days after rain or dewfall. However, if more than 2 days have elapsed since rain and/or dewfall, the effect of the last precipitation event on fuel moisture content is assumed to be zero, regardless of whether 3 days or 10 days have elapsed. This prescription is intended to keep fire behaviour within the low intensity range by avoidance of conditions when a high proportion of the thatch will burn.

Buttongrass burns are generally planned to have a single day burn-out timeframe, with burns undertaken during conditions in which fire will self-extinguish overnight (although some smouldering combustion may persist beyond this timeframe). This short burn time duration is well within normal Bureau of Meteorology weather forecasting timeframes of 3-4 days allowing selection of stable atmospheric conditions, when wind direction and speed is forecast to be generally desirable.

The period during the day available for burning in buttongrass is generally short. Unbounded buttongrass burning, which is principally practiced in low productivity moorland sites, is mostly undertaken in the April to May and mid-August to mid-September period. During these months day length is relatively short, maximum temperatures are at annual lows (from May to August more than 90% of days have a maximum temperature of less than 15^{o}C), and relative humidity is mostly within the 70-90% range throughout the day. Except on dry days with wind speed toward the upper end of the prescribed range, typical seasonal conditions are such that free-running fire will generally only occur for around 3 to 4 hours during the afternoon. If conditions over at least the past 48 hours have been dry, and wind speed is around 10km/hr or greater, then free running fire may be achieved from the late morning, adding an hour or two to the period that fire may spread.

During this autumn and early spring period, on days when burning conditions are within prescription, overnight temperature fall and humidity rise, and/or dewfall, are such that fire in buttongrass frequently self-extinguishes although there are some notable exceptions to this. One example was a near coastal situation when the forecast light wind and dew fall did not eventuate, wind speed stayed up all night, and the fire continued to spread. In low productivity buttongrass moorlands, the following overnight conditions are required for fires to self-extinguish (Marsden-Smedley, 2009):

- Surface wind speed (at 1.7 to 2 m) ≤ 5 km/hr;
- Relative Humidity > 60%;
- Temperature falling to <10°C; and
- Rain and/or dewfall to 09:00 the following day exceeding 0.1 mm.

2.4 Burn staging and sequencing

Buttongrass burning may involve a single stage, or a multiple stage burn.

Multiple stage burns mostly involve completion of edge burns adjacent to downwind boundaries or at-risk assets, to ensure security of burn boundaries is enhanced, and that assets are afforded protection by recently burn ground. Edge burns are subsequently followed by aerial burning with incendiary capsules of the remaining area.

For remote burns, weather and rainfall data may not be available to determine whether or not conditions are suitable for burning. In these situations an Automatic Weather Station with a satellite telephone link can be helpful. At accessible burns, rain gauges are routinely inserted and checked daily, while hazard sticks are placed in boundary forest and scrub vegetation to ensure that there is the required fuel moisture differential.

Low SDI values can be unreliable early in autumn and must be treated with caution. This is because the SDI formula does not adequately allow for the canopy intercept of rain in nearby rainforest and mixed forest – forest types that have a dense forest canopy. Light rainfalls can at times contribute little genuine change in SDI under dense forest canopy. Therefore thorough ground truthing of soil moisture conditions, possibly even digging soil pits, may be required to confirm presumed low SDI in nearby canopied areas. Once the SDI has reached zero, with several heavy rainfall events greater than 25 mm, the SDI values can be trusted. However, there is some evidence that following prolonged drought, organic soils undergo a waterproofing phenomenon and may require even more rain to properly moisten. In practical terms, this means that fire in organic soils may smoulder when the apparent SDI is less than 10.

2.5 Limiting conditions

The key to successful burning in buttongrass is keeping fire behaviour within the desired range.

While published burning guidelines do not specify fire behaviour prescriptions, the fuel and weather parameters prescribed are generally aimed at achieving an average head fire rate of spread of no more than 8 m/min (480 m/h). In older, heavier buttongrass fuels, headfires spreading at around 8 m/min can attain flame heights of 2 to 6 metres and typically will generate short distance spotting up to about 5 metres. Buttongrass fires with spread rates exceeding 8 m/min will be difficult to control, and their intensity will exceed desirable limits for planned burns.

The critical conditions for containing head fire rate of spread within desirable limits are fuel moisture content and wind speed.

Wind speeds for prescribed burning are set at a maximum of 20 km/hr (surface wind speed at 1.7 to 2 metres above the ground). This is reduced to a maximum of 10 km/hr where containment boundaries are relatively narrow mineral earth breaks such as roads or trails. In practice, wind speeds approaching 20 km/hr are likely to be unsuitable for prescribed burning in older fuels (notionally 10 years or older), except in high fuel moisture conditions when only the more exposed outer parts of grass tussocks will burn. If maintaining low fuel load is an objective, for example, in asset protection zones, burning of fuels in the 5 to 10 years since fire range is preferred.

For buttongrass burning, direct measures of dead fuel moisture content are not widely used. Fuel moisture may vary significantly from the outer to the inner parts of grass tussocks, and the fineness of the fuel means that fuels absorb and adsorb moisture rapidly. In moderate productivity sites, the depth of thatch can also 'insulate' the lower thatch from ambient humidity and light rainfall. This makes direct measurement of dead fuel moisture problematic.

The time elapsed since recent rain or dewfall and the current air temperature and relative humidity conditions in the field significantly influence fine fuel moisture content. Therefore, fire behaviour prediction for buttongrass is calculated using a 'predicted dead fuel moisture content' which is derived from combining a 'rainfall factor' that uses time since and amount of recent rain or dewfall and a 'humidity factor' which is a function of air temperature and relative humidity.

In general, fires will fail to burn with adequate rate of spread and intensity when the dead-fuel moisture content exceeds around 35%, but will exceed desirable planned burning intensity when the dead-fuel moisture falls below around 15% (Marsden-Smedley 2009).

Table 2 Rainfall and humidy factor in relation to buttongrass burning

Rainfall factor

Hours since rain stopped	Rain and/or dewfall (mm)				
	0.05	0.1	0.2	0.5	1+
0	10	18	31	53	64
3	8	14	24	41	50
6	6	11	19	32	38
9	4	8	14	25	30
12	3	6	11	19	23
24	1	2	4	7	8
48	0	0	1	1	1

Notes on rainfall factor:

Blue shaded figures are for rain or dewfall driven moisture levels which will generally be too high to support successful burning. Under desirable burning conditions, the minimum humidity factor will generally be not less than 15, so when added to high rainfall factors (as shaded in blue), dead-fuel moisture will exceed 35% – such conditions are marginal for sustaining fire spread however full self-extinguishment may not occur until dead-fuel moisture exceeds 76% .

Humidity factor

Temp (°C)	Relative humidity (%)				
	20	40	60	80	100
8	12	14	19	25	35
12	11	13	17	23	32
15	10	12	15	21	29
18	9	11	14	19	27
25	8	9	12	16	22
30	7	8	10	14	19
35	6	7	9	12	16

Notes on humidity factor:

Red shaded figures are for temperature and/or relative humidity outside acceptable prescribed burning range

Orange shaded figures are for days with a temperature of 18 – 25°C which in buttongrass areas of western Tasmania are unprecedented during the burning season

Dead fuel moisture and wind speed are vital to keeping fire behaviour within acceptable limits. While the above tables have been developed for predicting dead fuel moisture content, they are not routinely used by burn crews. In practice they generally select days when 1 to 3 days since rain or heavy dew has fallen, and when weather conditions will be within limits identified in prescribed burning guidelines.

Fire behaviour prediction tables have been developed for buttongrass, giving forward rate of spread predictions. Three tables have been developed for spread prediction in different age fuels – 5 year since last fire; 10 years since last fire; and 20+years since last fire. These tables cover severe wildfire weather conditions as well as those conditions commonly prescribed for burning. As already discussed, the upper-end limit for rate of spread is around 8 m/min (vigorous fire behaviour), although for ecological burns an upper-end limit of 5 m/min is more appropriate to achieve a greater degree of patchiness. A low-end limit for rate of spread is not identified in guidelines, however in practice, conditions in which forward rate of spread during the afternoon is less than 1 m/minute will be too marginal to achieve effective burning and desired objectives, with the possible exception of burns for which a very patchy discontinuous burn effect is desired. It should be noted that burns conducted where the rate of spread has been around 1 m/min or less are highly unlikely to have any value from a hazard reduction objective. Burns where hazard reduction is a key objective should ideally have a rate of spread exceeding 2 m/min (Marsden-Smedley, pers comm.).

Table 3 Five year old buttongrass moorland – predicted rate of head fire spread

Dead-fuel moisture (% dry weight)	**Wind Speed** (km/hr)					
	1	**5**	**10**	**20**	**40**	**60**
>100	Fires probably will not be sustained					
100	0	0	0	1.3	3.3	5.7
80	0	0	0.9	2.2	5.4	9.2
60	0	0.6	1.4	3.5	8.8	14.9
30	0.1	1.2	3.0	7.3	18.2	31.0
20	0.2	1.5	3.8	9.3	23.2	39.5
15	0.2	1.7	4.3	10.6	26.2	44.6
10	0.2	1.9	4.8	11.9	29.6	50.4
5	0.3	2.2	5.4	13.5	33.4	56.9

Legend:

- Fire spread too slow or dead fuel moisture too high for burning
- Conditions & predicted fire behaviour suitable for burning
- Conditions marginal/risky; fire behaviour too vigorous for burning
- Wind speed outside limits (too strong) for burning
- Conditions too warm and dry for burning

Table 4 Ten year old buttongrass moorland – predicted rate of head fire spread

Dead-fuel moisture (% dry weight)	**Wind Speed** (km/hr)					
	1	**5**	**10**	**20**	**40**	**60**
>100	Fires probably will not be sustained					
100	0	0	0	2.1	5.2	8.9
80	0	0	1.4	3.4	8.5	14.4
60	0.1	0.9	2.2	5.5	13.7	23.3
30	0.2	1.9	4.6	11.4	28.4	48.3
20	0.3	2.4	5.9	14.6	36.2	61.6
15	0.3	2.7	6.6	16.5	40.9	69.6
10	0.4	3.0	7.5	18.6	46.2	78.6
5	0.4	3.4	8.5	21.0	52.1	88.7

- Fire spread too slow or dead fuel moisture too high for burning
- Conditions & predicted fire behaviour suitable for burning
- Conditions marginal/risky; fire behaviour too vigorous for burning
- Wind speed outside limits (too strong) for burning
- Conditions too warm and dry for burning

Table 5 20+ year old buttongrass moorland – predicted rate of head fire spread

Dead-fuel moisture (% dry weight)	**Wind Speed** (km/hr)					
	1	**5**	**10**	**20**	**40**	**60**
>100	Fires probably will not be sustained					
100	0	0	0	2.8	6.8	11.6
80	0	0	1.8	4.5	11.1	18.9
60	0.1	1.2	2.9	7.2	18.0	30.6
30	0.3	2.4	6.0	15.0	37.3	63.5
20	0.4	3.1	7.7	19.2	47.5	80.9
15	0.4	3.5	8.7	21.6	53.7	91.4
10	0.5	4.0	9.8	24.4	60.6	103.3
5	0.5	4.5	11.1	27.6	68.5	116.5

- Fire spread too slow or dead fuel moisture too high for burning
- Conditions & predicted fire behaviour suitable for burning
- Conditions marginal/risky; fire behaviour too vigorous for burning
- Wind speed outside limits (too strong) for burning
- Conditions too warm and dry for burning

2.6 Developing prescriptions for the burn

Burning prescriptions for buttongrass moorland burning are taken from *Planned Burning in Tasmania – Operational Guidelines and Review of Current Knowledge* (Marsden-Smedley 2009).

For buttongrass burning, the guidelines differentiate between burning from secure natural boundaries (using adjoining vegetation in a non-flammable condition to limit fire spread) and burning from mineral earth lines. The latter is able to be done under dryer conditions to increase fuel consumption, but with lower wind speeds to reduce burn escape potential across containment lines.

2.7 Buttongrass burning guidelines:

Table 6 For fuel management burns from secure natural boundaries

Weather/fuel state variable	Units	Acceptable Range
Surface wind speed at 1.7 to 2m	km/h	≤ 20
Relative humidity	%	40 to 90
Dry bulb temperature	^{o}C	10 to 25
Days since rain (>2 mm)	days	2 to 10
Soil Dryness Index	dimensionless	≤ 10
Fire frequency	years	5 to 10
Moorland Fire Danger Rating	dimensionless	Less than ≤ 10

Table 7 For fuel management burns from mineral earth boundaries

Weather/fuel state variable	Units	Acceptable Range
Surface wind speed at 1.7 to 2m	km/h	≤ 10
Relative humidity	%	40 to 90
Dry bulb temperature	^{o}C	10 to 25
Days since rain (>2 mm)	days	4 to 10
Soil Dryness Index	dimensionless	≤ 20
Fire frequency	years	5 to 10
Moorland Fire Danger Rating	dimensionless	Less than ≤ 5 (low)

Table 8 For ecological management burns

Weather/fuel state variable	Units	Acceptable Range
Surface wind speed at 1.7 to 2m	km/h	≤ 20
Relative humidity	%	10 to 25
Dry bulb temperature	°C	10 to 25
Days since rain (>2 mm)	days	2 to 10
Soil Dryness Index	dimensionless	≤ 10
Fire frequency	As specified in management plans	
Moorland Fire Danger Rating	dimensionless	Less than ≤ 10

2.8 Pre-planning of lighting patterns for the burn

Field assessment of proposed burn sites is important to verify that information relied on or assumed during prior planning phases is correct and representative of conditions at the site.

It is particularly important during field inspection to identify:

- Areas with different fuel ages and fuel types, and their arrangement in the landscape;
- Burning unit shape, size and boundary characteristics;
- The condition and width of vegetation types intended to be used as secure natural boundaries to limit fire spread;
- The location of assets requiring protection in relation to fire hazards; and
- The adequacy of perimeter trails for fire containment should also be checked and potential weak areas identified for preparatory works and/or noting in the burn plan.

While all planned burn areas should have a lighting plan customised to the specific features of the block, in general the following lighting sequence and patterns are applied for larger sized burn blocks:

- Lighting is usually commenced at the beginning of a stable weather cycle. Winds on the selected burn day should be relatively consistent in direction, without significant or erratic wind change events;
- Buttongrass fires, particularly those in low productivity moorlands, spread with the wind. Backing fire into the wind achieves very low rates of spread (typically one tenth of forward spread rate), and is generally only used in asset protection or downwind edge burn sections;
- Downwind edges may be burnt initially to deepen boundaries on downwind edges, and then a spot ignition pattern using aerial incendiaries can be used at a spacing tailored to the conditions to maximise the area burnt by flank and backing fire; and

- Lighting patterns and sequences should be devised such that weaker boundary areas are not impacted by running head fires during peak fire conditions, but rather when fire spread conditions are moderating late in the day. Alternatively, weak boundaries are lit ahead of peak conditions.

2.9 Burn day selection

For buttongrass moorland burning, selection of burn-timing is about picking the intersection of favourable SDI conditions (≤10), optimal timing after rain or dewfall such that dead-fuel moisture will be within the 15 – 35% range (typically 1 to 3 days after rain), and daily weather conditions favourable for burning. Generally, ideal conditions will be on dry, stable days, with surface winds of 5 to 15 km/h, 1 to 3 days after previous rainfall.

Monitoring rainfall, dew fall, boundary fuel moisture content (e.g. hazard sticks) and field confirmation of SDI are routine requirements for burn day selection.

Four and seven day weather forecast products from the Bureau of Meteorology are monitored to identify stable atmospheric periods when weather parameters are forecast to be within prescriptions. Days with stable atmospheric conditions, such as when a high pressure system is positioned over Tasmania, generally bring cool overnight temperatures, high overnight humidity with heavy dew fall and light overnight winds – these conditions are favourable for fire self-extinguishing in buttongrass overnight.

Organising crews, equipment and helicopters can take several days, so day of burn planning should start at least two days ahead, preferably longer. Fortunately, the approach of stable high pressure systems can usually be identified in forecast weather maps four to seven days ahead.

Subject to resources being available, days when fuel moisture and forecast weather cycles are both suitable, and no adverse fire weather is foreseeable in the four day forecast, are selected for burning.

3 Burn plan preparation

Tasmanian fire and land management agencies have in place a structured burn plan preparation process. Standards for burn planning are set out in agency procedures.

Tasmanian PWS burn planning process and standards are summarised below:

A Planned Burning Form is completed identifying:

- Key characteristics of the area to be burnt and the burn type;
- Conditions under which the burn can proceed;
- The manner in which the burn is to be conducted (including preparations), including:
    - An Operations Map showing burn boundaries, areas and assets to be protected, access, control points and safe area locations, fireground organisation and planned lighting patterns;

    - A risk assessment using the Bushfire Risk Assessment Tool[1] (BRAT); and
    - Crew, equipment and fireground communications information, including key neighbour/stakeholder contacts.

- Related measures to protect burn crew staff, the public and things of value;
- Contingency arrangements for burn escape or other unintended events;
- Any factors that are to be the subject of ongoing monitoring or review during the course of the burn including those intended to detect the onset of contingencies;
- The briefing to be provided to those involved in the burn (for finalisation on the day of the burn); and
- Burn approvals documentation that includes peer review and area managers.

4 Burning operations implementation

4.1 Obtain approval to conduct burn

The Tasmania PWS has a structured process for seeking approval for burn ignition. For all burns this is detailed in the Planned Burning Policy. Once an operational burn plan is prepared and has undergone peer review, final sign off is given by different levels of manager, depending on the level of burn risk calculated by the BRAT.

4.2 Obtain weather forecasts for the burn area and verify with on-site conditions

Weather forecasts for the planned burn site should be obtained from the Bureau of Meteorology, relevant for the location(s) where burning will be carried out. Upon arrival at the burn site during the morning, field weather readings should be checked for alignment/variance with forecast conditions, and fuel moisture readings taken in surface and near-surface fuels. Dead fuel moisture content should be predicted using Rainfall and Humidity factors.

4.3 Operational preparations and briefings

Routine procedures for staff and equipment checks and preparedness are undertaken and planning information distributed to burn crews. A routine pre-burn operations briefing is conducted and crews dispersed to take up planned sectors/roles as per the burn plan and briefing which follows a

[1] The Bushfire Risk Assessment Tool (BRAT) is a spreadsheet that calculates consequence categories based on a comprehensive list of factors relating to fuels, vegetation, boundaries, weather, landscape context and topography. The BRAT also calculates fire behaviour predictions such as rate of spread and flame height.

standard SMEACS[2] format. Authorisation to proceed with ignition is requested and obtained from the appropriate manager.

4.4 Conduct fire behaviour prediction and test fire

Once fuels are within the desired moisture range, as calculated from recent rainfall events and from humidity, conduct fire behaviour predictions. Select an exposed area location for field weather observations to base dead fuel moisture and fire behaviour predictions on.

Inputs:

- Time since last rain and/or dewfall and amount;
- Air (dry bulb) temperature;
- Relative humidity; and
- Surface wind speed (at 1.7 to 2 m) and forecast wind speed at 10 m.

Calculate two sets of fire behaviour predictions:

1. Current – using field weather observations; and
2. Mid-afternoon predicted – using forecast afternoon wind speed, and expected afternoon dead fuel moisture content.

In an open location where fire can be readily suppressed if required, conduct a test fire using a strip ignition to observe rate of spread and flame height and compare with calculated fire behaviour predictions, to confirm fire behaviour is within prescription.

Consider the time of day the test fire is lit, the results of the test fire and how dead fuel moisture and weather conditions are predicted to develop during the afternoon.

4.5 Conduct burning operations

Subject to successful conduct of the test burn (if unsuccessful the test burn is put out), lighting operations are executed in accordance with the burn plan.

While the *Planned Burn Form* typically provides a general level of information about burn stages/sequence, ignition methods (e.g. ground or aerial), and lighting direction, the more precise detail of lighting patterns (i.e. selection of line or spot ignition techniques, spacing of lines or spot ignitions, orientation of ignition direction to terrain features/wind direction etc.) is left to the burn supervisor to determine based on fire behaviour predictions and test fire results.

Selection of lighting patterns appropriate to the local terrain, fuel and weather conditions will be based on:

[2] A model used in emergency management for operational briefings. The acronym stands topics to cover in the briefing including Situation, Mission, Execution, Administration, Command/Control/Coordination and Communication and Safety.

- Where fire behaviour predictions and test fire results fit within the acceptable range of prescribed conditions. For example, if dead fuel moisture is toward the lower end of the acceptable range and weather conditions toward the upper end of the acceptable range, a conservative spot ignition pattern may be adopted to start with. On the other hand, if dead fuel moisture is toward the high end and weather observations toward the low end of the acceptable range, a more closely spaced spot or line ignition lighting pattern may be selected;

- The degree of dead fuel moisture variability within the burn block, particularly in adjacent vegetation types. Where compatible with burn security and risk management objectives, lighting may commence in dryer areas and progress to moister areas as dead fuel moisture responds to diurnal temperature and relative humidity variation during the afternoon. Lighting pattern selection must take into account fuel moisture and wind variability within a burn site; and

- Resources available to control the burn. It is generally desirable to conduct burning operations as efficiently as possible so that operational costs are contained to reasonable levels. Burn supervisors will need to select a lighting pattern that can be effectively delivered with the available resources, and with burn security able to be maintained throughout the burn. Buttongrass burns are sometimes done with relatively low levels of ground resources, for example, where secure natural boundaries are to be used or for remote unbounded burns. By contrast a small block of 20 hectares near a town may have 20 fire-fighters and 10 tankers. As the burn risk increases, as calculated by the BRAT, then increased resources are required.

As a general principle, it is best to start with a conservative lighting pattern and progress up to higher intensity patterns as required, rather than starting with a higher intensity pattern and subsequently having to back it off.

Fire behaviour and on-site weather need to be monitored throughout the burn (with results recorded at least hourly) to ensure conditions remain within prescription, and that where necessary, lighting patterns can be modified as conditions change.

Burn security requires continuous monitoring throughout the burn, to identify and address potential escape points. Where mineral earth boundaries are used along burn edges, mop-up activity may need to be applied. If the SDI is genuinely in the prescribed range then mop up can usually be completed on the day of burn, with a patrol on the following day, and no further action required. If smouldering organic soil is present on vulnerable boundaries, then mop up can take several days.

Once lighting operations are completed and any edge mop-up activity winds down, the burn supervisor will need to assess the extent of unburnt fuels remaining, and assess overnight fire behaviour potential, to make a decision on patrol requirements, in particular if and when resources can safely depart the burn site overnight and the timing of patrol checks the following day (if any). These decisions need to be made based on forecast weather (overnight and days following the burn).

Assessment also needs to be made of likely smoke transport and settling locations to inform placement of smoke hazard signs on public roads and any other prudent smoke management actions.

Figure 2 Buttongrass burn ignition

5 Evaluate results of burning operation

Upon completion of the burn, evaluation of burn results is undertaken and recorded on the Post Burn Evaluation page of the Operational Burn Plan:

- Fuel consumption over the entire burn area is assessed and recorded, dividing the block into sub-units if required (e.g. different aspects);
- A map is prepared of the final burn area. This will require GPS used either on foot or from a vehicle or helicopter;
- Evaluation of whether the burn objectives and success criteria have been met; and
- Lodge the completed Operational Burn Plan and final map with Fire Management Section. This should include all burn day records (notification checklist, weather observations, fuel dryness measurements and test fire) and evaluation.

If a significant escape has occurred then an After Action Review is conducted.

Figure 3 Buttongrass burn edge

Note how fire has spread across open button grass plain areas including over wet areas with surface water still visible, while fire has gone out as it has entered the edges of moist forest areas fringing the plains.

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7 References and further reading

King KJ, Cary GJ, Bradstock BA, Chapman J, Pyrke A, and Marsden-Smedley JB (2006) Simulation of Prescribed Burning Strategies in South West Tasmania, Australia: effects on unplanned fires, fire regimes, and ecological management values. *International Journal of Wildland Fire,* 2006, **15**, 527–540

King KJ, Bradstock BA, Cary GJ, Chapman J, and Marsden-Smedley JB (2008) The Relative Importance of Fine-Scale Fuel Mosaics on Reducing Fire Risk in South West Tasmania, Australia. *International Journal of Wildland Fire,* 2008, **17**, 421– 430

Marsden-Smedley JB (2011a) Planned burning in Tasmania I: a review of current practice and supporting information. University of Tasmania (Hobart)

Marsden-Smedley JB (2011b) Planned burning in Tasmania II: fire risk assessment and the development of a standardised Burn Risk Assessment Tool (BRAT). University of Tasmania (Hobart)

Marsden-Smedley JB (2011c) Planned burning in Tasmania III: revised guidelines for conducting planned burning. University of Tasmania (Hobart)

Marsden-Smedley JB (2009) Planned Burning in Tasmania – Operational Guidelines and Review of Current Knowledge. Department of Primary Industries, Parks, Water and the Environment (Hobart)

Marsden-Smedley JB, Rudman T, Pyrke A and Catchpole WR (1999) Buttongrass moorland fire-behaviour prediction and management. Department of Primary Industries, Water and Environment (Tasmania: Hobart)

Marsden-Smedley JB, Catchpole WR, and Pyrke A (2001) Fire Modelling in Tasmanian Buttongrass Moorlands. IV Sustaining versus non-sustaining fires. *International Journal of Wildland Fire*, 2001, **10**, pp. 255–262

Marsden-Smedley JB (2009) Planned Burning in Tasmania – Operational Guidelines and Review of Current Knowledge. Department of Primary Industries, Parks, Water and the Environment

Parks and Wildlife Service Tasmania (2013) Buttongrass moorland – a unique habitat <http://www.parks.tas.gov.au/indeX.aspX?base=3224> [verified October 2015]

Tasmania PWS (2009) Fire Planning Policy. Department of Primary Industries, Parks, Water and Environment, Parks and Wildlife Service (Tasmania)