# WILD FIRE HAZARD IN THE ENVIRONS OF HOBART

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## PREFACE AND SUMMARY OF RECOMMENDATIONS

The 1967 Hobart bush fire disaster brought into sharp focus the need for an effective fire management programme. Such a programme, as has since been implemented, necessarily has as its basic objective the protection of life and property.

In approaching this area of work we have recognized this basic principle underlying the fire management of the area but feel there exists the danger of becoming too single minded in the pursuit of this objective. We feel that the area represents more than just a fire hazard to life and property and that a simplistic approach is likely to come into conflict with other values and uses of the area.

It has been our endeavour to attempt to minimise this conflict with other values and uses and yet still maintain an adequate degree of protection for life and property. Working from this frame of reference and considering the physical factors outlined in the body of this work we would make the following recommendations with respect to fire management within the area concerned:

a) A de-emphasis of broad area hazard reduction burning in the fire protection strategy of the Hobart Special Fire Area and its restriction to upper northern and western slopes of dry sclerophyll and woodland proximate to settlement.

b) The establishment of on-going research programmes into the ecological effects of hazard reduction burning, including its short and long term effects on vegetation, soil and wildlife.

c) Continued evaluation by the authorities involved of the rates of fuel accumulation to enable burning intervals to be consistent with actual accumulation rates rather than using a 'blanket prescription' burning regime.

d) The appointment of a research officer as a permanent member of the Rural Fires Board staff, responsible for such investigations as outlined in (b) and (c) above would be highly desirable. Such an officer could, in addition to undertaking specific research personally, also initiate and co-ordinate research efforts into such problems by personnel from other Institutions.

e) The drawing up and introduction of Local Government Regulations requiring that all new buildings and developments conform to specifications aimed at reducing the external fire threat posed to such buildings and developments.

f) The implementation of an education programme directed towards initiating self-help activities aimed at protecting life and property.

g) The establishment and maintenance of a low fuel buffer zone between housing development and contiguous bushland.

h) Permits to 'burn-off' be required throughout the year with the difficulty of obtaining such a permit increasing with the fire danger.

i) No fire should be permitted to burn freely within a fire danger period. All illegal fires should be promptly suppressed and fires burning under permit should not extend over more than one day.

j) The establishment and maintenance of a detailed 'master map' showing the location extent and date of all burns including wild-fires in the H.S.F.A. covering more than 10 ha. Updated copies of this map should then be forwarded to Brigade Captains prior to each fire season.

Such a record is fundamental to suppression tactics and invaluable to research activities.

## SUMMARY

This work investigates and makes recommendation on the wild fire hazard that exists in the environs of Hobart. The underlying theme is that of protecting life and property while still giving due cognizance to other environmental and social values that exist in the area.

The factors that influence fire behaviour are discussed and then applied to the Hobart area thereby qualifying it from a general fire danger perspective and showing that variations in fire danger occur over the area commensurate with variations in topography, vegetation and precipitation.

The ways in which a bush fire conflagration may threaten or destroy life and property are detailed and from this perspective protection and survival techniques are proposed.

The present programme aimed at ameliorating the wild fire hazard is briefly outlined; the main aspects of this programme involve the control of fires during fire danger periods, and reduction of fuel loadings, the suppression of outbreaks and public education.

The hazard reduction burning aspect of the current fire management programme is discussed with respect to its rationale and environmental implications, including the possible effects on vegetation, soil and wildlife.

An attempt is made to rationalize the wild fire management programme in the area in such a way that greater emphasis may be given to other environmental and social values that exist within the area. This rationalization or reorientation involves the de-emphasising of the part currently played by broad area hazard reduction burning combined with a greater emphasis on localized protection and effective prevention and suppression of fire outbreaks.

## 1. INTRODUCTION

A number of prerequisites must be fulfilled before a wildfire can ignite and maintain itself in native vegetation. There must be sufficient fuel to sustain a fire and this fuel must be sufficiently dry to ignite and burn. Drought, solar radiation and strong winds can make forest litter into a highly inflammable fuel, which in turn needs an ignition source before wildfire can occur.

The intensity of such a wildfire will be controlled by fuel and weather. The threat posed by the fire to life and property is influenced by individual knowledge and experience of fire behaviour, the layout and juxtaposition of dwellings and bush and many other human habits and responses. One need look no further into the past than the 7th February, 1967, for an example of a wildfire in which the combination of physical and human parameters led to a disaster.

In the aftermath of the '67 fires, Mr. D.M. Chambers, Q.C. and Mr. C.G. Brettingham-Moore were commissioned by the Tasmanian Parliament to collect evidence and report on the disaster; their findings were presented in Parliamentary Paper Number Sixteen of 1967: "The Bush Fire Disaster of 7th February, 1967, Report and Summary of Evidence".

A second committee was later appointed by the Administrator-in-Council to make recommendations with respect to future fire prevention and control activities. This committee consisted of Mr. D.M. Chambers, Q.C.; Mr. G.G. Sinclair, O.B.E.; Mr. A.G. McArthur, B.Sc.(For.); and Mr. D.L. Burbury. Their recommendations were presented in Parliamentary Paper Number Twenty Eight of 1967. The Rural Fire Act, 1967, draws heavily on the recommendations made in this report and virtually provides the legislative framework needed to support the principal recommendations of the committee.

One of the principal recommendations of this second committee was the establishment of a special fire protection area around the fringes of Hobart and Glenorchy:

> *"6. The fringe area lying generally to the west of the cities of Hobart and Glenorchy should be declared a special fire area. Administration of fire control should be in the hands of a Special Committee comprising the State Fire Control Officer, representatives of the Hobart and Glenorchy City Councils, the Kingborough*

*Municipality and a representative of the Hobart Fire Brigade Board."*[1]

This recommendation found legal realisation in section 25 of the Rural Fires Act, 1967:

> *"25-(1) The area comprising -*
>
> *(a) such parts of the cities of Hobart and Glenorchy as are not included within a district constituted under the Fires Brigades Act, 1945; and*
>
> *(b) such parts of the municipalities of New Norfolk, Kingborough and Huon as may be specified by the Minister, by notice in the Gazette,*
>
> *is a special fire area for the purposes of this Act under the name of the Hobart special fire area."*[2]

Our studies this year have been concerned with this Hobart Special Fire Area whose boundaries are shown in Figure 1. We have attempted in our work to create an understanding of the factors influencing fire behaviour, the distribution and variation of these factors over the study area and the ways in which bush fires threaten life and property. From this perspective we go on to consider certain aspects of the present fire management programme and directions in which this programme may constructively move in the future.

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[1] Chambers, D.M. et al., 1967; *Report of the Select Committee into Fire Prevention and Suppression*, p.34; Parliament of Tasmania, Parliamentary Paper no.28, 1967, Hobart.

[2] Parliament of Tasmania, 1967; *Rural Fires Act 1967*, section 25-(1).

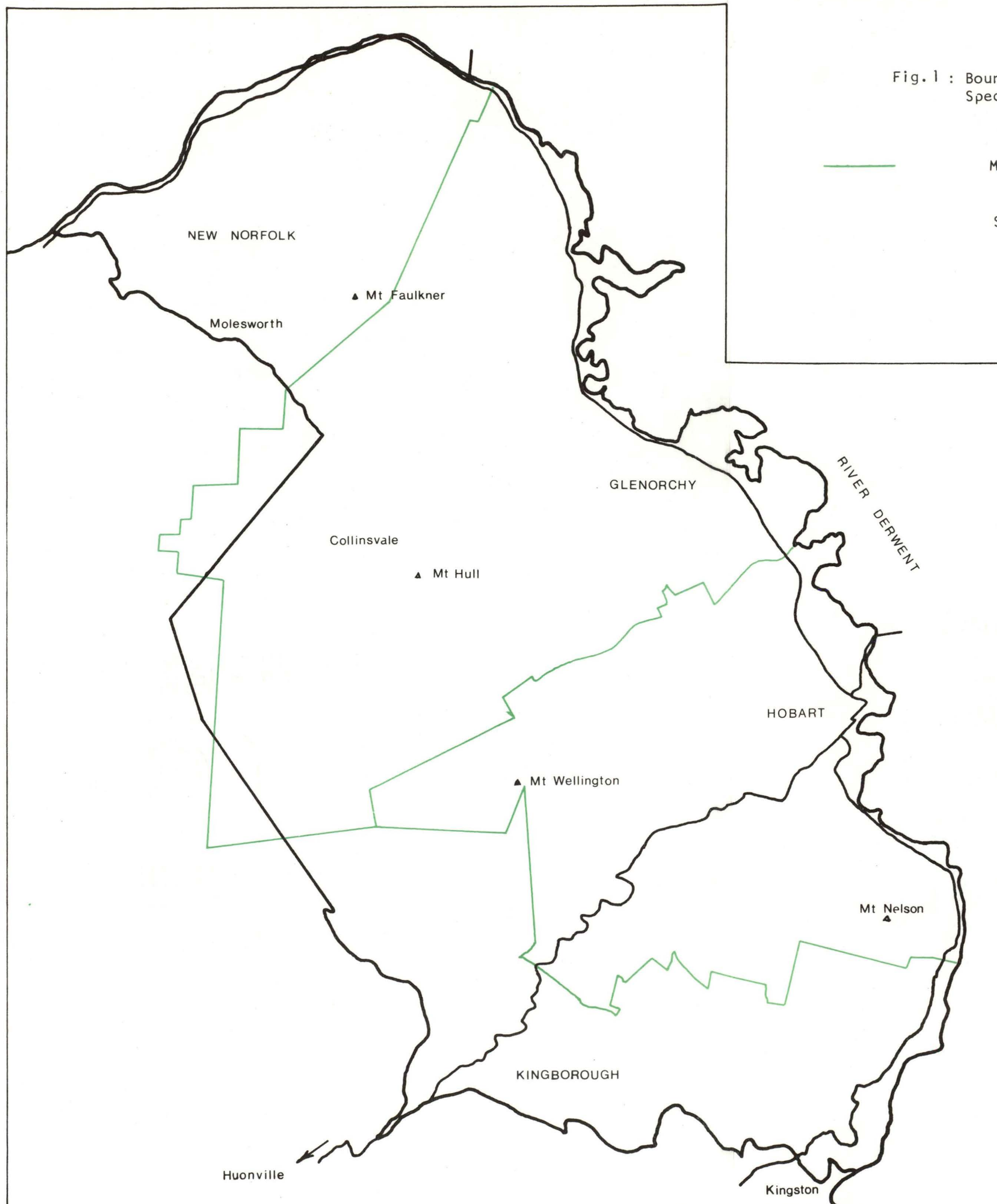


Fig. 1 : Boundaries and Location of Hobart Special Fire Area

Municipal boundaries (approximate)

Scale: 1 : 100000

# 2. THE FIRE RISK COMPLEX

## 2.1 The Human Element

In Tasmania it is human behaviour that makes a bush fire hazard out of the bush fire potential. Men light most fires and build where fires will burn them out. Jackson makes the point that very few fires are caused by lightning strikes in Tasmania and that the majority of uncontrolled fires are escapes from deliberately lit fires[3]; reference to the 1967 fires illustrates this point rather well. Of the 110 identified fires that were burning on 7th February, 88 were deliberately lit. The remaining 22 started accidently either spotted from other fires or escaped from incinerators, rubbish dumps, etc.[4] All of the fires had human origins, either accidently or deliberately.

The threat to property from bush fire in the Hobart area is compounded by the structure of the housing development. The greatest threat occurs at the bush-urban interface. Thus, were the city housing perimeter circular, the risk would be at a minimum. However in Hobart, fingers of housing stretch out into the bush along creek beds and ridge tops (Figure 2), and hence help in creating a larger fire risk to property than would normally be expected.[5]

## 2.2 Factors Influencing Fire Behaviour

An understanding of the way in which the environmental complex influences the behaviour of a fire is fundamental to both the formulation of effective fire prevention plans and to the effective suppression of a wildfire in the field. The factors which affect the ignition probability and the fire behaviour once initiated are best thought of as interacting to form a fire environment. Climate, fuel, vegetation type, topography, and time, all effect the inception, growth and behaviour of a fire.

### 2.2.1 The Air-mass Factor

Air mass characteristics important in the context of fire behaviour are wind, humidity, precipitation, temperature and atmospheric stability.

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[3] Jackson, W.D., 1969; *Fire and the Tasmanian Flora*; Tasmanian Year Book 1969, Hobart.

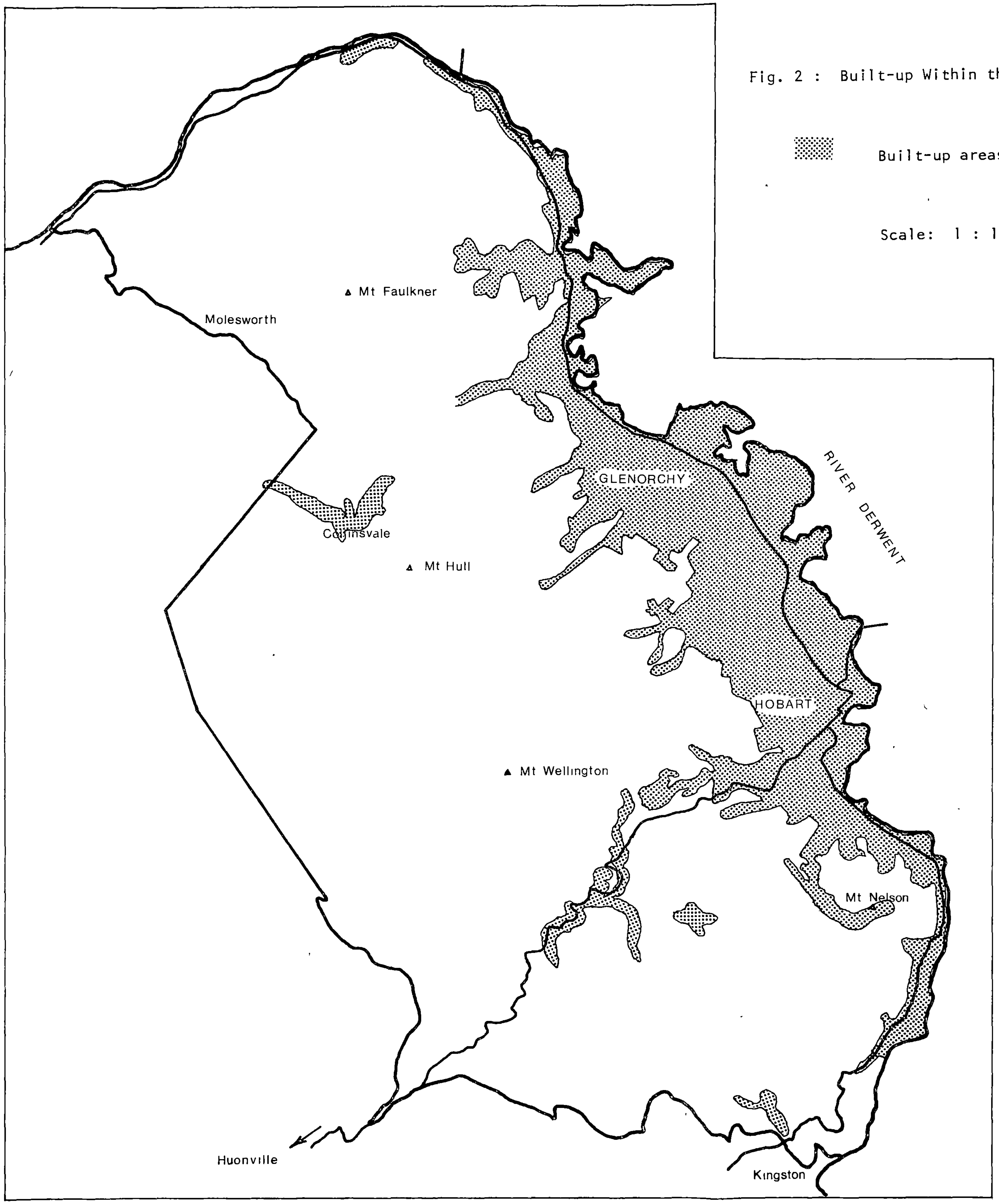
[4] Chambers, D.M. & Brettingham-Moore, C.G., 1967; *Report and Summary of Evidence of the Bush Fire Disaster of 7 February, 1967. Appendix A;* Parliament of Tasmania, Parliamentary Paper no.16, 1967, Hobart.

[5] McArthur, A.G., 1968; *The Tasmanian Bushfires of 7 February, 1967, and Associated Fire Behaviour Characteristics*, p.37; 2nd Australian National Conference on Fire, Sydney.

Fig. 2 : Built-up Within the Hobart Special Fire Area

Built-up areas (approximate)

Scale: 1 : 100000



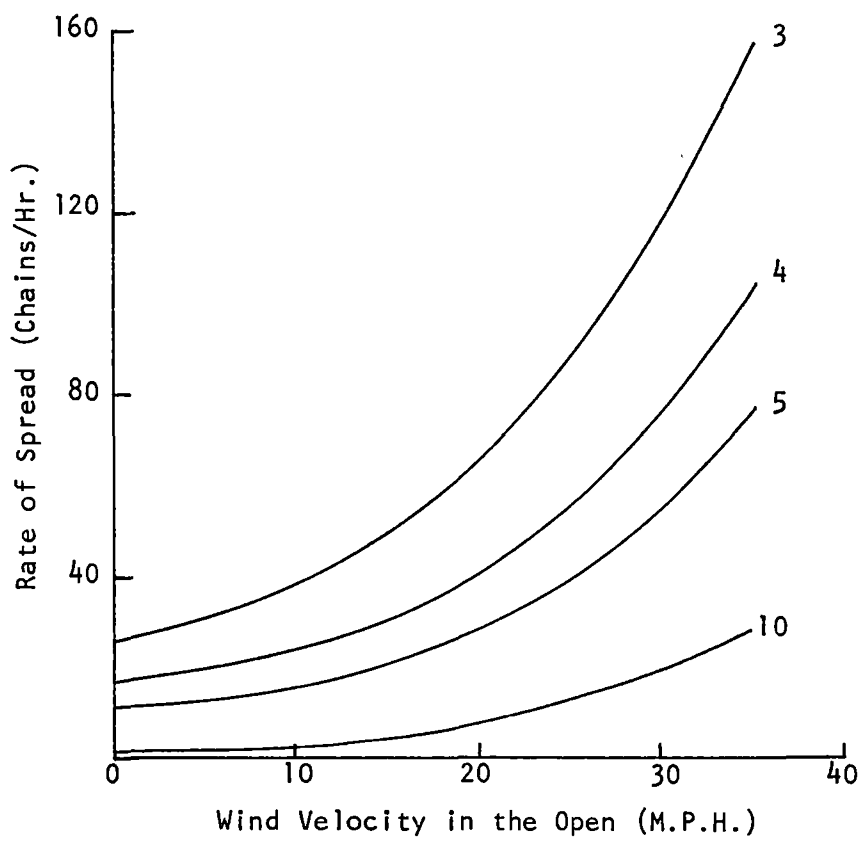
Wind and atmospheric stability have direct effects on fire behaviour, the other characteristics indirectly influencing fire behaviour by their integrative effect on fuel moisture content.

a. Direct Effects

The surface wind velocity has a profound effect on the rate of spread of a fire especially at low fuel moisture contents (Figure 3). The rate of spread is roughly proportional to the square of the wind velocity.

Figure 3

The effect of wind velocity on rate of spread at fuel moisture contents of 3, 4, 5, and 10 percent. (From McArthur, A.G., 1967; *Fire Behaviour in Eucalypt Forests;* Forestry and Timber Bureau Leaflet no.107, Canberra).

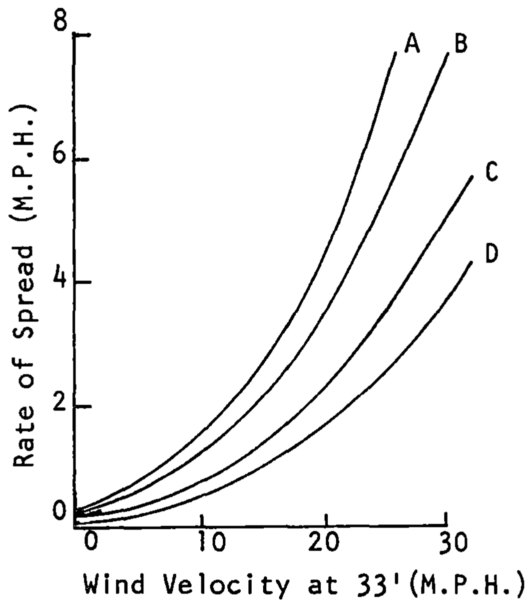



The interaction of moisture content with wind velocity in affecting rates of spread has been explained in terms of a short distance spotting process. Wind ensures the transport of burning embers and low fuel moisture contents ensure that even the smallest of these can effectively initiate a new fire front. Even with higher fuel moisture contents, however, wind still exerts considerable influence by supplying oxygen to the fire, driving the flames into the unburnt fuel and providing more efficient pre-heating

The effect of wind speed on grass fires is particularly dramatic since the grass fuel is open to the full force of the wind. The effect of wind velocity on rate of spread of grass fires is shown in Figure 4.

Figure 4

The effect of wind velocity on the rate of spread of a grassfire for four conditions of fuel moisture content. (From McArthur, A.G., 1966; *Weather and Grassland Fire Behaviour;* Forestry and Timber Bureau, Leaflet no.100, Canberra)




| | | | |
|---|---|---|---|
| A | T.100 | RH.10 | FMC.3.0 |
| B | 90 | 15 | 4.7 |
| C | 85 | 25 | 7.0 |
| D | 60 | 25 | 10.0 |

Wind velocities in excess of about 50 kph apparently cause a rapid reduction in the rate of spread of grass fires. Under strong winds the head fire tends to become fragmented and proceeds in a series of narrow tongues of fire, many of which are self-extinguishing. This effect has been observed for the 1967 Hobart fires and for others in Victoria[6].

Crown fire formation in the forest is also inhibited with strong winds. Atmospheric instability significantly effects fire behaviour by providing the general conditions conducive to the formation of a strong convection column over the fire which in turn determines the potential for long distance spotting and the intensity of indraft winds at the surface, thus influencing the fire intensity.

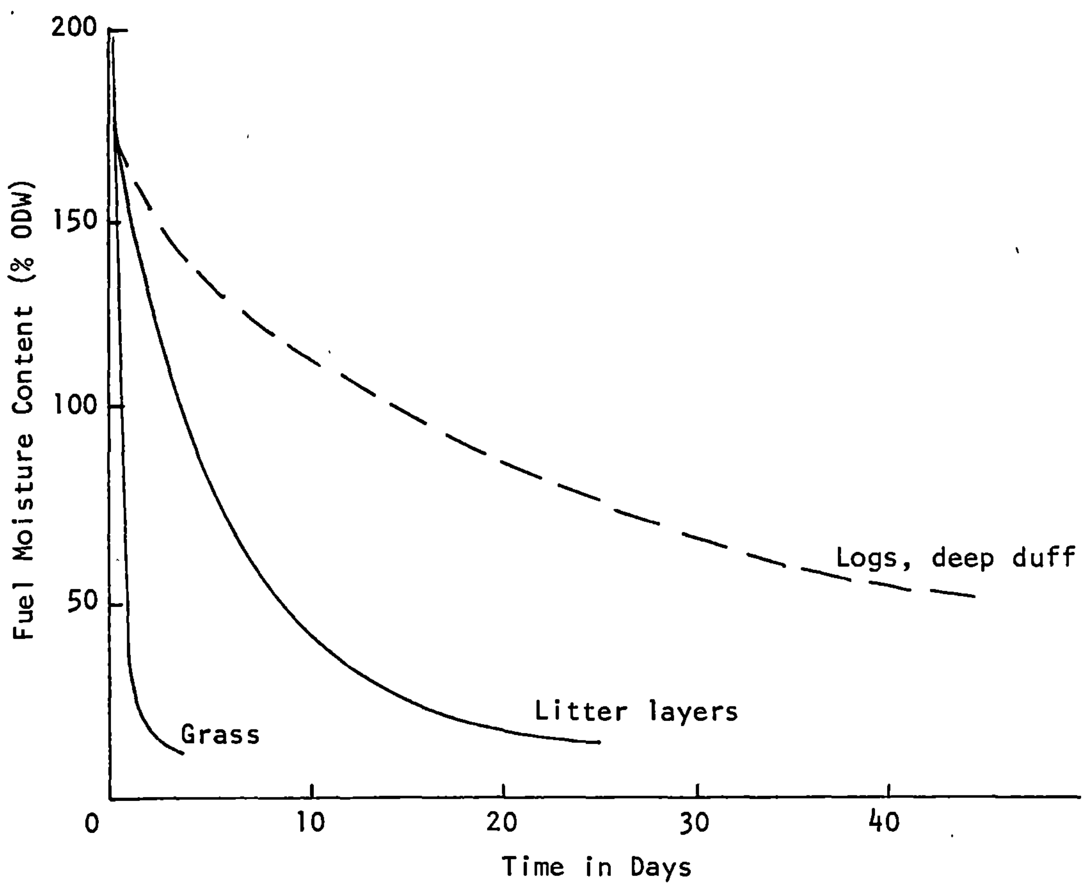
[6] *ibid.*, p.46.

b. Indirect Effects

Wind, humidity, temperature and precipitation, determine the fuel moisture content and its variation down the ground fuel profile and amongst different fuel components. The rate at which fuel dries is dependent on the combined effects of temperature, humidity and wind over the drying period. Drying rates differ between different sized fuel components and within the ground fuel profile. Deeper litter layers and larger fuel components dry more slowly than fine surface fuels (Figure 5)[7].

Figure 5

Rates of drying of various fuel components after initial saturation. (From Forests Commission Victoria; Fire Control Notes 1974)




7 Jarvis, J.M. & Tucker, R.E., 1968; *Drought Index as a Predictor of Moisture Content in L and F Horizons on an Upland White Spruce - Trembling Aspen Cut-over Area;* Canadian Forestry Branch Publication no.1237.

After a variable time period dependent on the long term site drying conditions, the moisture content of the surface fuels will approach equilibrium with the prevailing temperature and relative humidity conditions. This attainment of an equilibrium moisture content by the surface fuels, however, is complicated by the existence of a moisture gradient in the fuel complex. Surface fuels tend to gain moisture from the layers beneath and will generally be of 2-3% higher moisture content for a give combination of temperature and relative humidity than in its absence[8].

Table 1 illustrates the relationship of the equilibrium moisture content of the surface fuels to the temperature and humidity conditions, the values are considered to be reasonably typical of mid-summer conditions on a very dry fuel bed.

Table 1

Relationship of equilibrium moisture content of surface fuels to temperature and humidity. (From McArthur, A.G., 1967; *Fire Behaviour in Eucalypt Forests;* Forestry and Timber Bureau, Leaflet no.107, Canberra)

| Relative Humidity | Air Temperature °F | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 | 95 | 100 | 105 |
| 5 | - | - | - | - | - | - | 3½ | 3½ | 3½ | 3 | 3 | 3 |
| 10 | - | - | - | - | - | - | 3½ | 3½ | 3½ | 3½ | 3 | 3 |
| 15 | - | - | - | - | - | 4 | 4 | 4 | 3½ | 3½ | 3½ | 3 |
| 20 | - | - | - | - | 4½ | 4½ | 4 | 4 | 4 | 3½ | 3½ | 3½ |
| 25 | - | - | 5½ | 5½ | 5 | 5 | 4½ | 4½ | 4 | 4 | 4 | 3½ |
| 30 | 7 | 6½ | 6 | 6 | 5½ | 5½ | 5 | 5 | 4½ | 4½ | 4 | 4 |
| 35 | 7½ | 7 | 6½ | 6½ | 6 | 6 | 5½ | 5½ | 5 | 5 | 4½ | 4½ |
| 40 | 8½ | 8 | 7½ | 7 | 6½ | 6½ | 6 | 6 | 5½ | 5 | 5 | - |
| 50 | 10½ | 9½ | 9 | 8½ | 8 | 8 | 7½ | 7 | 6½ | - | - | - |
| 60 | 14 | 12 | 11 | 10 | 9½ | 9 | - | - | - | - | - | - |
| 70 | 19 | 16½ | 14½ | 12½ | - | - | - | - | - | - | - | - |

The moisture content of living fuel, shrubs, etc., is less readily correlated with either drought or ambient humidity and temperature although prolonged drought periods extending over some months can cause extreme soil moisture deficits and green vegetation may reach a moisture content of 50-70% from the more normal 120% upward[9].

8 Forests Commission Victoria, 1974; *Fire Control Notes,* Melbourne.
9 *ibid.*

### 2.2.2 The Fuel Factor

Under a given combination of weather and topographic conditions the characteristics of the fuel in which a fire is burning are critical in determining the fire behaviour. It is the major determining variable and unfortunately also the most complex to quantify and use in predicting fire behaviour.

Fuel characteristics important in predicting fire behaviour normally include the following:

a. fuel quantity

All organic material is potentially capable of supporting combustion. The total dry fuel weight in an area sets the maximum potential energy that may be released during combustion.

Fuel is found in almost infinite combinations of kind, size and arrangement. The proportion of the total fuel which actually burns in a fire is dependent on the scale of the fire which in turn is largely related to other aspects of the fuel complex. Thus different combinations of kind, size and arrangement of fuel all with the same total fuel weight will exhibit different fire behaviour and different proportions of the total fuel weight will actually be consumed.

Practical experience has shown that the fine component (material 1 cm thick) of most forest fuels is important in contributing to fire behaviour. The fuel available for combustion is, for all practical purposes, equated to this fine fuel component with appropriate reductions according to the moisture content profile in the fuel bed (see fuel moisture content later).

The rate of forward spread of a fire is directly proportional to the available fuel quantity. Thus as the fuel quantity doubles, so will the rate of spread[10].

The fire intensity is related to both the rate of spread and the available fuel quantity according to the following equation

$I = Hwr$ where $I$ = fire intensity
$H$ = heat yield of fuel per unit mass
$w$ = weight of available fuel
$r$ = rate of spread.

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[10] McArthur, A.G., 1967; *Fire Behaviour in Eucalypt Forests*, p.10; Forestry and Timber Bureau, Leaflet no.107, Canberra.

It can be readily seen that as the fuel quantity doubles, the fire intensity will increase fourfold.

b. fuel size and arrangement

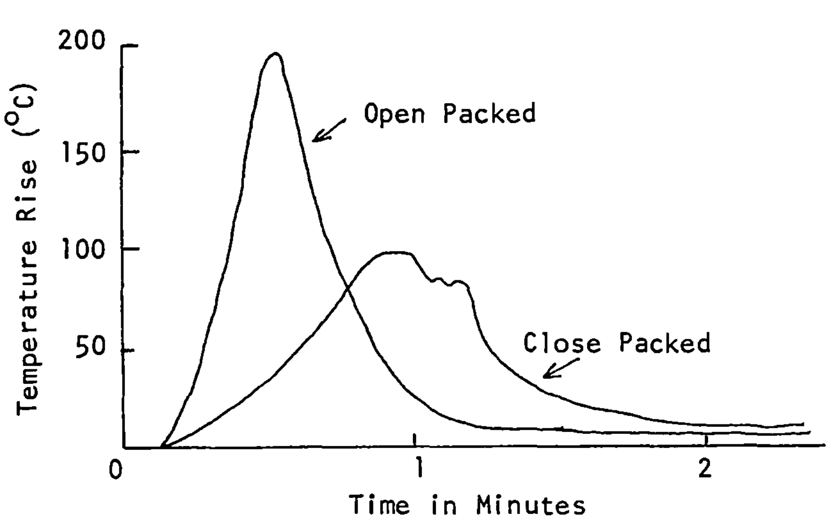
The combustion rate and the rate of spread of a fire vary inversely as the thickness of the fuel particles, thus explaining the importance of the fine fuel component to fire behaviour[11].

The arrangement of the fuel particles in both the horizontal and vertical dimensions is also critical to fire behaviour.

The relative compactness of a fuel bed determines to a large part how rapidly the fuel will burn. Differences in the rate of combustion in different fuel arrangements can cause marked differences in fire behaviour. The general relationship of compaction on combustion rate is illustrated in Figure 6.

Figure 6

Combustion rates in loosely compacted and closely compacted eucalypt leaves. (From Forests Commission Victoria; Fire Control Notes 1974)




c. fuel moisture content

Moisture content has a profound impact on the burning properties of the fuel complex and in ignition probability. The enormous change in the burning characteristics of fuel with increasing moisture content probably

11 *ibid.*, p.8.

results from two effects acting in combination. These are the direct cooling effect of evaporation[12] and the smothering effect of water vapour thereby reducing the emission of radiant heat[13].

At a moisture content of 7%, eucalypt litter may only be ignited effectively by large flaming brands whereas at moisture contents of 4% or less, even the smallest of burning embers has a high chance of starting a fire[14].

The fuel moisture content also has a tremendous impact on the rate of spread. Studies done by McArthur [15] in sclerophyll forests indicate an exponential increase in rates of spread with decreasing fuel moisture content. With moisture contents below 7%, a reduction of 2% will double the rate of spread. Fuel moisture contents of about 20-25% would appear to be the upper limit in which a self sustaining fire can occur in eucalypt litter[16].

d. <u>fuel chemical composition</u>

The heats of combustion of a wide variety of oven-dried material, including pine leaves, eucalypt leaves, bracken and grass have been found to be very similar and within the range of 14.7 - 16.8 $^{KJ}/gram$.[17] There is then little difference in the total heat content of forest fuels.

Chemical differences, however, may be reflected in the combustion rate. King and Vines[18] studied the relative inflammability of the oven-dried leaves of a wide variety of Australian species and found marked differences between species which they related to the mineral content of the leaf material (Table 2). They also found that the presence of essential oils greatly increased the rate of combustion.

Thus, abrupt changes in fire behaviour may occur coincident with community or species changes due to interspecific variation in mineral

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12 Anderson, H.E., 1969; *Heat Transfer and Fire Spread;* United States Department of Agriculture, Forest Service Research Paper INT-69 Washington.
13 Pompe, A. & Vines, R.G., 1966; The Influence of Moisture on the Combustion of Leaves, *Australian Forestry*, 30:3, pp.231-241.
14 McArthur, A.G.; *op.cit.* p.17.
15 *ibid.* p.3.
16 Mount, A.B., 1975; *Guidelines for Protective Burning;* Internal working manuscript for officers of the Forestry Commission of Tasmania.
17 Pompe, A. & Vines, R.G.; *op.cit.*
18 King, N.K. & Vines, R.G., 1969; *Variation in the Flammability of the Leaves of some Australian Forest Species;* Commonwealth Scientific and Industrial Research Organisation, Division of Applied Chemistry, Melbourne.

and essential oil content. Generally most broad leaved shrub species are much less inflammable than sclerophyllous shrubs. The leaves of *Bedfordia salicina* can even be used to extinguish small fires[19].

Table 2

Relative inflammability of a number of oven-dried leaves of a variety of Australian species. (Adapted from King, N.K. & Vines, R.G., 1969; *Variation in the Flammability of the Leaves of Some Australian Forest Species;* Commonwealth Scientific and Industrial Research Organisation, Division of Applied Chem., Melbourne)

| Species | Total Minerals % | Burning Quality | Representation in H.S.F.A. |
|---|---|---|---|
| Tamarix | 9.30 | very bad | - |
| Phytolacca octandra | 11.05 | very bad | - |
| Physalis peruviana | 6.10 | very bad | - |
| Ficus fraseri | 5.59 | ? | - |
| Bedfordia salicina | 6.35 | bad | species |
| Myoporum insulare | 9.65 | bad | species |
| Lantana camara | 4.88 | ? | - |
| Solanum sporadotrichum | 7.39 | bad | genus |
| Coprosma | 4.88 | bad | genus |
| Solanum auriculatum | 4.09 | fair | genus |
| Acacia longifolia | 7.39 | fair | genus |
| Dioscorea transversa | 4.14 | good | - |
| Acacia maidenii | 2.86 | good | genus |
| Cissus antarctica | 2.91 | good | - |
| Legnephora moorei | 2.56 | fair | - |
| Eucalyptus acmenioides | 2.43 | good | genus |
| Eucalyptus saligna | 2.49 | very good | genus |
| Tristania conferta | 2.66 | very good | - |
| Eucalyptus ficifolia | 2.49 | very good | genus |
| Orites excelsa | 2.14 | very good | genus |
| Mixed eucalypt | 1.82 | excellent | genus |

e. fuel temperature

High fuel temperatures normally result from high incidence and intensity of solar radiation; high temperatures reduce the amount of heat required to bring the fuel to ignition temperature. Thus, the temperature of the fuel could be expected to influence the rate of spread, and the ignition probability of the fuel bed.

19 Mount, A.B., 1964; The Interdependence of the Eucalypts and Forest Fires in Southern Australia; *Australian Forestry*, 28: 3, pp.116-172.

### 2.2.3 The Topographic Complex

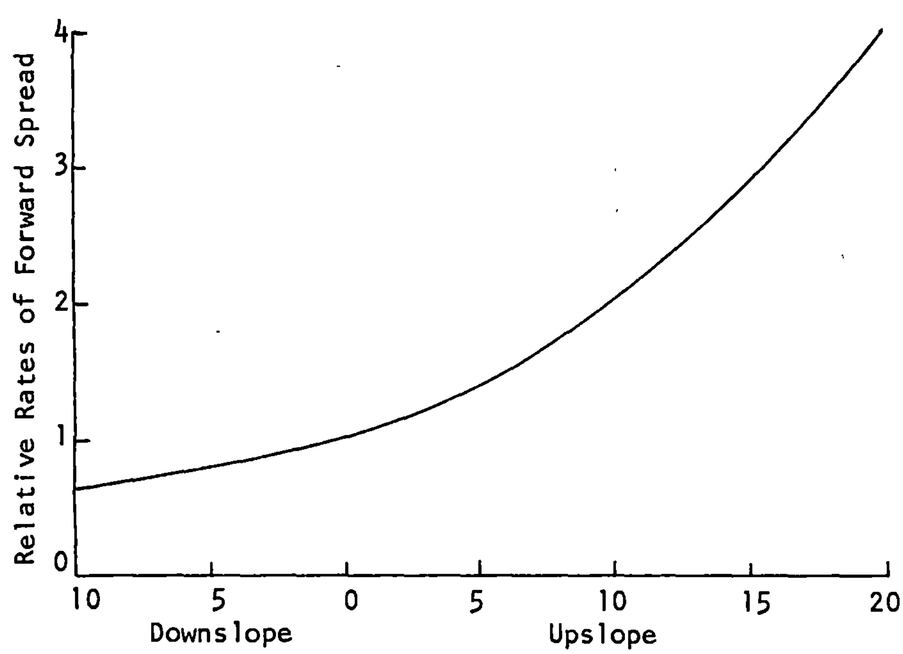
#### a. Direct Effects

Fires spread more rapidly upslope than on level ground because fuels are heated from below and upslope winds are generated. Similar effects cause a fire burning downslope to be slower than on level terrain.

Experimental fire behaviour studies done by McArthur indicate that the rate of forward progress of a fire in eucalypt fuels will double on a 10° slope and increase fourfold up a 20° slope (Figure 7).

Figure 7

The effect of slope on the forward progress of fires in eucalypt fuels. (From McArthur, A.G., 1967; *Fire Behaviour in Eucalypt Forests;* Forestry and Timber Bureau, Leaflet no.107, Canberra)




#### b. Indirect Effects

Topography plays a major role in giving rise to microclimatic differences between sites. In the fire context, this translates into spatial variations in fuel moisture content, the species composition of the fuel complex and surface wind velocity and direction.

In rugged and broken terrain, significant changes in the fire environment can occur over very short distances.

The aspect of a slope is a major control on the total possible incidence of solar radiation, which in turn largely determines the rate at which fuels lose moisture. Sheltered aspects exhibit a less severe drying climate and similarly have lower temperatures and higher relative humidities than their exposed counterparts. The former means that the fuels will retain high moisture contents longer and the latter causes the equilibrium moisture contents of the surface fuels to always be higher.

Vegetative cover also influences the amount of solar radiation reaching the ground fuels. Sheltered aspects often have a taller and denser vegetation which reinforces the above effects.

The influence of topography on the wind field is a problem of flow. Variations in surface wind velocity and direction being brought about by barrier and channelling effects[20].

### 2.2.4 The Spotting Process

This process, reasonably defined as the transport of burning embers ahead of the fire front to initiate new fires, is well developed in the eucalypt forest and can occur over short and long distances from the fire front. Two distinct patterns can be recognized[21]. In one, the concentration of spot fires decreases with distance from the fire front. In the other, spot fires are concentrated in distinct groups at varying distance from the fire front. These patterns are normally associated with short and long distance spotting respectively. The former can result in simultaneous ignition of large areas ahead of the fire and produce disastrous fire storm effects.

Spotting is enhanced by high fire intensities, crown fires, strong winds and strong convection columns. The last is particularly conducive to long distance spotting.

Although the bark of most eucalypt species will spot to some extent, there is considerable variation in spotting potential. Some degree of differentiation is possible between bark types (Table 3).

The stringybark and candlebark species have the highest spotting potential. Fire brands of stringybark are frequently small and flaming

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[20] Slatyer, R.O. & McIlory, I.C., 1961; *Practical Microclimatology;* Commonwealth Scientific and Industrial Research Organization, Australia.

[21] Cheney, N.P., & Bary, G.A.V., 1969; The Propagation of Mass Conflagration in a Standing Eucalypt Forest by the Spotting Process; Paper presented at *Mass Fire Symposium,* vol.1, Commonwealth of Australia.

Table 3

Bark types in the genus eucalyptus and their relative spotting potential in the Hobart Special Fire Area. (Adapted from Cheney, N.P. & Bary, G.A.V., 1969; The Propagation of Mass Conflagration in a Standing Eucalypt Forest by the Spotting Process; Paper presented at *Mass Fire Symposium,* vol.2, Commonwealth of Australia)

| Bark Type | Description | Spotting Potential |
|---|---|---|
| **ROUGH BARKS** | | |
| Peppermint | | |
| eg. *E. amygdalina* | Fine textured, moderately rough and fibrous. Can be peeled from tree in short lengths. | Moderate to high: distances short. |
| Stringybark | | |
| *E. obliqua* | Rough long fibres, often appears corrugated. Can be peeled from tree in long wide strips. | Very high up to 3 km. |
| **GUM BARKS** | | |
| Smooth-bark | | |
| *E. pulchella*<br>*E. tenuiramis*<br>*E. viminalis* | Bark sheds in small flakes or irregular patches. Appear mottled after bark shed. Loose bark persists on stem for a short period. | Low. Some types moderate during bark shed. |
| Candlebark | | |
| *E. globulus*<br>*E. regnans* | Bark smooth but shed in long strips. Long streamers of bark held up in branches. | High. Very high during bark shed. Long distance spotting. |
| Half-bark | | |
| *E. delegatensis*<br>*E. ovata* | Rough fibrous bark on the lower portions of the bole and extending to about half tree height. Smooth or candle bark on the upper limbs. | High; particularly when a combination of stringy bark and candle-bark occurs. |

when they hit the fuel bed and although these firebrands usually burn up over long distances, they have a high ignition probability over short distances. The candle bark type decorticates in long ribbon-like strips and is responsible for all spotting over 5-6 km. in advance of the main front.

The spotting process by virtue of its potential for creating fire storm effects and its ability to enable fire to spread over fire breaks is perhaps the forest fire characteristic most frustrating and dangerous to suppression efforts.

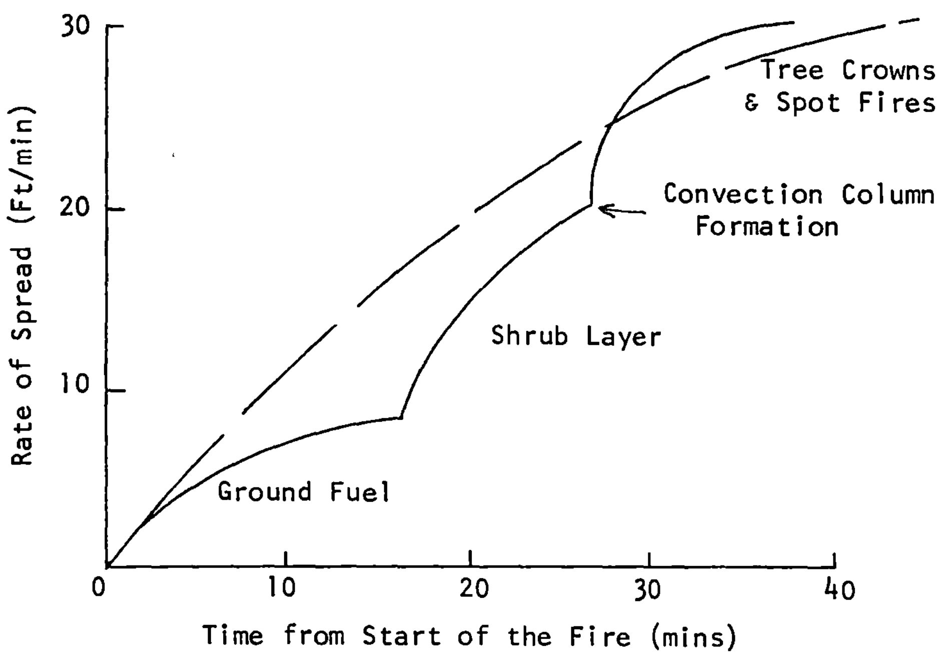
### 2.2.5 The Time Factor

Under severe burning conditions, rate of spread, flame height, fire intensity, convective circulation, and the spotting process in eucalypt forest tend to increase with time.

This effect can be explained by the progressive availability of the different fuel components as time and hence total heat release increases. Figure 8 illustrates this effect.

Figure 8

Successive stages in the acceleration of a fire burning in a eucalypt fuel type containing a well developed shrub layer. (From McArthur, A.G., 1967; *Fire Behaviour in Eucalypt Forests;* Forestry and Timber Bureau, Leaflet no.107, Canberra)



In heavy fuel concentrations and under severe burning conditions probably the only chance of controlling a fire occurs in the first 15-30 minutes of its life[22].

## 2.3 The Fire Environment of the Hobart Special Fire Area

The preceding section has outlined the environmental factors of relevance to fire behaviour. This section attempts to relate these factors to conditions in the Hobart Special Fire Area (H.S.F.A.)[23] and provides a framework within which plans for fire protection of both life and property can be formulated.

### 2.3.1 The General Fire Climate

A complete appraisal of the fire weather of Hobart can only be gained by a comprehensive review of the long term history of local Fire Danger Indices.[24] This data is not readily available[25]; records of Fire Danger Indices kept by the Meteorological Bureau being largely incomplete and derived from readings taken at 3 p.m. at which time the influence of the sea breeze may cause such readings to be totally unrepresentative of the actual fire danger conditions over most of the day.

Nevertheless, some general perspectives to the fire weather in Hobart can still be given.

In common with most of south-eastern Australia, the period within which weather conditions are occasionally such as to be conducive to the outbreak of severe wildfires comprises the months of December to March inclusive. Outside this period, fires causing suppression difficulties rarely occur[26].

The specific set of meteorological conditions which give rise to high fire danger levels in south-eastern Australia are well known.

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22 McArthur, A.G.; *op.cit.*, p.22.

23 Since the term Hobart Special Fire Area shall be used frequently throughout the text the abbreviation H.S.F.A. shall be introduced at this stage and used to signify that same area.

24 The Forest Fire Danger Index, developed by A.G. McArthur, is derived from the integration of temperature, relative humidity, wind velocity and rainfall deficiency. On a relative scale of 1-100 it relates to both the ignition probability of the fuel bed and the subsequent difficulty of control of a fire burning in typical dry sclerophyll forest carrying 12.5 tonnes per hectare of fine fuel over level to undulating country. Indices are normally grouped into fire danger classes: 0-5, Low; 6-11, Moderate; 12-23, High; 24-29, Very High; 50-100, Extreme.

25 Some work in this context is currently being undertaken by Mr. W. Chynoweth of the T.C.A.E., Hobart. However, the study is not yet completed.

26 Luke, R.H., 1961; *Bush Fire Control in Australia*, Hodder and Stoughton, Melbourne.

Anticyclonic subsidence in summer leads to the development of air masses with high temperatures and low relative humidities. The west to east movement of anticyclones, usually in the latitude of the Tasman Sea, brings hot dry northerly or north-westerly winds from the centre of the continent[27]. These conditions expressed to varying degrees are relatively common over the summer months and when coincident with a long-term rainfall deficiency are potentially conducive to disastrous wildfires.

The Hobart Fires of 1967 occurred under an extreme example of such a coincidence of long term drought, very strong north-westerly winds, very high temperatures and very low relative humidities. These extreme conditions, although rare, are by no means unique to the 7th February, 1967, as evidenced by reviewing the weather conditions for some previous days on which severe fires were known to have occurred (Table 4).

Table 4

Forest Fire Danger Rating at Hobart on Historical "blow-up" Days (3 p.m. readings). (From McArthur, A.G. & Cheney, N.P., 1967; *Appendix G of Report and Summary of Evidence of the Bush Fire Disaster of 7 February 1967*, Parliament of Tasmania.)

| Year | Date | Temp (°C) | R.H. | Wind Velocity (km/h) | Drought Factor[28] | Fire Danger Index |
|---|---|---|---|---|---|---|
| 1912 | 14/1 | 37 | 7 | NW 56 | 7 | 84 |
| 1914 | 14/2 | 34 | 15 | NW 35 | 9 | 46 |
| 1927 | 11/2 | 39 | 15 | WNW 54 | 9 | 83 |
| 1934 | 9/2 | 37 | 11 | NW 53 | 9 | 87 |
| 1940 | 11/3 | 37 | 10 | NW 35 | 9 | 60 |
| 1967 | 7/2 | 39 | 13 | NW 48 | 9 | 78 |

27 Edgell, M.C.R. & Brown, E.H., 1975; The Bushfire environment of south-eastern Australia, *Journal of Environmental Management*, 3, pp.329-349.

28 This is a measure of fuel availability as determined by both the seasonal drought severity and the effects of recent rainfall. It is measured on a relative scale from 0-10.

Conditions similar to 1967 have then occurred on perhaps four occasions in the past 55 years[29].

An appraisal of historical bad fire years reinforced by a study revealing that a summer rainfall deficit generally follows a quite pronounced 6-7 year cycle[30], has led to the suggestion that bad fire years and in particular "blow-up" days of extreme severity occur roughly every 13 years in south-eastern Australia with a secondary cycle of generally less severity every 6-7 years.

Days in Hobart which are likely to have had Fire Danger Indices in excess of 30 are shown in Table 5.

Although there is some suggestion of a 6-7 year cycle of bad fire days in this sequence, there is equally an indication that such days can occur independently. The potential benefits to fire control planning to be gained from being able to confidently predict bad fire seasons in advance obviously justifies considerable local research in this field but the above results do not engender much optimism over the possibility of obtaining a predictive model of practical application to fire control.

What is apparent from Table 5 is that days of very high and extreme fire danger are very infrequent, occurring on the average perhaps once every three years. The remainder of days during the fire season generally present little concern. This is exemplified by Figure 9 which shows the relative breakup of days into their respective Fire Danger Indices for the 1975/76 fire season which was generally above average in terms of fire danger.

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29 A.B. Mount of the Forestry Commission derived lower Drought Factors for the above days prior to 1967 than was used in this Table and consequently arrived at much lower Fire Danger Indices with 1967 clearly being the worst recorded day. Nevertheless these other days still remained of very high and extreme fire dangers and the point about the non-uniqueness of 1967 is still practically valid.

30 Vines, R.G., 1974; *Weather Patterns and Bush Fire Cycles in Southern Australia*, C.S.I.R.O., Division of Chemical Technology, Technical Paper No.2.

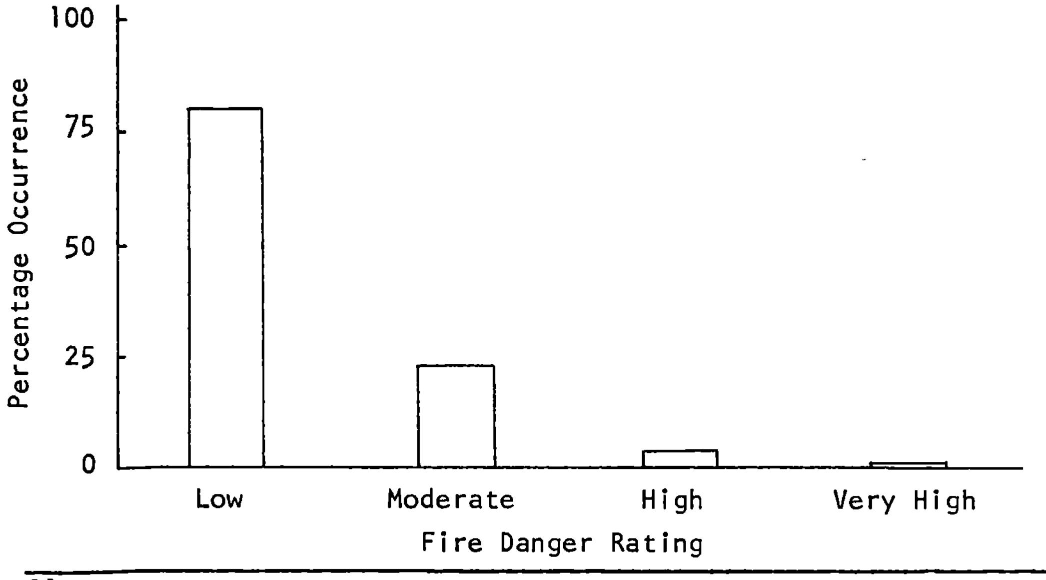
Table 5

Days in Hobart 1895-1967 with a Peak Fire Danger Index of Greater than Thirty

| Year | Date | Estimated Peak Fire Danger Indices[31] |
|---|---|---|
| 1897 | 31/12 | 48 |
| 1899 | 12/2 | 36 |
| 1901 | 7/2 | 38 |
| 1912 | 14/1 | 42 |
| 1912 | 3/2 | 32 |
| 1913 | 13/1 | 35 |
| 1914 | 14/2 | 34 |
| 1914 | 8/10 | 38 |
| 1927 | 11/2 | 34 |
| 1927 | 12/2 | 67 |
| 1928 | 11/1 | 43 |
| 1934 | 9/2 | 51 |
| 1940 | 13/3 | 45 |
| 1943 | 28/1 | 33 |
| 1944 | 22/1 | 32 |
| 1946 | 20/12 | 32 |
| 1951 | ? | ? |
| 1954 | 16/1 | 34 |
| 1960 | 7/1 | 32 |
| 1960 | 8/1 | 34 |
| 1960 | 16/1 | 47 |
| 1961 | ? | ? |
| 1966 | 23/11 | 36 |
| 1967 | 7/2 | 108 |

Figure 9

Fire Danger Ratings for the 1975/76 Fire Season (From Meteorological Bureau Records (3 p.m. readings).




[31] From an unpublished report on the 1967 Fires by A.B. Mount, Forestry Commission, Tasmania.

Hobart (and Tasmania in general) on the average experiences much less frequent severe fire danger conditions than the rest of Southern Australia. A survey of Forest Fire Danger Indices for Melbourne[32] shows a total of at least 24 days of extreme fire danger between 1911 and 1969, as compared to perhaps four such days for Hobart in the same period. Furthermore most years in Melbourne exhibit many more days of high but not extreme Fire Danger than in Hobart.

For the period 1937-1969, Melbourne experienced over 100 days in excess of a Fire Danger Index of 30, whereas Hobart had only 12 such days.

The Hobart Fire Weather is then characterized by very infrequent days of very high and extreme fire danger, perhaps occurring to a large extent on a cyclic pattern of every 6-7 years, interspersed with occasional days of high fire danger with the bulk of days made up of low and moderate fire danger.

### 2.3.2 Topography

The H.S.F.A. is characterized by high local relief (Figure 10, Plate 1) and consequently by a high proportion of steeply sloping land (Figure 11, Table 6).

Table 6

Percentage Occurrence of Slope Classes in H.S.F.A.

| Slope Class | Percentage Occurrence |
|---|---|
| 0-10$^\circ$ | 22 |
| 10-20$^\circ$ | 44 |
| 20-30$^\circ$ | 27 |
| $> 30^\circ$ | 7 |

The high proportion of slopes in excess of 10$^\circ$ makes fire suppression difficult by increasing the rate of spread and intensity of fires, and by making ready access difficult.

[32] Vines, R.G., 1969; A survey of forest fire danger in Victoria (1937-1969), *Australian Forest Research,* Vol.4, No.2, pp.39-44.

Fig..10 : Topography of Hobart Special Fire Area

Scale : 1 : 100 000

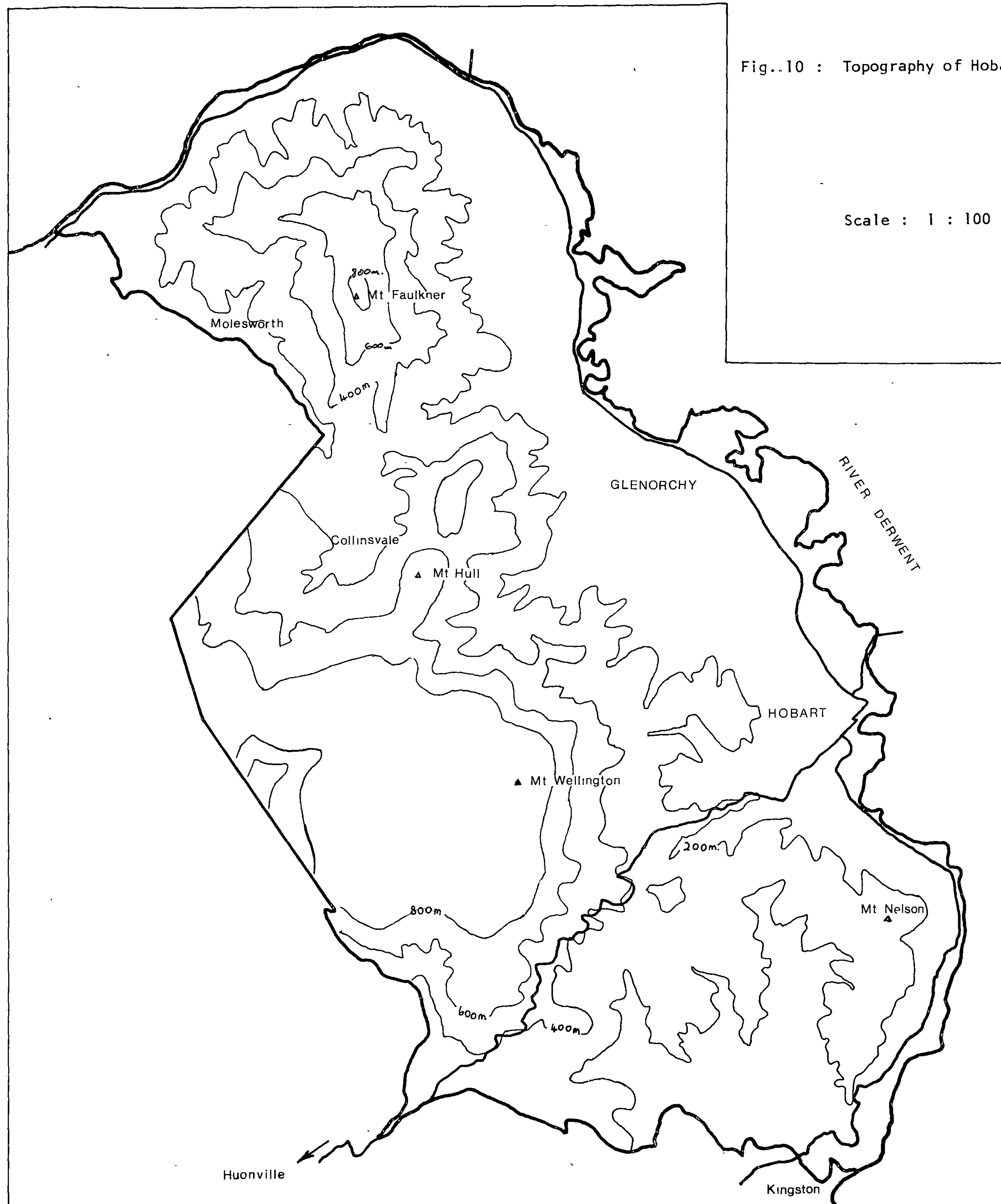
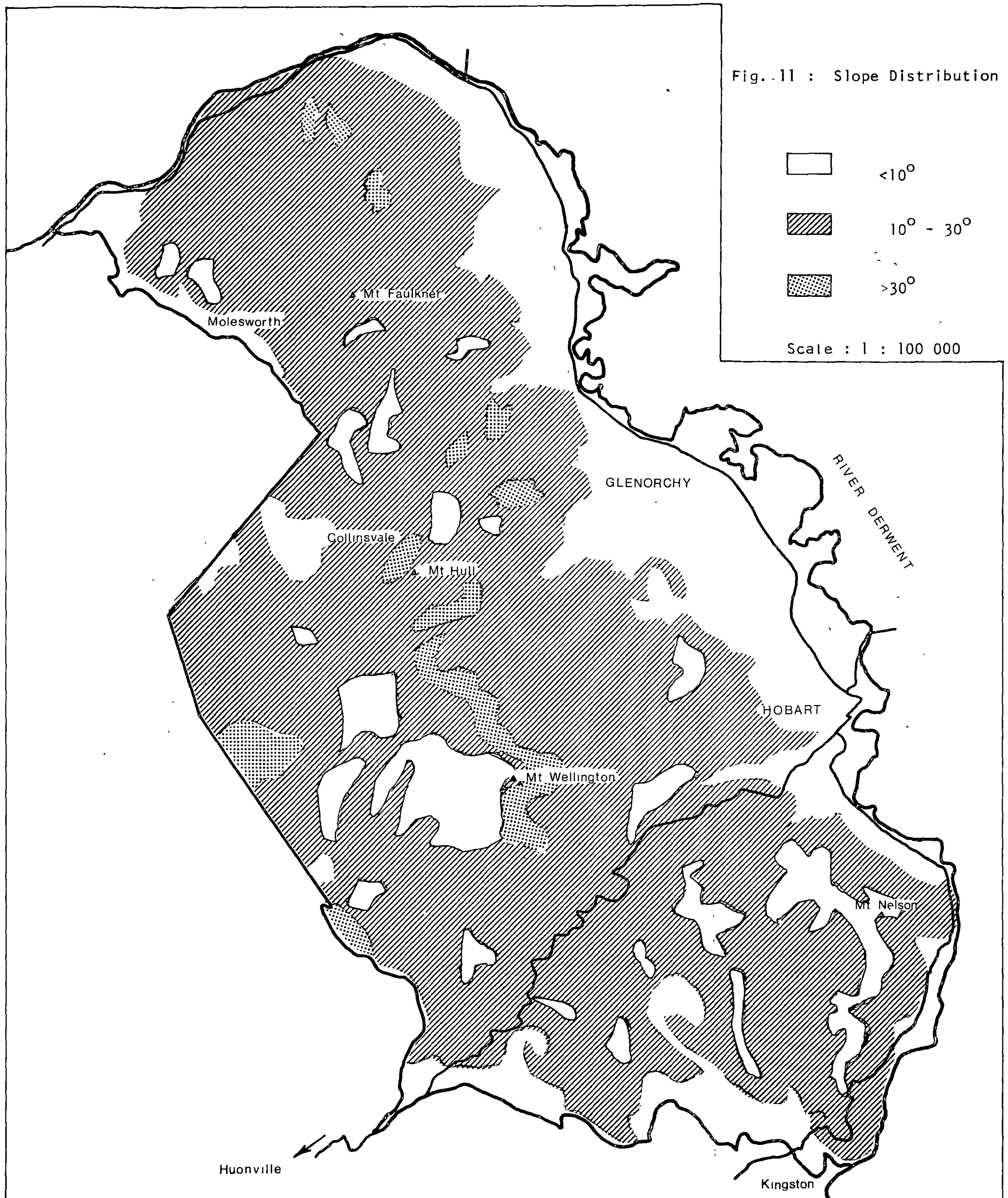


Plate 1: A view of typical terrain within the H.S.F.A.

Fig. 11 : Slope Distribution over Hobart Special Fire Area




<10°

10° - 30°

>30°

Scale : 1 : 100 000

### 2.3.3 The Fuel Complex

The structure and inflammability of the fuel complex is to a large part determined by the composition and structure of the plant communities occurring in a given area. A large variety of plant communities occur in the H.S.F.A., reflecting the large range of microclimatic and edaphic conditions as well as a varied fire history. With the exception of cleared land and small sections of alpine heaths and herblands, most of the area is covered by eucalypt forest and woodlands, thereby ensuring accumulation of ground fuel in the form of eucalypt leaves and twigs and a relatively high potential for spot fire generation. Further definition of the fuel complex can be made relating primarily to the composition and structure of the understorey. For the present purposes, the vegetation has been sub-divided into a number of broad classes[33] (Table 7), the approximate distribution of which are shown in Figure 12.

Although research on the fire behaviour characteristics of specific vegetation types is yet in its infancy[34], some general comments relating to the fuel properties of the above types can nevertheless be made.

a. Total Fuel Loadings

High rates of litter accumulation together with a taller and denser understorey in the wet sclerophyll forests clearly cause these forests to have the highest total fuel loadings potentially capable of contributing to combustion and resulting in very severe fire behaviour, including a high potential for crownfire development.

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[33] The distribution of these fuel types was developed from a variety of sources, including geological maps, aerial photos and field observations. Vegetation maps available for some of the area were also used, viz: Hamilton, D. & Lane, D., 1968; *A Botanical Survey of Mt. Wellington Park, Ridgeway Reserve and Knocklofty Reserve,* unpublished report by Lands Department dealing with the recovery of the Vegetation after the 1967 Fire. Martin,D.M., 1940; The Vegetation of Mt. Wellington, Tasmania, *Proceedings Royal Society Tasmania,* pp.97-124. The resultant map must be considered only indicative of the general distribution.

[34] Some work has recently been begun by the Forests Commission, Victoria orientated towards observing the specific fire behaviour of discrete plant communities (D. Williams 1976, pers. comm.). The expansion of such research could prove of immense value to the formulation of plans for fire prevention and suppression by identifying the more inflammable communities.

Fig. 12 : Fuel Types in H.S.F.A.

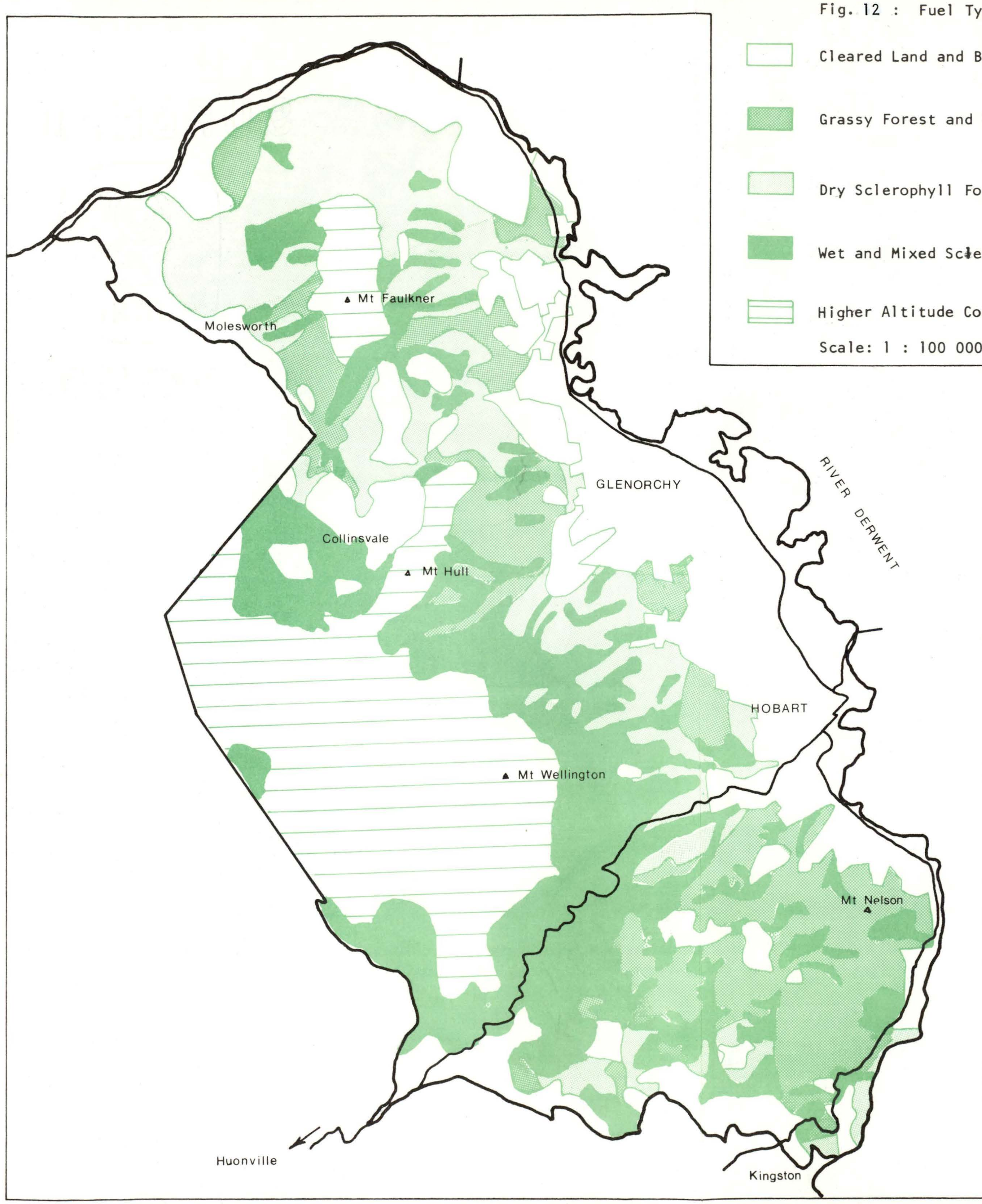

Table 7

Fuel Types in the H.S.F.A.

| Classification | Typical Understorey | Dominant Eucalypt Species |
|---|---|---|
| Cleared land | Very variable, ranging from managed annual grasses etc. to unmanaged areas which bracken, gorse (*Ulex europaeus)* or blackberries *(Rubus fruticosus)* have subsequently invaded. | - |
| Grassy Forest & Woodland | High proportion of grasses (*Themeda australis, Poa spp.*). Variable admixture of dry sclerophyll shrubs and sedges. | *E. globulus, E.pulchella, scattered E.viminalis, E. ovata* on poorly drained sites. |
| Dry Sclerophyll Forest | Variable admixture of dry sclerophyll shrubs and sedges. Very sparse understorey on drier slopes and ridgetops. | *E. tenuiramis,E. amygdalina,* some *E. viminalis* and *E. obliqua.* |
| Wet Sclerophyll & Mixed Sclerophyll Forest | Broad-leaved shrubs in true wet sclerophyll phasing into mixture of broad-leaved and sclerophyllous shrubs in mixed sclerophyll. Generally much taller and denser understorey than in dry sclerophyll forest. Variable component of bracken and sedges. | *E. obliqua, E. globulus, E. viminalis, E. regnans.* |
| Higher Altitude Communities | Variable; ranging from broad-leaved wet sclerophyll shrubs to australmontane shrubberies. Broken, rocky terrain common. | *E. delegatensis* phasing into *E. urnigera, E. johnstonii* and *E. coccifera* above about 800 m. |

The lowest total fuel loadings would be found in the sparse, open dry sclerophyll ridgetops where eucalypt litter is often the only fuel available apart from scattered shrubs. This would be closely followed by the open grassy woodlands where although a continuous ground fuel cover of grasses is present in addition to the eucalypt litter bed, the former contributes little to total fuel weight. Such forests would seldom accumulate more than about 15 tonnes per hectare of fuel[35].

[35] McArthur, A.G., 1967; *Fire Behaviour in Eucalypt Forests,* Forestry and Timber Bureau, Leaflet No.107, p.12.

The total fuel loading is however only of interest to the extent that it sets the maximum potential energy which can be released as heat energy under the worst possible conditions. In the practical context, it conveys little about the relative fire danger represented by different vegetation types nor can be used by itself in predicting fire behaviour.

Different vegetation types must be qualified in terms of their relative inflammability, which relates to both ignition probability and the rate of combustion and energy release.

b. Inherent Inflammability

Most of the fuel types in the H.S.F.A. have a significant component of eucalypt litter in common, however differences in inflammability are apparent between understorey types.

The broad-leaved shrubs found in the wet and mixed sclerophyll communities are relatively non-flammable in comparison with the sclerophyll shrubs encountered in the drier communities[36].

The leaves of the latter species have high oil contents and although still requiring an existing ground fire to maintain combustion under most conditions, burn much more readily and with higher rates of heat energy than the broad-leaved shrubs.

Grassy understories by virtue of their very fine dead fuel component are particularly inflammable and exhibit high rates of spread. Severe fire behaviour and localized fire storms were a common occurrence in the woodland fuel type during the 1967 Hobart Fire, largely due to intensive short distance spotting[37].

Understories of sedges and rushes, e.g. *Gahnia grandis, Lomandra longifolia* or of bracken *(Pteridium esculentum)* are also of high inflammability[38] and would closely follow grasses in this respect as well as exhibiting higher fuel loadings.

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36 Mount, A.B., 1964; The Interdependence of the Eucalypts and Forest Fires in Southern Australia, *Australian Forestry*, 28:3.

37 McArthur, A.G., 1968; *The Tasmanian Bushfires of 7th February 1967, and Associated Fire Behaviour Characteristics*, 2nd Australian National Conference on Fire, Sydney, p.37.

38 Mount, A.B., 1965; *The Vegetation as a Guide to Prescribed Burning in Tasmania*, unpublished paper presented at Hobart Conference of Institute of Foresters of Australia.
See also McArthur A.G., 1962; *Fire Behaviour Characteristics of the Longford Fire*, Forestry and Timber Bureau, Leaflet No.91, p.10.

Both wet and dry sclerophyll communities may be directed towards a condition of higher inflammability by too frequent firing. The more normal complement of sclerophyll or broad-leaved shrubs being largely replaced by a cover of grasses, sedges or bracken[39].

The invasion of some exotic shrubs such as gorse and blackberry into disused and formerly cleared land, along roadsides and creek beds and to a small extent within the sclerophyll forests also represents a significant increase in site inflammability[40].

c. Spotting Potential

Although some overlap may occur, in general terms each designated fuel type has its own characteristic array of eucalypt species as shown previously in Table 7.

The relatively high proportion of *E. obliqua* and *E. globulus* in the wet and mixed sclerophyll communities imparts to these communities a high potential for spot fire generation. The ability to fully realise this potential over much of the area however must be somewhat limited due to the restriction of this community type to southerly aspects largely sheltered from the north-westerly winds typical of fire danger weather.

A correspondingly lowest spotting potential would be exhibited by the dry sclerophyll forest in which *E. tenuiramis* is the dominant species. Effective spotting under the influence of strong winds can however still occur from these communities as was evident in the 1967 Hobart Fires where several spot fires appear to have originated from the *E. tenuiramis* slopes above Limekiln Gully Reservoir[41].

Although the importance of the general structure, species composition and inherent inflammability of the understorey and eucalypt overstorey to fire behaviour cannot be ignored, in most instances the fuel moisture content is the critical factor controlling the relative inflammability and spotting potential of the fuel complex as a whole.

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39 See 4.3.3 of this thesis.

40 Ross-Cochrane, G., 1963; Vegetation Studies in Forest-Fire Areas of the Mt. Lofty Ranges, S.A., *Ecology*, 44:1, p.47.

41 See map showing the progress of the Main Hobart Fire in McArthur, A.G., 1968; *The Tasmanian Bushfires of 7th February 1967, and Associated Fire Behaviour Characteristics*, 2nd Australian National Conference on Fire, Sydney, p.47.

Microclimatic variations in rainfall and incident solar radiation associated with the variable topography of the H.S.F.A. inevitably will result in spatial variations in fuel moisture content at any given time.

Table 8 and Figure 13 summarize the theoretical amounts of solar radiation received on clear days relative to aspect and slope for the appropriate latitude of Hobart[42].

Table 8

Solar Radiation (direct and diffuse) Received on Clear Days on Various Slopes and Aspects at Hobart (kj per $m^2$ per day)

| Aspect | Slope | Full Year | Fire Season (Dec-March) |
|---|---|---|---|
| level | - | 20616 | 28525 |
| N | $10^{o}$ | 22908 | 30193 |
| | $20^{o}$ | 24662 | 31139 |
| | $30^{o}$ | 25813 | 31269 |
| NE/NW | $10^{o}$ | 22252 | 29730 |
| | $20^{o}$ | 23424 | 30322 |
| | $30^{o}$ | 24135 | 30343 |
| E/W | $10^{o}$ | 20648 | 28568 |
| | $20^{o}$ | 20379 | 28127 |
| | $30^{o}$ | 19906 | 27352 |
| SE/SW | $10^{o}$ | 19013 | 27352 |
| | $20^{o}$ | 17065 | 25501 |
| | $30^{o}$ | 15042 | 23155 |
| S | $10^{o}$ | 18303 | 26846 |
| | $20^{o}$ | 15548 | 24425 |
| | $30^{o}$ | 12847 | 21316 |

This translates into differential drying climates on northerly, east/west and southerly slopes, the difference increasing with slope gradient. A denser and taller natural vegetation on southerly slopes and a prevailing northerly wind in summer serve to reinforce the difference in drying climate between northerly and southerly slopes.

Westerly slopes although receiving similar amounts of solar radiation as easterly slopes, are likely to experience higher maximum temperatures and hence higher drying rates due to the fact that maximal solar radiation on these slopes occur later in the day when general ambient temperatures are higher (Figure 14).

[42] Developed from the results of a computer analysis kindly provided by A.B. Mount of Forestry Commission, Tasmania.

Figure 13

Solar Radiation Received on Different Aspects and Slopes on Clear Days at Hobart

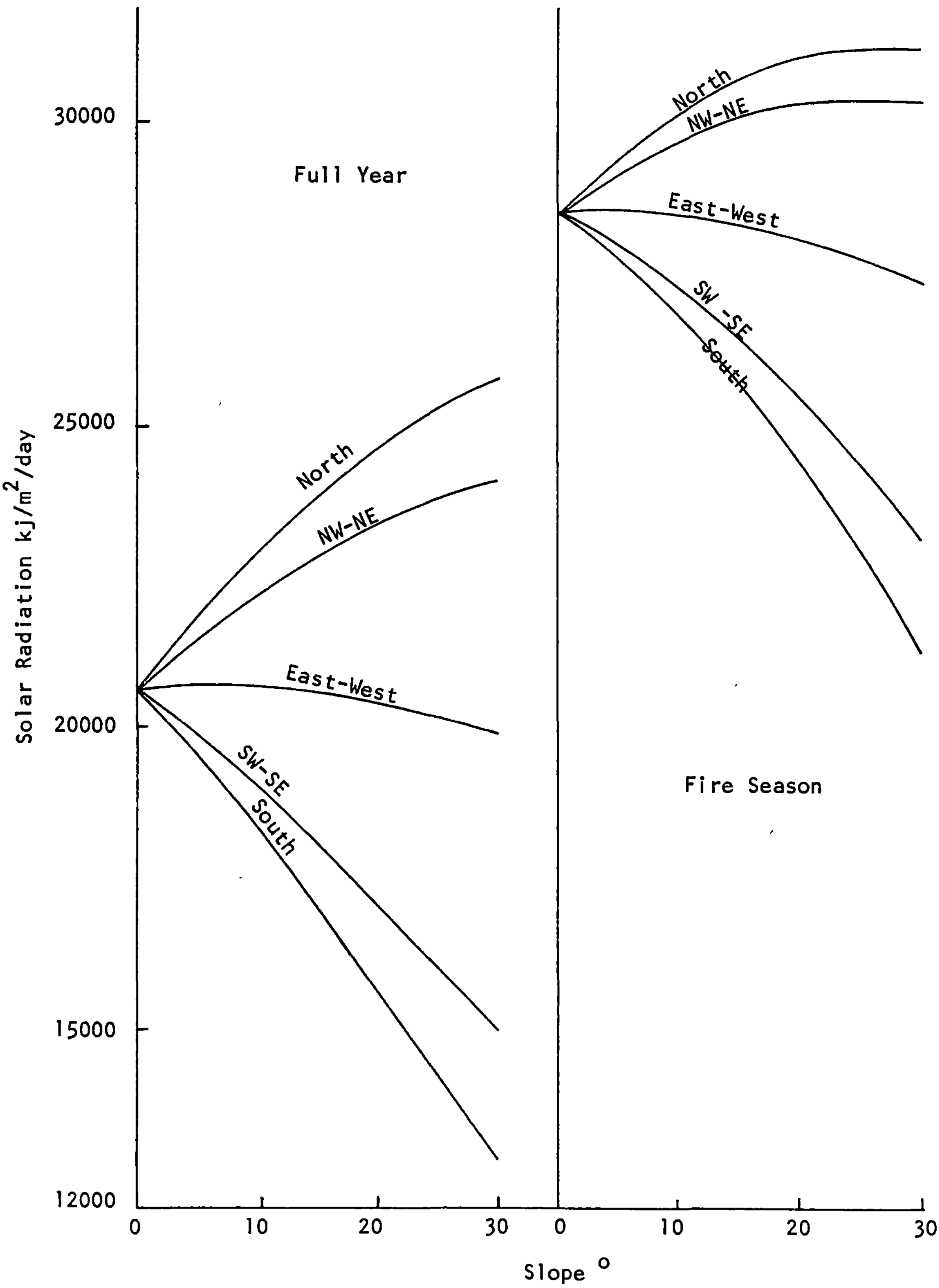
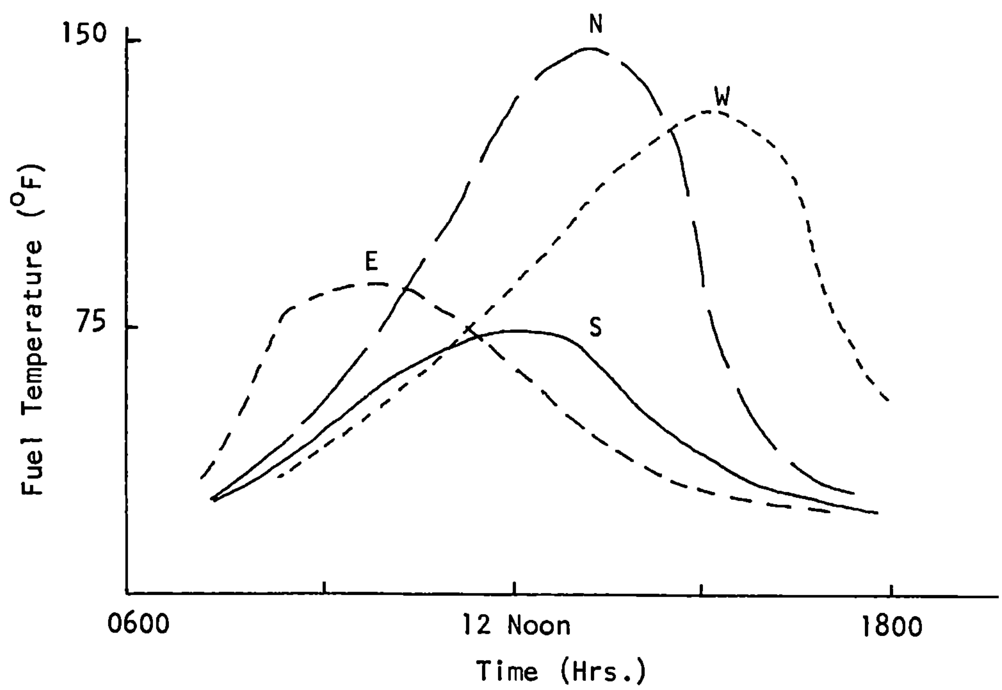


Figure 14

Fuel Temperatures in Summer Relative to Aspect
(From Forests Commission, Victoria, *Fire Control Notes)*




Precipitation over the H.S.F.A. shows considerable variation. Figure 15 shows the annual rainfall distribution and rainfall over the fire season probably shows a similar gradient[43].

To a large extent the spatial variation in moisture availability over the summer and consequent variation in fuel moisture contents is reflected in the relative distribution of wet and dry sclerophyll or woodlands communities.

Nevertheless within a given vegetation type, topographic location is an additional variable which can be used as a guide to relative fuel moisture contents and hence actual fire danger in comparison with the standard Fire Danger Index as determined from observations at the Meteorological Bureau in Hobart.

In terms of relative fuel moisture contents over the fire season, the following scale of fire danger is proposed (Table 9).

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[43] Average rainfall over the months December to March inclusive is consistently around 30% of annual total at three stations in the H.S.F.A. as calculated from rainfall records of Meteorological Bureau, Hobart.

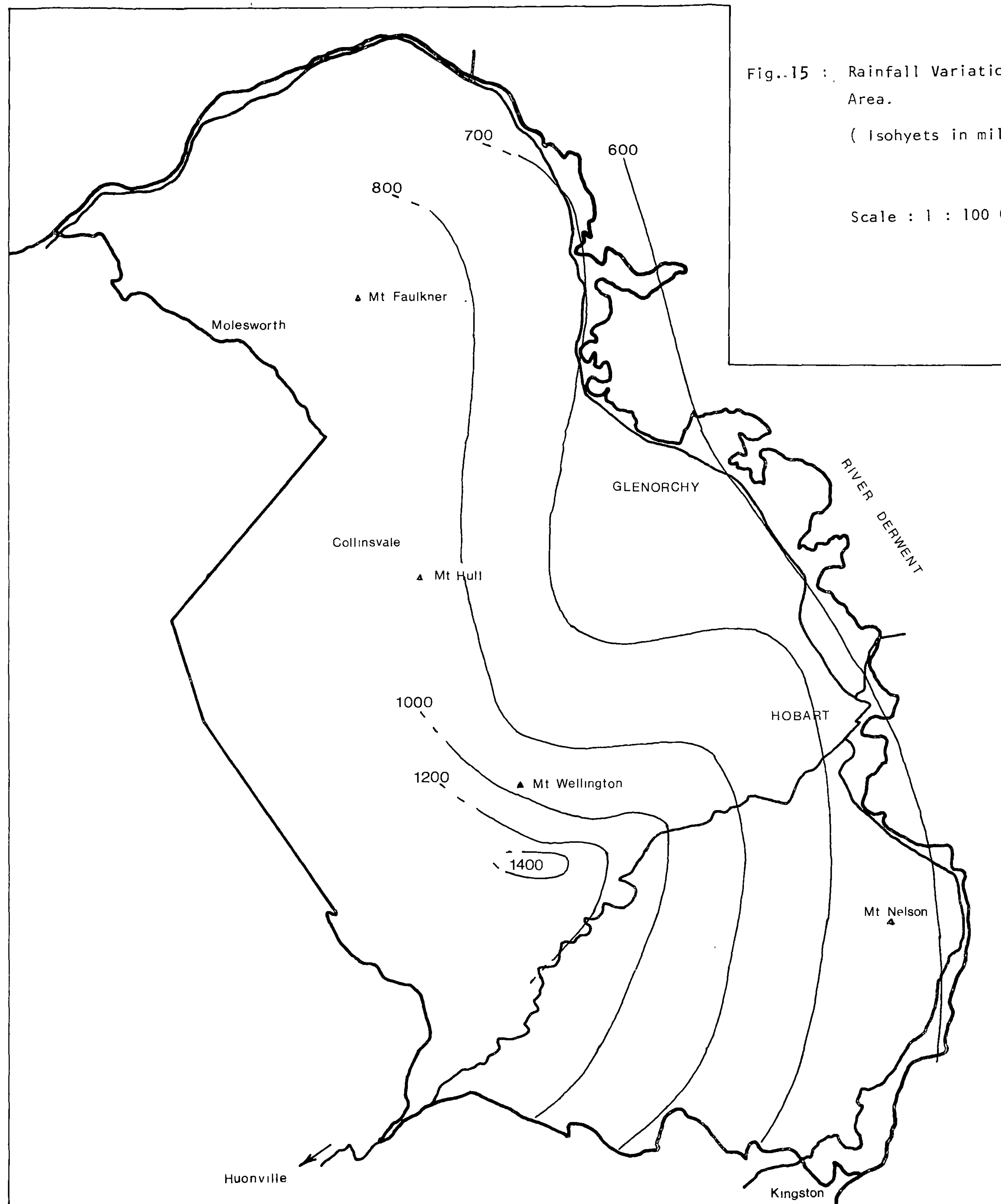


Fig. 15 : Rainfall Variation over the Hobart Special Fire Area.

( Isohyets in millimetres. )

Scale : 1 : 100 000

Table 9

Fire Danger Relative to Vegetation Type and Aspect

| | Aspect | Vegetation Type |
|---|---|---|
| Increasing Fire Danger ↓ | S, S.W., S.E. | Wet sclerophyll |
| | Easterly | Higher Altitude Communities |
| | Westerly | Mixed Sclerophyll |
| | N, N.W., N.E. | Dry Sclerophyll & Woodlands |

For high Soil Dryness Indices[44] the differences in fire danger are likely to be practically insignificant in terms of fire control difficulty, but for most fire season conditions, particularly between the scale extremes, e.g. northern dry sclerophyll slopes versus southern slopes of wet sclerophyll, the difference is likely to be of considerable significance to both ignition probability and subsequent fire behaviour.

Areas of high fire danger are capable of carrying a severe fire on more days during the fire season than the moister sites which may only burn and exhibit fire control difficulties under relatively severe conditions.

### 2.3.4 Surface Wind Variation

The prevailing wind direction over the fire season for the H.S.F.A. is north-westerly, usually being replaced by a cooler and moister sea-breeze from the south-east sometime after 3 p.m.

Owing to the very variable topography over the H.S.F.A., considerable differences in localized wind direction and velocity occur in response to this prevailing wind. These local wind patterns are not known. It may be said, however, that northerly slopes, by virtue of their aspect and the fact that windward slopes experience marked increases in wind velocity[45], may be considered to be especially hazardous in terms of wind exposure and spotting from the upper part of these slopes may be particularly intense.

Wind conditions coupled with the relative dryness of northern and western slopes of dry sclerophyll and woodland would cause fire control difficulties in these areas over a large spectrum of Fire Danger Indices. Figure 16 shows the distribution of such areas over the H.S.F.A.

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[44] Soil Dryness Indices are a measure of seasonal severity and fuel availability. They are derived from daily records of maximum temperature and rainfall.

[45] Geiger, R., 1950; *The Climate Near the Ground*, Harvard University Press.

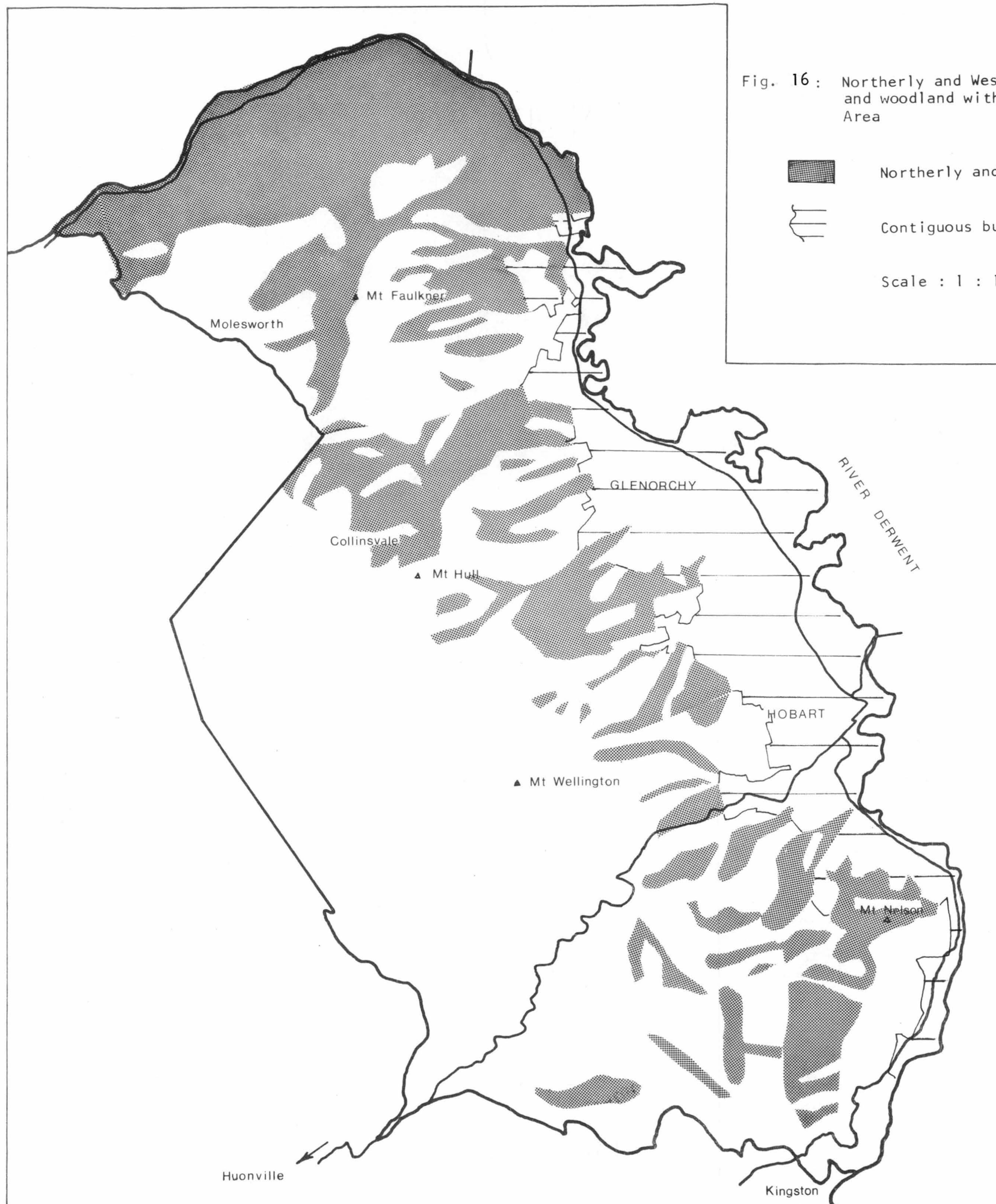


Fig. 16 : Northerly and Westerly Slopes of Dry Sclerophyll and woodland within the Hobart Special Fire Area

## 2.4 Fire Threat to Life and Property

The protection of some asset of value is usually the underlying reason for most fire management programmes. In some areas this asset may be valuable timber, in others it may be the maintenance of particular ecosystems; in the H.S.F.A. the primary aim of the fire management programme is the protection of human life and property. Thus, in developing a fire protection programme for the H.S.F.A., knowledge of the ways in which life and property may be destroyed, or conversely may be protected is a necessity.

In a fire situation there are five possible causes of death that are directly attributable to the fire[46]. A brief consideration of each of these factors will show that the last item, heat regulation failure, is the most significant cause of death in bushfires.

a) burning : although many victims may display burns of varying degrees of severity they are rarely, if ever, the cause of death. Heat regulation failure is usually diagnosed as cause of death, the burns being sustained after death.

b) carbon monoxide or toxic gas poisoning : due to the usually abundant supply of oxygen to a fire, only minute amounts of carbon monoxide are generated in a bush fire, certainly in insufficient quantities to cause poisoning. Greater quantities may be generated in the incomplete combustion of a fire storm, however any person who was in a position to be affected by the gas would have previously succumbed to heat regulation failure.

c) lung searing with superheated gases : medical investigation in America has indicated that dry, heated air at 500°C can be breathed for three minutes without causing damage to mammalian lung tissue[47]. When one considers that the air adjacent to even severe bush fires may only rarely reach such peaks as those considered in the American investigations then this problem may be dismissed as an unlikely cause of fatality.

d) suffocation due to oxygen deficiency and smoke : a deficiency of oxygen in a bushfire is a highly unlikely occurrence as fresh air is

[46] Vines, R.G., 1969; *Proceedings of the Rural Fires Conference, Academy of Science, Canberra, 15-17 July, 1969.* Forestry and Timber Bureau of the Department of National Development and C.S.I.R.O. Canberra.

[47] Moritz, A.R., et al., 1945; The Effects of Inhaled Heat on the Air Passages and Lungs, *American Journal of Pathology,* XXI, pp.311-331.

drawn in to the base of a fire and is always present at ground level. Cheney has shown that combustion cannot be supported when oxygen concentration drops to twelve percent of the available air[48]; at these concentrations life may still be supported. As far as is known no bushfire has ever extinguished itself due to a lack of oxygen. The continual flow of fresh air into a fire also makes death from smoke suffocation unlikely although the irritating, choking effect of smoke may complicate the issue by encouraging irrational behaviour, leading to death from some other cause.

e) failure of body's heat regulation mechanism : if a body absorbs heat at a rate greater than it may dissipate heat then the temperature of that body will rise. The human body temperature may rise a few degrees without suffering any serious ill effects. However, should the body temperature exceed 103°F, collapse and death can be expected. Body temperature will rise 1°F for every 35,000 calories gained[49]. A person close to a fire front will be heated by radiation from the sun, radiation from the fire, convection from the fire, and heat developed within the body due to muscular activity; heat loss is primarily effected by the evaporation of moisture from the skin and lungs. It has been shown that the potential for heat gain from fire radiation is far in excess of any other heat gain or heat loss[50]. Radiant energy is thus the main peril in a wild fire and may well lead to exhaustion, collapse and death[51].

Most survival advice that is distributed, either through fire fighting organizations or mass media, is based upon this knowledge. It states briefly that one should reduce exertion to a minimum and make every effort to shield oneself from radiation. After the passage of the fire front, it should then be possible to move onto burnt ground and safety.

Housing development adjacent to bushland is aggravating the threat posed to habitation by bush fires. The threat posed to an individual house is not necessarily any greater than with less intense development, but the number of houses threatened certainly is. Many residents in fire prone

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48 Cheney, N.P., 1970; *N.S.W. Bush Fire Bulletin;* Winter 1970.

49 Du Bois, E.F., 1936; *Basal Metabolism in Health and Disease;* Bailliere, Tindall and Cox, London.

50 King, A.R., 1962; *The Efficiency of Rural Fire Fighters;* Chemical Research Laboratories Technical Paper No.4, C.S.I.R.O. Melbourne.

51 King, A.R., 1961; Bushfire Sense, *Rural Research No.38,* December 1961, Melbourne.

areas are rather fatalistic about any fire threat to their property and are of the opinion that there is little or nothing that they can do to mitigate the threat or save their property in the event of a fire sweeping through the area. Experience has shown that such is not the case:

> "*One feature of housing losses in these fringe developments was the fact that groups of houses tended to survive in some localities, notably along Waterworks Road.*
>
> *When these situations were investigated, it was found that in all cases a group of people under strong leadership had stayed and fought the fires with garden hoses, wet bags and any other rough and ready means available.*
>
> *... The majority of urban houses which burnt were unattended at the time they caught alight. Even houses with a small separation distance from an adjoining burning house could be saved from destruction by an ablebodied householder and an assistant.*"[52]

The reason why a few people with relatively meagre resources can be so effective in protecting dwellings from a bush fire threat may be explained by looking at the ways in which such dwellings may catch fire.

Houses generally ignite because of air borne embers and burning brands lodging in sheltered parts and there starting a fire which leads to the destruction of the house[53]. There are three principal places where such fires start; under the eaves amongst roof timbers and/or litter; under the floor amongst litter and/or wood etc.; and amongst internal fittings or furnishings when embers may gain entry through an open window or door. Each of these mechanisms of fire initiation are independent of external wall and roofing material and are more dependent on the method of building construction employed; this point is made by Barrow[54] and further confirmed by Vines in investigating the Hobart fires[55].

A substantial degree of protection may be given to houses by ensuring that sparks are prevented from entering. This may be effectively achieved by boxing in eaves, totally enclosing all underfloor areas and placing mesh across ventilators and other openings.

Houses may also be ignited if flames of the main fire make contact with the building; this requires that contiguous combustable litter and/or vegetation exists up to the walls or roof of the building and in many

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52 McArthur, A.G., 1968; *The Tasmanian Bushfires of 7 February, 1967, and Associated Fire Behaviour Characteristics;* 2nd Australian National Conference on Fire, Sydney.

53 Barrow, G.J., 1945; A Survey of Houses Affected in the Beaumaris Fire *C.S.I.R.O. Journal 18*, p.27, Melbourne.

54 Ibid.

55 Vines, R.G., 1967; *Report and Summary of Evidence of the Bush Fire Disaster of 7 February, 1967, Appendix C.;* Parliament of Tasmania, Parliamentary Paper No.16, 1967, Hobart.

modern bush settings this may well be the case. Again ignition points are principally under floors and under eaves and again a fair degree of protection may be achieved by preventing the entry of sparks and further by ensuring that combustible material is cleared from around the house.

As earlier experience has shown dwellings may be saved in a bush fire by promptly extinguishing any points of fire initiation about the house; this job is made easier if a certain amount of preventive maintenance is carried out before hand.

Obviously a large part of this work is the responsibility of the home owner who should remove litter and combustible material from the house (e.g. gutters, underfloor, etc.) and around the house (e.g. shrubs, grass, etc.) as well as making sure that the house is well sealed against the entry of sparks and embers. Such preventive measures along with the provision of a few simple fire fighting implements can go a long way towards ensuring the survival of a house in a bush fire. Of course the success of such a house protection programme is entirely dependent on the resident(s) of the house and their perception of the bush fire risk. If the risk is perceived as being high, protection measures are usually undertaken and vice-versa. However, because of this differing perception and response to the hazard, the hazard that often exists on public land and the need for public education, there exists an area of public responsibility in protecting life and property from bush fires. The execution of this public responsibility may be done by co-operation and/or coercion, the former being the more preferable and the latter being resorted to only on the failure of the former.

Before a person may undertake any effective measures against a bush fire risk, there needs to be an understanding of the risks involved and the established techniques of reducing that risk, hence the need for a public education campaign; this shall be looked at in a little more detail later. In an attempt to reduce fuel loads near dwellings it may be necessary to remove fuel from public lands; this does not necessarily imply broad area hazard reduction burning (see section 5.3). It would also be possible to achieve a considerable degree of "inbuilt" fire protection when constructing new houses and new housing developments if such tasks were undertaken with a bush fire risk in mind. It is not possible to detail here the techniques that may be employed in achieving this inbuilt protection but building regulations could be used to ensure that houses are effectively sealed against the entry of airborne embers and buffer zones could be established between housing and the bush.

## 3. THE PRESENT AMELIORATION SYSTEM

The present fire management programme that is practised in the Hobart Special Fire Area was developed as a result of the 1967 fires. Current hazard amelioration practices fall into four broad areas:

### 3.1 Control of Fires in Fire Danger Period

Prior to 1967 the regulations pertaining to the lighting of fires during fire danger periods was ineffective and unduly complicated[56]. In an attempt to rationalise this situation, two distinct fire restriction periods were created in the Rural Fires Act 1967: a day of total fire ban during which no fires whatsoever shall be lit or maintained in the open air[57], and a fire danger period during which any uncontrolled fire is likely to cause damage and during which persons wishing to burn off should observe certain essential precautions[58]. The dates of fire danger periods are recommended to the Rural Fires Board by municipal fire committees[59], and declarations of same made through the local press, radio and television. During such a period it is illegal for a person to light or allow to remain alight any fire which is not authorised or in accordance with the conditions of a permit granted by a fire permit officer[60]. Fire permit officers are appointed by municipal fire committees[61]; there are eight such officers in the H.S.F.A.

The aim of such a system is to ensure that burning practices are in accord with the prevailing seasonal conditions and that there are a limited number of fires burning at any one time. Should any person wish to start a fire for any reason during a fire danger period, he must make application to a fire permit officer who, after consideration of prevailing conditions, possibly visiting the site, and possibly consulting with other officers, shall decide whether to issue a permit to light a fire. Table 10 shows the numbers of such permits that were issued during the 75/76 fire season in the H.S.F.A.

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56 Chambers, D.M. et al., 1967; *Report of the Select Committee into Fire Prevention and Suppression;* Parliament of Tasmania, Parliamentary Paper no.25, p.20, Hobart.

57 Parliament of Tasmania, 1967; *Rural Fires Act* 1967, Section 44-(1).

58 *Ibid.*, section 36-41

59 *Ibid.*, section 20-(6)(a)

60 *Ibid.*, section 39-(1)

61 *Ibid.*, section 21.

Table 10

Fire Permits Issued in the H.S.F.A. during 1975-76 Season

| Officer | Location | Garden Rubbish | Hazard Reduction |
|---|---|---|---|
| Knott & Bradfield | Hobart | 13 | 26 |
| Glazebrook & Dean | Glenorchy | 1 | 9 |
| Schir | Collinsvale | 8 | 19 |
| McNiece | Taroona | 12 | 6 |
| Wilson | Longley | 2 | 6 |
| Sutton | Molesworth | 5 | 2 |
| | TOTAL | 41 | 68 |

The time and date of any permit issued is reported to the Rural Fires Board headquarters so that any smoke seen by watchers can be classified as legal or illegal. All illegal fires are attended.

## 3.2 Reduction of Fuel Load

The need and technique for hazard reduction burning was expressed by the committee for fire prevention and suppression:

> *"... the necessity for a systematic programme of hazard reduction in the forested land of the mountain and beyond and around the fringe urban developments. As the slopes of Mt. Wellington have a very high scenic and recreational value, hazard reduction by burning would need to be very carefully planned and executed."* [62]

The need for care, planning and investigation with respect to control burning practices have been emphasised on many previous occasions:

> "...(8) *All authorities or persons responsible for hazard reduction must consider the environmental and scenic effects of the various methods used.*
> (a) *There is a need for research into the long term effects on flora, fauna, soil fertility and other values of fires of various intensities and at various frequencies..."* [63]

and again,

> *"Consequently hazard reduction measures on these lands must be carried out with all possible resource values clearly established. Certainly it must be carried out with the greatest of care."* [64]

It is unfortunate that such investigations and planning are obviously non-existent.

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62 Chambers, D.M. et al., 1967; *op.cit.*, p.26.
63 Roberts, T.L. et al., 1973; Committee to Review Various Aspects of Hazard Reduction Burning, Hobart.
64 Chambers, D.M. et al., 1967; *op.cit.*, p.30.

There are four groups of individuals involved with hazard reduction burning within the H.S.F.A.; these are the Rural Fires Board, the Hobart City Council, private property owners and some rural fire brigades.

Private property owners may burn off their land without giving notice or obtaining permission at any time during the year except those periods that are declared fire danger periods; during this period they must first obtain a fire permit before lighting any fire. Owners may execute the burn themselves or, if they feel it too large a job, enlist the help of local Rural Fires Board staff or volunteers. If it is felt by local brigade officers or municipal fire control officers or Rural Fires Board staff that the combustible material on a property poses a hazard to an area, then an abatement notice may be served on that property owner to remove the hazard[65]. Five hundred and thirty one such notices were served in the Hobart City Council area last fire season with a ninety percent voluntary compliance. Whatever the motivation or method adopted in private hazard reduction burning, there is no record kept anywhere of the areas burnt and often little experience possessed by those doing the burn.

The Hobart City Council assume the responsibility for hazard reduction within their council area; the activities undertaken include hazard reduction burning, mechanical hazard removal and hazard removal from private property where necessary. The costs involved in removal of hazards from public lands (excepting council owned land) is charged to the Rural Fires Board. The responsibility of executing the burning programme rests with the mountain park superintendent who decides which areas are to be burnt and when they shall be burnt. Records of approximate areas burnt have been roughly kept since 1971/72, and these areas are shown in Figure 17. This information is not kept by the regional staff of the Rural Fires Board. The area actually burnt by the council varies from year to year depending on meteorological conditions. Table 11 shows the approximate areas burnt by the Hobart City Council in the past five fire seasons.

Those areas outside the Hobart city boundaries are the responsibility of the Rural Fires Board and are managed by the officers of the Derwent region. The decisions on what to burn and when to burn are made by the fire control officer of the

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65 Parliament of Tasmania, 1962; Local Government Act, 1962, section 599-(1)(i)(ii).

Fig. 17 : Areas Burnt by Hobart City Council Since 1971 / 72.

Burnt once

Burnt twice

Scale : 1 : 100 000

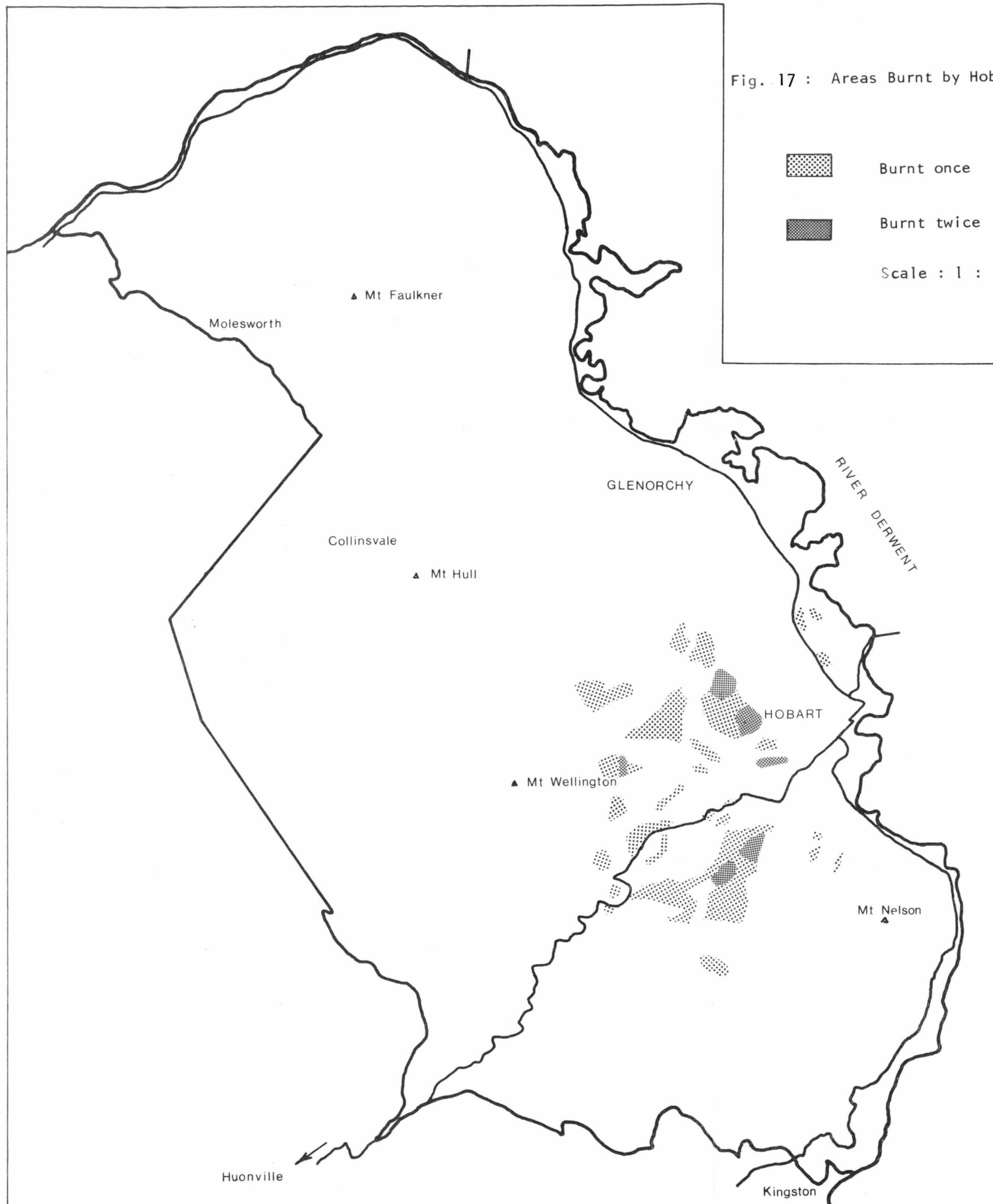

Table 11

Approximate Areas Burnt by Hobart City Council 71/72 - 75/76 incl.

| Fire Season | Approx. area burnt (hectares) |
|---|---|
| 71/72 | 250 |
| 72/73 | 110 |
| 73/74 | 70 |
| 74/75 | 70 |
| 75/76 | 180 |

region. The area burnt annually depends primarily on meteorological conditions. A record of the areas burnt has been kept since 71/72 and is shown on Figure 18, the total areas burnt each season are shown in Table 12.

Table 12

Approximate Areas Burnt by Rural Fires Board 71/72 - 75/76 incl.

| Fire Season | Approx. area burnt (hectares) |
|---|---|
| 71/72 | 410 |
| 72/73 | 1080 |
| 73/74 | 540 |
| 74/75 | 600 |
| 75/76 | 1200 |

Local brigades control burn within their own areas. This achieves the aim of fuel reduction as well as providing training for local brigade members. Such burns usually cover only small areas with the decision of what and when to burn resting with the brigade captain. The extent to which a brigade becomes involved in this activity varies throughout the area with some brigades doing none at all. Recording of areas burnt also varies between brigades and an attempt to collect this information from different brigades proved difficult or impossible. The regional office of the Rural Fires Board has no record of these burns.

Broad acre burns are usually contained between trails and/or natural boundaries and are lit by a gang of men walking through the area with drip torches. The fires thus started do not necessarily cover the entire area and hence burn all the available fuel. The success of such a burn depends to a large extent on the diligence of the lighters and the prevailing meteorological and fuel conditions.

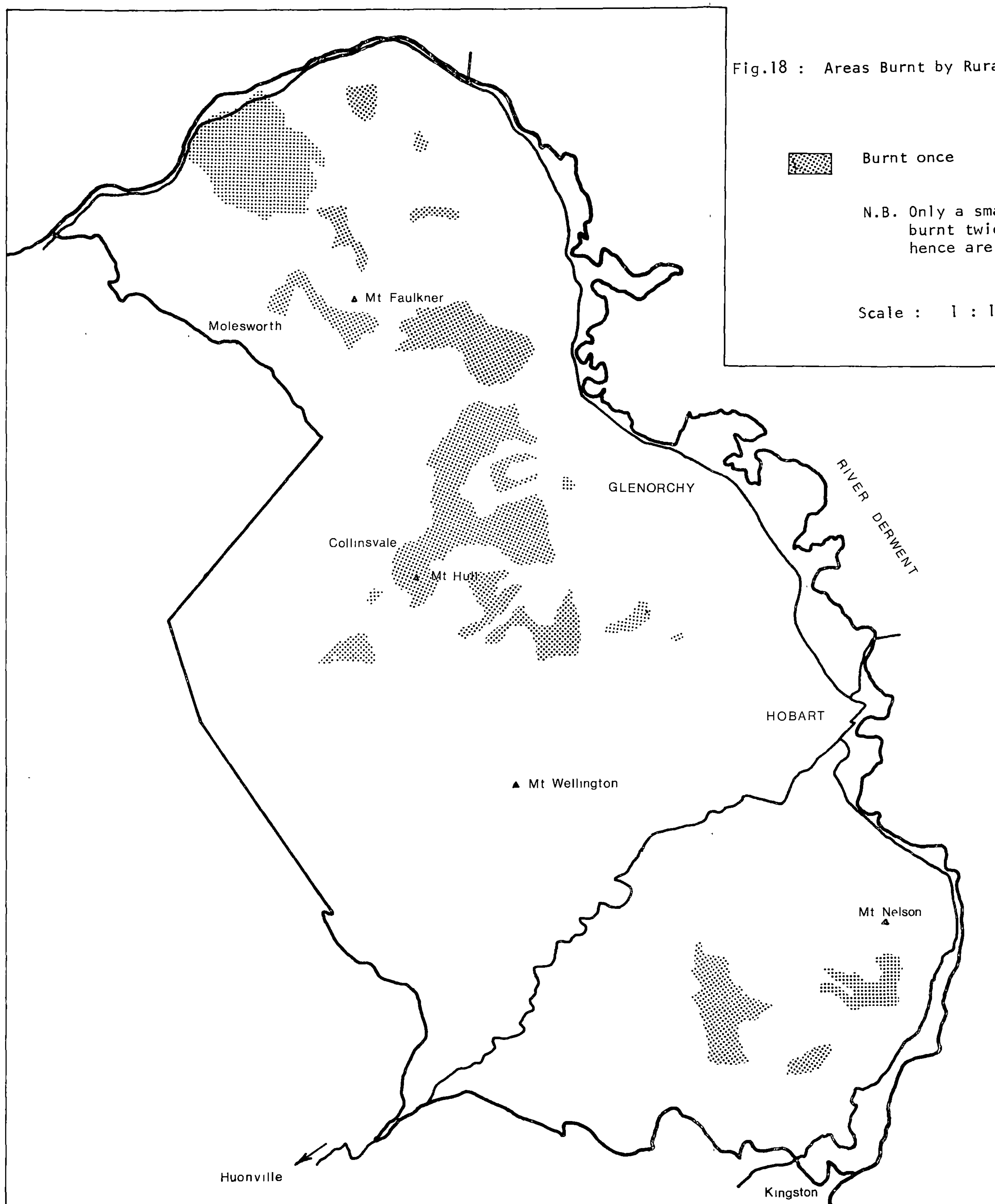


Fig.18 : Areas Burnt by Rural Fires Board Since 1971 / 72.

There are a large number of organizations and individuals involved with hazard reduction burning in the H.S.F.A., and to a certain extent they work independently of each other. This is not consistent with planning of hazard reduction burning. Any planning that is done is done independently within the groups and relates only to the next fire season. If the desirable aims of investigation and careful planning are to be achieved, there would need to be a considerable change from present practices.

### 3.3 Suppression of Outbreaks

This work may be considered as occurring in three main areas; detection, access and suppression. Each of these shall be considered in turn.

#### 3.3.1 Detection

Fires need to be detected before they can be suppressed.

> *"At a fire danger index of 100, probably the only chance of controlling a fire in heavy fuel concentrations occurs in the first 15-30 minutes of its life. Beyond this period, the fire must be considered uncontrollable despite a maximum suppression effort."* [66]

To facilitate the early detection and exact location of a fire within the H.S.F.A., there are a number of lookouts located within the area and others that look into the area. The location, communication facilities and manning responsibility of each of these stations is listed below.

a) Mt. Faulkner - Lookout cabin located just below the peak of Mt. Faulkner. Radio communication to R.F.B. or Derwent region headquarters. The decision to man the lookout is made by the regional officer of the Derwent region.

b) Chimney Pot Hill - Use is made of the microwave communication tower located on the top of Chimney Pot Hill. Bearings may be taken on fires and the information radioed to the Hobart City Council Mountain Park depot. Manning of the lookout is determined by the Hobart City Council's mountain superintendent.

c) Herringback - Lookout cabin located on summit of Herringback. Radio communication to R.F.B. headquarters or Huon region headquarters. The decision to man the lookout is made by the regional officer of the Huon region.

d) Rosny Fire Station - Reports and bearings may be obtained from the hose drying tower of the Rosny fire station. The station is manned all the time but only reports when directly requested; such requests

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[66] McArthur, A.G., 1967; *Fire Behaviour in Eucalypt Forests*, p.22; Forestry and Timber Bureau, Leaflet no.107, Canberra.

would be initiated by the regional officer of the Derwent Region. Such requests have never yet been made.

e) Mt. Wellington - A mounting for an azimuth is located just below the organ pipes on Mt. Wellington. If the mountain park superintendent of the Hobart City Council considers that conditions warrant it, a man is located at this station. Communication is made via car radio to the mountain park depot. This location is very rarely manned.

f) Black Hills - Lookout cabin at Black Hills. Under the control of the regional officer of the Derwent region. The location has never been manned due to difficult logistics and a poor field of view.

Those lookouts under the control of the Rural Fires Board are manned on days during the fire danger period unless such days are obviously of low risk. The final manning decision rests with the relevant regional officer concerned who primarily uses personal judgement in making such a decision. The same practices apply to the H.C.C. watches where the manning decisions are made by the mountain superintendent.

These watches can see considerable areas outside the H.S.F.A., yet several areas in the H.S.F.A. are out of view of all watches (Figure 19). The gap around Collinsvale is of particular concern. The area is relatively large and it is likely that on a severe fire danger day a fire initiated in this area may threaten the greater Hobart area. It is difficult to say how long it would take before an alarm would be raised in this area; it is sufficient to say that at this stage any immediate detection and exact location would rely upon local information.

3.3.2 Access

Prior to 1967 there was very limited vehicular access to the timbered areas surrounding Hobart. Such lack of access obviously limited effective suppression:

> *"The nature of the country where the fire was burning was such as to render impossible the entry of any vehicle beyond a point several hundred yards past Neily's quarry."*[67]

> *"The dominant consideration with respect to the Limekiln Gully fire appears to have been that it was burning in rough country impossible of access to vehicles ...."*[68]

Among the activities that succeeded the fires of 1967, the need to pro-

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[67] Chambers, D.M. & Brettingham-Moore, G.G., 1967; *Report and Summary of Evidence of the Bush Fire Disaster of 7 February 1967;* Parliament of Tasmania, Parliamentary Paper No.16, 1967, Hobart.

[68] *Ibid.*

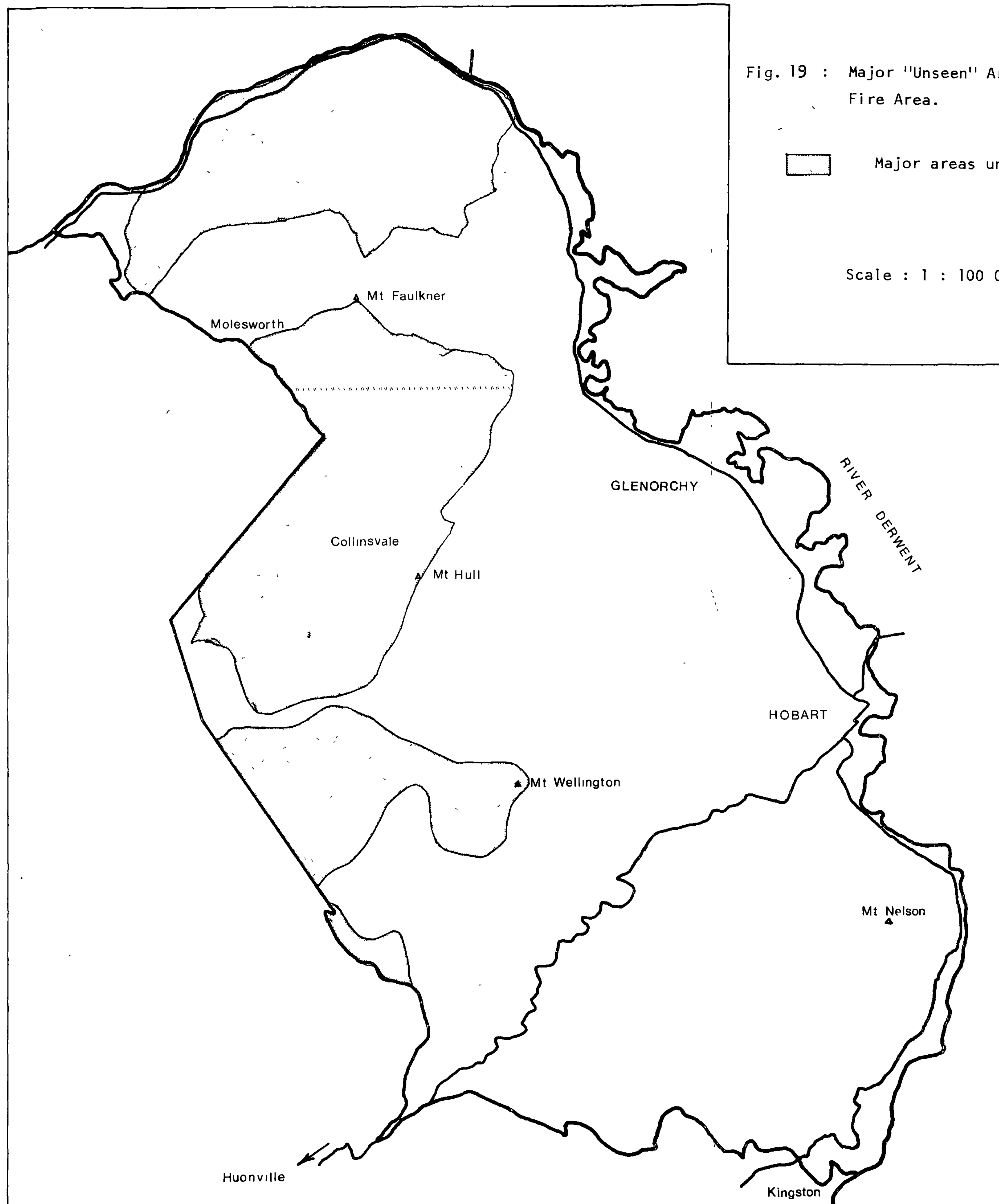



Fig. 19 : Major "Unseen" Areas Within the Hobart Special Fire Area.

vide access and break the area up into manageable sections was given a high priority.

> *"Many special fire control problems exist in this Hobart fringe area ... it is perhaps relevant to list some of the more urgent which have been submitted to and accepted by the committee ...*
> *(i) ...*
> *(ii) The need for more access tracks and trails trafficable to 4-wheel drive vehicles;*
> *(iii) ..."* [69]

The techniques used to provide this needed access were simply the opening up of abandoned tracks and the construction of new tracks. The perceived desirability of undertaking this task as quickly as possible may be illustrated by reference to the monies spent on trail construction in the years following 1967 (Table 13).

Table 13

Expenditure by Rural Fires Board on Fire Trail Construction 68/69 - 73/74 [70]

| Fiscal Year | Total Expenditure on Trail Construction $ | % of total H.S.F.A. Expenditure |
|---|---|---|
| 68/69 | 10,005 | 33 |
| 69/70 | 13,753 | 27 |
| 70/71 | 15,798 | 24 |
| 71/72 | 7,158 | 13 |
| 72/73 | 2,675 | 4 |
| 73/74 | 2,967 | 4.5 |

Location of trails was determined on a broad scale by the regional staff employed at the time and approved by the Special Fire Area committee. However, the exact location of any proposed trail rested with the driver of the bull-dozer, who achieved the broadly stated goal by whichever means proved practical or expedient at the time. The network of tracks throughout the area is now largely completed and is shown in Figure 20.

The work of the Rural Fires Board in this area is now primarily one of maintenance. The trails are frequently driven to make sure they remain open. However, the main problem of maintenance is one of drainage and erosion. The adequate correction of these problems is hampered by a general shortage of funds.

69 Chambers, D.M. et al., 1967; *Report of the Select Committee into Fire Prevention and Suppression;* Parliament of Tasmania, Parliamentary Paper No.25, 1967, Hobart.

70 Parliament of Tasmania; *Rural Fires Board Annual Report;* Nos. 1-6 incl.

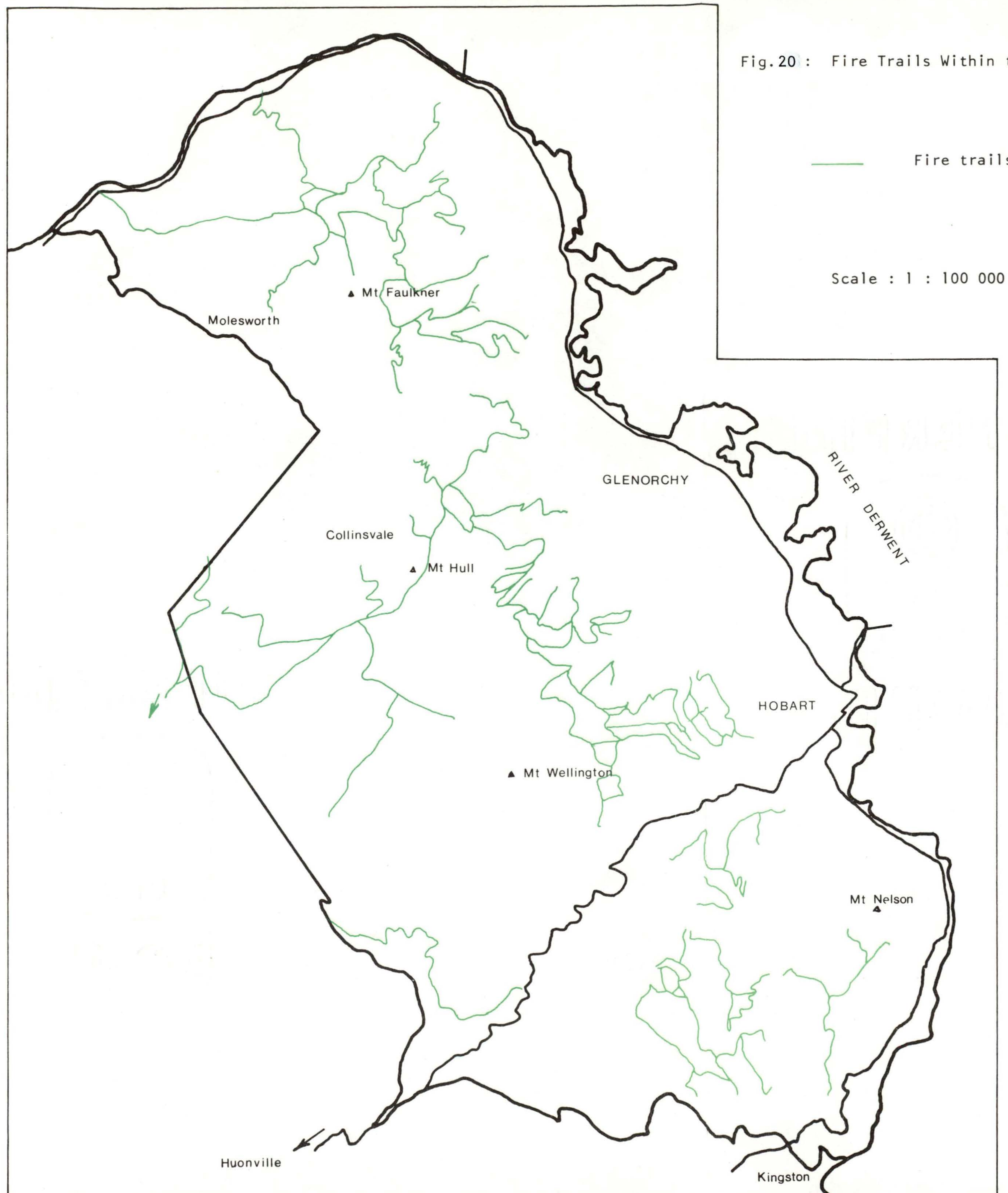



Fig.20 : Fire Trails Within the Hobart Special Fire Area.

Fire trails.

Scale : 1 : 100 000

### 3.3.3 Suppression

The principal suppression force within the H.S.F.A. is provided by volunteer rural fire brigades. Specific provision was made in the Rural Fires Act 1950 for the formation of rural fire brigades, however between 1951 and 1967 very little progress had been made in this direction. As of June 1967 only 48 rural fire brigades had been formed throughout Tasmania, one of these being located within the H.S.F.A. at Collinsvale. This lack of preparedness was commented on by the Fire Prevention and Suppression committee[71] and recommendation made to encourage and assist the formation of rural fire brigades[72].

The post 1967 effort to establish brigades had considerably more success than the pre-1967 efforts; as at the 30 June 1975 there existed 335 brigades and 8,152 personnel available throughout the state. Out of this total those shown in Table 14 were located within the H.S.F.A.

Table 14

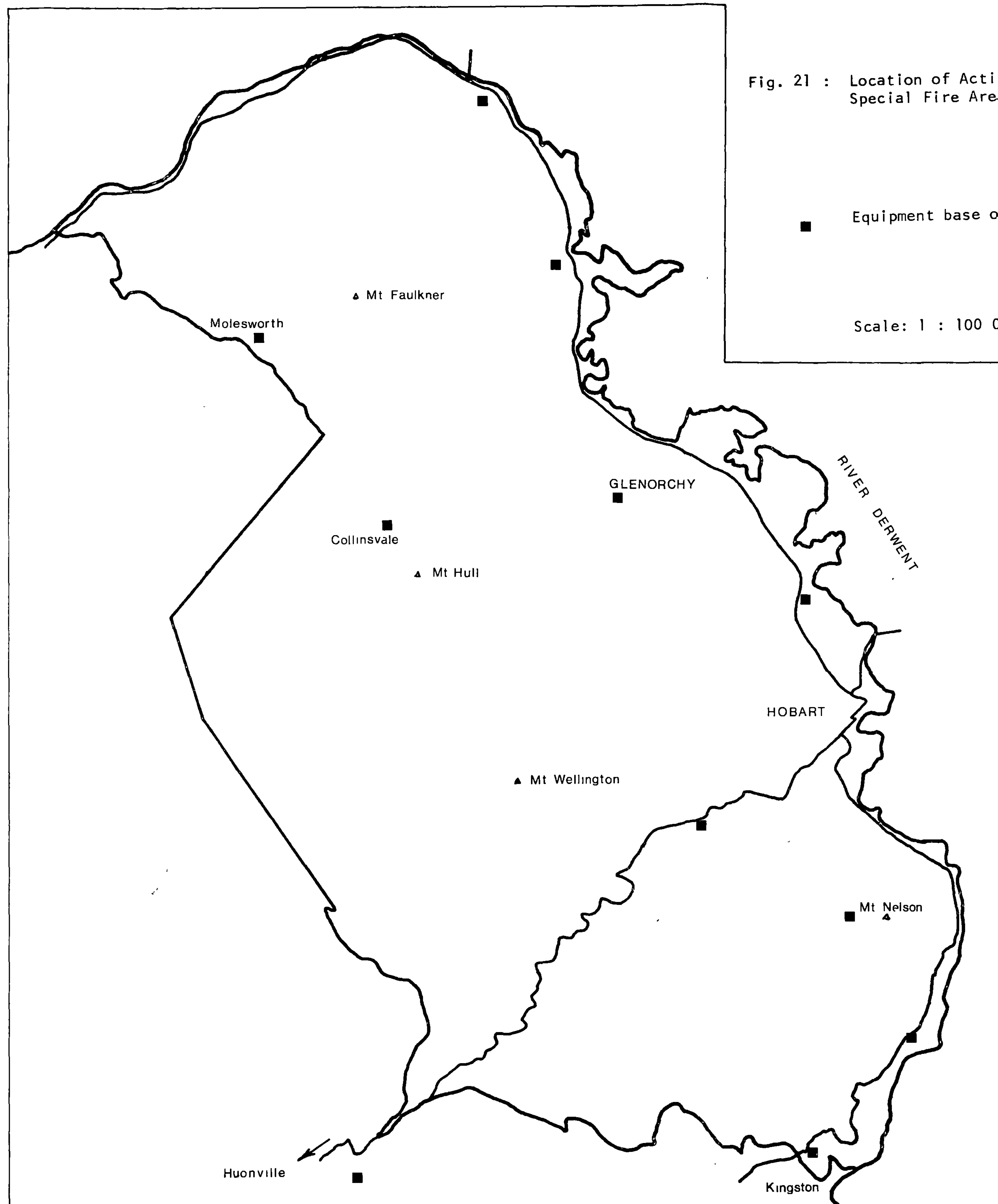
Rural Fire Brigades available within the Hobart Special Fire Area[73]

| Rural Fire Brigade | Strength |
|---|---|
| Glenorchy No.1 | 9 |
| Glenorchy No.2 | 9 |
| T.G.R. Claremont | 9 |
| T.G.R. Hobart | 7 |
| Glenorchy City Council | 7 |
| Claremont | 28 |
| Collinsvale | 34 |
| Four Wheel Drive Club | 15 |
| Granton | 11 |
| H.C.C. Cleary Gates | 53 |
| H.C.C. Mountain Park | 10 |
| H.C.C. Reserves Dept. | 22 |
| Royal Tasmanian Botanical Gardens | 27 |
| Marlyn Road - Strickland Avenue | 16 |
| Nelson | 30 |
| Ridgeway | 9 |
| Kingston | 53 |
| Longley | 35 |
| Taroona | 23 |
| Molesworth | 26 |

The location of active brigades is shown in Figure 21.

71 Chambers, D.M. et al., 1967; *op.cit.*, p.15.
72 *Ibid.*, p.35
73 Parliament of Tasmania, 1975; *Rural Fires Board Seventh Annual Report*, pp.65-70. At the present time not all of these brigades are active; some have been deregistered and others are registered for the workers' compensation afforded to the persons involved.

Fig. 21 : Location of Active Brigades within the Hobart Special Fire Area



A listing of total tanker strength gives an indication of equipment availability in a fire situation (Table 15).

Table 15

Tankers available within the Hobart Special Fire Area[74]

| Vehicle Type | Number | Capacity (galls.) |
|---|---|---|
| Heavy 4WD | 3 | 750 |
| Medium 4WD | 5 | 450 |
| Light 4WD | 6 | 200-250 |
| Trailer Units | 2 | 150-250 |

Manpower and equipment availability give an indication, but by no means a total picture of effectiveness in suppression. Morale and motivation within brigades are also important. Such qualities are, of course, difficult of definition and may be described here only in extremes. Those brigades strong in motivation are largely self maintaining and perform functions beyond the limited responsibility of attending fires. These include fund raising activities, community education and training programmes. Such units are inevitably under the control of a strong brigade captain and work together well as an efficient fire fighting team. The other extreme consists of those brigades where the brigade members would not recognise other brigade members should they meet in the street. Both extremes exist within the H.S.F.A.

### 3.4 Education Programme

The educational activities of the Rural Fires Board fall into two broad areas. Firstly the area of general public education:

> *"Every effort should be made to bring about a greater public awareness of the dangers of fire and the measures that can and ought to be taken to prevent it ..."*[75]

and secondly the area of brigade member training:

> *"There should be more intensive training for members of rural fire brigades."*[76]

The Rural Fires Act 1967 legislates in a general way for such educational activities:

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[74] Crawford, A., 1976; personal communication from Regional Officer (Derwent).

[75] Chambers, D.M. et al., 1967; *Report of the Select Committee into Fire Prevention and Suppression;* Parliament of Tasmania, Parliamentary Paper No.28, 1967, p.34, Hobart.

[76] *Ibid.*, p.35.

"12. *Subject to the directions of the Minister, the functions and duties of the Board are - ...*
*(c) to make investigations into the use of fire in areas, to instruct the public in the wise use of fire, to disseminate information regarding fire protection measures and matters incidental thereto; ...*
*(e) to encourage and assist in the formation, development and improvement of rural fire brigades and to assist in the training of, and the provision of equipment for use by members of these brigades; ...*"[77]

As well as publicity campaigns operating through the media, the Board maintains attendance at a number of agricultural shows, with equipment displays and distribution of pamphlets. Roadside gallows signs warning motorists of the dangers of fire, and fire danger signs that indicate current fire danger ratings are installed and maintained by the Rural Fires Board. Most of this work concerning public education is undertaken by a commercial advertising agency, except for those activities requiring the immediate involvement of an officer of the Board, for example, visiting schools or addressing public groups.

The need for general public education is undoubted but the effectiveness and direction of the present programme needs consideration. As there are some sections of the area under study that are under greater fire risk than others, it is obviously the residents of these high fire risk areas who are in greatest need of education. As far as could be determined, such a concentration of effort does not occur.

It is one of the duties of a regional fire control officer to promote the formation of rural fire brigades and supervise the training of members of rural fire brigades[78]. The training programme for a particular brigade is determined by the regional officer and the brigade captain and depends to a large extent on the motivation that exists within the brigade. If a brigade increases in size and becomes sufficiently self motivated, it may initiate a self training programme and actually extend its activities into the area of community education.

Fire schools and conferences are held throughout the state and throughout the year and cover activities such as map reading, radio use, rescue techniques and general fire behaviour. These schools are attended by regional fire officers and brigade members.

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[77] Parliament of Tasmania, 1967; *Rural Fires Act 1967*, section 12.
[78] *Ibid.* Section 16-(4)(a), 16-(4)(b)(i).

# 4. HAZARD REDUCTION BURNING[79]

A large part of the fire protection strategy adopted in the H.S.F.A., is directed towards the reduction of fuel levels on a broad area basis by controlled burning. The desirability and necessity of such a programme of hazard reduction has been a focus for considerable controversy, the resolution of which must ultimately lie in an understanding of the broad rationale behind hazard reduction burning together with its possible environmental implications.

## 4.1 The Rationale Behind Hazard Reduction Burning

Of all the factors affecting fire behaviour, only the fuel complex is practically amenable to modification by man. The importance of the quantity of available fuel in a given fuel type to fire behaviour has quite naturally led to the practice of reducing this fuel quantity in order to lessen the severity of fires and to render them more amenable to control under all weather conditions (Figure 22 ). Fires burning with intensities up to 3500 kw/m are amenable to control but if the intensity rises much beyond this figure the chances of control diminish rapidly.[80]

Fuel reduction can be achieved by methods other than burning. Practical methods such as raking, mowing, grazing, ploughing, pulverizing, and bulldozing exist which may be more desirable or appropriate in some circumstances but are mainly restricted in their application by economic and terrain constraints. Herbicide spraying has been suggested as another means of reducing shrub fuel levels. However, in the short term, dead shrubs are likely to constitute a much higher hazard than live shrubs and there appears little to recommend in such a method even ignoring possible ecological effects resulting from the release of herbicide to the environment.

Burning remains the only means of fuel reduction which is not restricted by terrain constraints and which enables large areas to be dealt with at a minimal cost.

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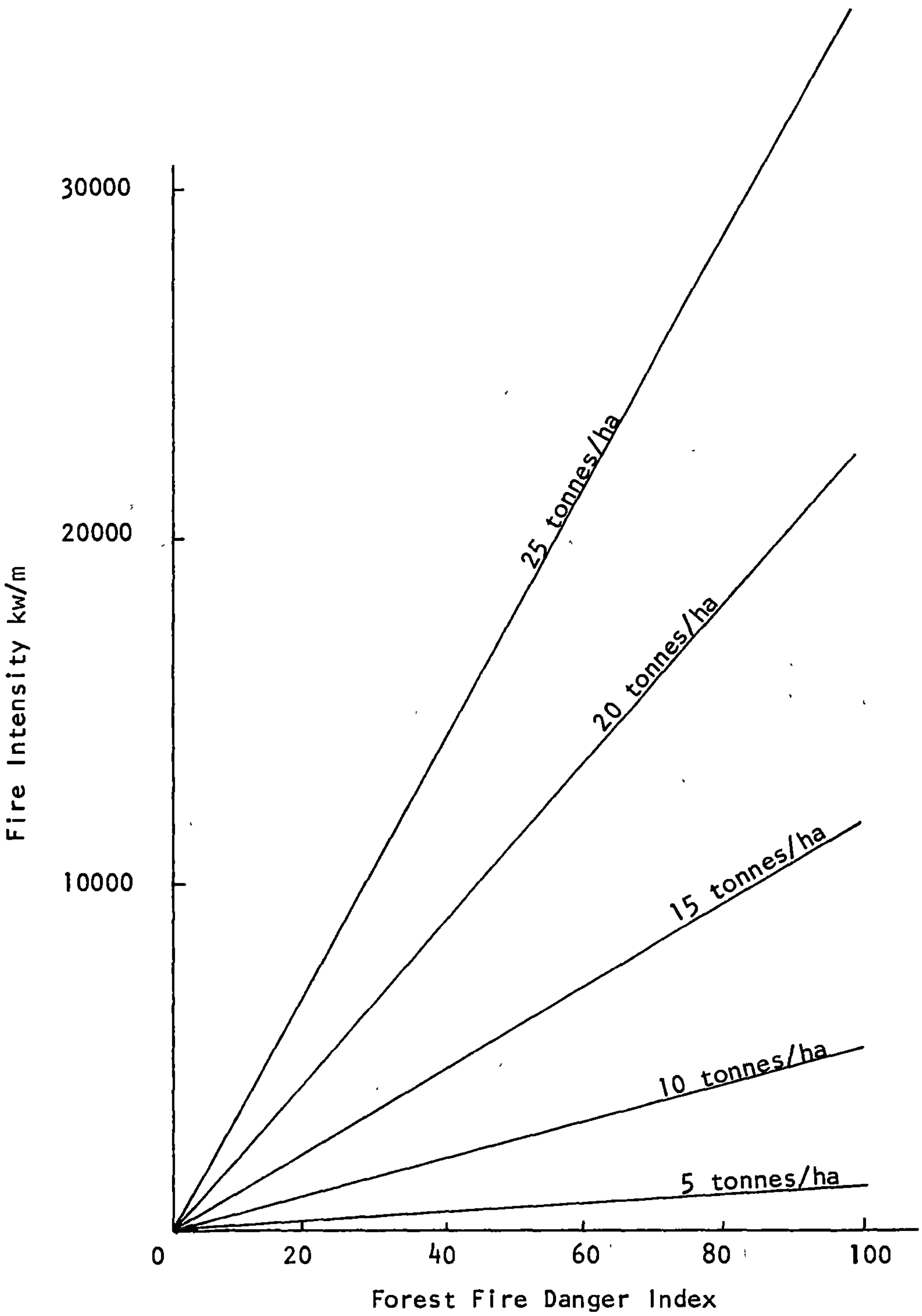
79 Hazard reduction burning falls into the general category of prescribed or control burning. These terms are used to describe the planned application of fire to a plant community. All have been used to describe the practice of fuel reduction by burning, however, hazard reduction burning appears to be the most appropriate as it completely clarifies the management objective.

80 Vines, R.G., 1975; Bushfire Research in C.S.I.R.O., *Search, Vol. 6 No. 3*, p.76.

Figure 22

Fire Intensity Relative to Fuel Loading and Fire Danger Index (Derived by reference to the McArthur Forest Fire Danger Index and the expected fire behaviour of fires burning in the specific forest type to which the index applies).



## 4.2 The Technique

In terms of the spatial distribution of hazard reduced areas, two basically different strategies in its application can be identified. The first of these strategies aims at the reduction of fuel in strategic positions mainly in the form of firebreaks around areas required to be protected such as houses or other property of value. The second strategy, born out of the continued frustration from the disconcerting ability of fires in eucalypt fores to spot freely across relatively narrow firebreaks, involves the reduction of fuel over broad areas causing a mosaic of fuel reduced units to be developed over the entire area thereby facilitating fire control generally and giving 'defence in depth'

Any particular fire protection scheme is likely to exhibit both of the above strategies with variable degrees of expression.

It is interesting to note that the strategy of area hazard reduction burning was initially developed for use in commercial forests where the protected property is in fact spatially continuous. Thus damaging wildfires are detrimental to timber values wherever they occur. The direct extrapolation of this strategy in its entirety to the protection of property not spatially continuous such as houses, is, at least in principle, less justified.

All proponents of hazard reduction burning emphasize that the technique except perhaps on the small firebreak scale, should never be considered as a 'scorched earth' policy.[81]

Hazard reduction burning in its ideal form aims to reduce fuel accumulation to levels consistent with reasonable ease of control by fire suppression crews in the event of a subsequent wildfire without causing anything but absolute minimal damage to the soil, the trees and wildlife. Excessive scorching of the tree overstorey crowns is decidedly counterproductive as a subsequent leaf fall of up to 7.5 tonnes per hectare can occur;[82] not to mention the undesirability of scorched foliage in terms of aesthetics.

Such ideal burns should have fire intensities between 45-175 kw/m giving scorch heights less than 5m. Guidelines to follow in hazard reduction

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81 McArthur, A.G., 1962; *Control Burning in Eucalypt Forests;* Forestry and Timber Bureau Leaflet No.80; p.9.

82 Foster, E., 1976; *Bushfire: History, Prevention and Control;* A.H. & A.W. Reed Pty. Ltd., Sydney-Wellington-London, p.131.

burning operations to assist in meeting these criteria have been available for many years.[83] Modification to these guidelines are necessary however in fuel types dissimilar to those for which the guidelines were developed.[84]

This ideal has not been met in practice in a significant proportion of hazard reduction burns carried out in the H.S.F.A. as illustrated in Plate 2. Plate 3 shows a burn closer to ideal with very little scorching.

Irrespective of the broader environmental effects of hazard reduction burning, it must be emphasized that hazard reduction burns of the type shown in Plate 2 are decidedly not acceptable under any circumstances. The fact that these "too hot burns" were carried out by "well intentioned people who had insufficient knowledge and experience" is small consolation and merely emphasizes that the technique of hazard reduction burning is not an easy one to properly implement and hence much more care and attention to the scientific basis of fire behaviour is needed in field implementation.

The time interval between successive hazard reduction burns on an area designated for fuel management is ultimately determined by a consideration of the fuel levels considered maximal in terms of wild fire control, what can be practically achieved, and the rate at which fuel accumulates at the site.

Table 16 illustrates the calculated fire intensities at the head fire for fires burning through dry sclerophyll forest as defined by McArthur relative to Fire Danger Index, fuel loading and slope. This Table shows that to ensure fires are controllable on most slopes encountered in the field under the most severe conditions it is necessary to maintain fuel levels below about 5 tonnes per hectare, which is an unrealizable goal under most forest conditions.[85]

The technique of area hazard reduction burning can then hardly be regarded as a panacea to the fire control problem. Uncontrollable fires as in the 1967 Hobart Fires could still have occurred under these very

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83 McArthur, A.G., 1962; *op.cit.*

84 The guidelines strictly apply to a dry sclerophyll fuel type without a significant grassy component and with a relatively sparse shrub layer about 1m in height.

85 See Roberts, T.L. (Chairman), 1973; *A Report to the Honourable the Premier by a Committee Formed to Review Various Aspects of Hazard Reduction Burning*, p.9.

Plate 2: Crown scorch in a less than ideal hazard reduction burn

Plate 3: Hazard reduction burn showing little crown or bole scorching

Table 16

Fire Intensity of Head Fire for Various Combinations of Fire Danger, Fuel Loading and Slope in Dry Sclerophyll Forest (kw/m).
(Developed from McArthur Forest Fire Danger Meter and the relationship between intensity (I), fuel loading (W), and rate of spread (r).
I=Hwr (H, the heat of combustion of fuel was assumed to be 16 KJ/gram or 3800 calorie/gram).

| Fire Danger Index | Fuel Loading (tonnes/ha) | level | $5^o$ | $10^o$ | $15^o$ | $20^o$ |
|---|---|---|---|---|---|---|
| 15 | 5 | 200 | 280 | 400 | 560 | 800 |
| | 8 | 510 | 710 | 1020 | 1430 | 2040 |
| | 10 | 810 | 1130 | 1620 | 2270 | 3240 |
| | 12 | 1170 | 1640 | 2340 | 3280 | 4680+ |
| 20 | 5 | 370 | 380 | 540 | 760 | 1080 |
| | 8 | 690 | 970 | 1380 | 1930 | 2760 |
| | 10 | 1030 | 1440 | 2060 | 2880 | 4120 |
| | 12 | 1480 | 2070 | 2960 | 4140+ | 5920+ |
| 30 | 5 | 380 | 530 | 760 | 1060 | 1520 |
| | 8 | 970 | 1360 | 1940 | 2720 | 3880+ |
| | 10 | 1520 | 2130 | 3040 | 4260+ | 6080+ |
| | 12 | 2190 | 3070 | 4380+ | 3160+ | 8760+ |
| 40 | 5 | 510 | 710 | 1020 | 1430 | 2040 |
| | 8 | 1300 | 1820 | 2600 | 3640+ | 5200+ |
| | 10 | 2020 | 2830 | 4040+ | 5660+ | 8080+ |
| | 12 | 2910 | 4070+ | 5820+ | 8150+ | 11640+ |
| 60 | 5 | 760 | 1060 | 1520 | 2130 | 3040 |
| | 8 | 1950 | 2730 | 3900+ | 5460+ | 7800+ |
| | 10 | 3000 | 4200+ | 6000+ | 8400+ | 12000+ |
| | 12 | 4320+ | 6050+ | 8640+ | 12100+ | 17280+ |
| 80 | 5 | 1010 | 1410 | 2020 | 2830 | 4040+ |
| | 8 | 2590 | 3630+ | 5180+ | 7250+ | 10360+ |
| | 10 | 3990+ | 5590+ | 7980+ | 11170+ | 15960+ |
| | 12 | 5750+ | 8050+ | 11500+ | 16100+ | 23000+ |

\+ definite control difficulties

severe conditions in areas subject to all but the more recent hazard reduction treatment.[86]

No informed person actually views hazard reduction burning as a panacea to fire control. The accepted view is that the technique provides for a reasonable level of fire control under most burning conditions and in this context fuel loadings of around 7 or 8 tonnes per hectare are considered as sufficiently low for most purposes.[87]

[86] Many prescriptions for hazard reduction burning recommend that fuel quantities of this order should remain after a burn to afford protection to the soil and in any case many sites would regain such fuel levels in less than two years.

[87] Foster, E., 1976; *op.cit.*, p.128.

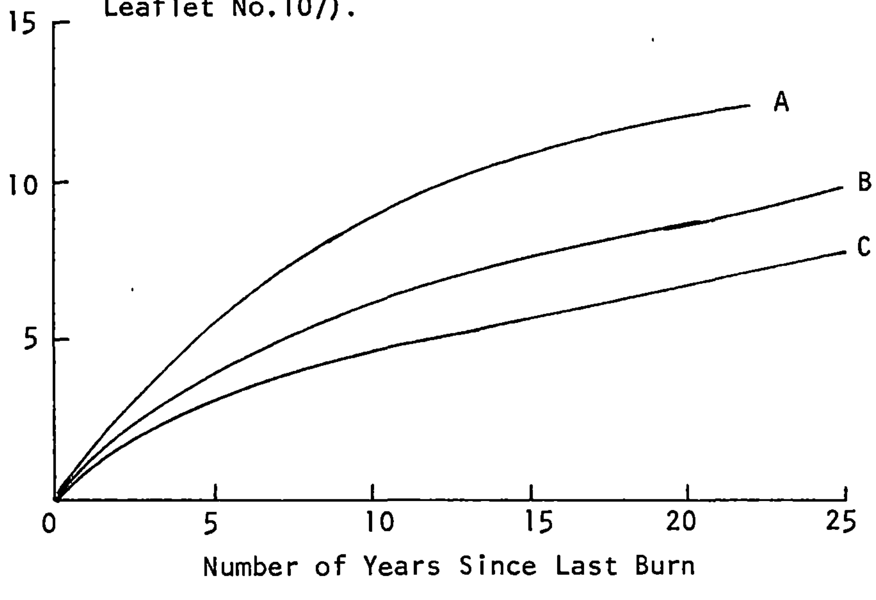
The rate at which fuel accumulates at a given site is a complex area of investigation to which considerable research effort is being directed.

The accumulation of dead fuel on the ground is a function of the rate of litter accession by the vegetation less the rate of breakdown by the soil microfauna. Hence differences in accumulation rates between sites tend to parallel differences in vegetation type and microclimate.

Studies done on the accumulation of litter in various forest types [88] indicate that wet sclerophyll forests exhibit a more rapid building up of fuel in comparison to the drier forests and that in all cases there is a levelling off of fuel accumulation as dynamic equilibrium between litter accession and decomposition is reached (Figure 23).

Figure 23

Fuel Accumulation Rates in Western Australia (From McArthur, A.G., 1967; *Fire Behaviour in Eucalypt Forests;* Forestry and Timber Bureau Leaflet No.107).




A. Karri (wet sclerophyll) 60-90 percent canopy cover with open shrub strata (after Loneragan).
B. Jarrah (dry sclerophyll) 90 percent canopy cover (after Hatch).
C. Jarrah with 50 percent canopy cover (after Hatch).

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[88] e.g. Peet, G.B., 1971; Litter accumulation in jarrah and karri forests; *Australian Forestry*, 35, pp.259-262: and, McArthur, A.G., 1962; *op.cit.*, p.14.

Although these general trends in litter accumulation have been generally accepted, some studies indicate that for some sites,litter accumulation after hazard reduction burning is much more rapid, regaining original fuel levels after very short intervals.[89] The benefit to be gained from reducing the fuel load by burning on some sites must then be seriously questioned.

If hazard reduction burning is to be used as a fire control tool there is the need for research into accumulation rates in the forest types designated for fire management in order to isolate types in which hazard reduction burning is of benefit and also to enable logical burning intervals to be derived for different areas based on actual accumulation rates.

A limited field study was undertaken by the authors in dry sclerophyll forest and woodland and in an area near Hobart to investigate fuel accumulation after eight years and to compare this accumulation to that predicted from existing mainland accumulation models. The report on this study is included as Appendix A. Fuel loadings of dead fine fuel ranged from close to 5 tonnes/ha in very open forest (eucalypt crown covers of about 25%) to 10 tonnes/ha in medium dense stands (50% crown cover). The predominant component of this fuel complex was eucalypt litter with a variable component of grasses (up to 2.5 tonnes/ha) and litter from other species (notably *Casuarina stricta*). The results indicate that to maintain dead fine fuel loadings of less than 8 tonnes/ha, variable burning intervals could be used ranging from possibly 5 years upwards dependent on the percentage cover of different species at a given site.

The manner in which live vegetation can be incorporated into the total fuel loading presents particular problems and, for this reason, was not assessed in the field study. Live vegetation invariably has high moisture contents even under drought conditions and hence will not burn until sufficiently dried out by an existing ground fire. Furthermore considerable differences in inflammability exist between species.

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89 See Van Loon, A.P., 1970; *Investigations into the Effects of Prescribed Burning on Young, Even-Aged Blackbutt, First Interim Progress Report* Forestry Commission of N.S.W., Research Note No. 23, p. 4. Van Loon found that the weight of fine fuels on plots in E-pilularis which were control burnt two years previously was exactly the same as that on similar plots unburnt for more than twenty-one years i.e. ]5 tonnes/ha.

Much research is needed into the relative inflammability of different shrub associations and into the way in which fire behaviour is influenced by different relative loadings of live shrub and dead litter under different fire weather conditions before the nature of the fire hazard presented by live vegetation can be fully appreciated and utilized in hazard reduction programmes.

## 4.3 Ecological Perspective[90]

### 4.3.1 Fire as an environmental factor

It would be exceedingly naive and unrealistic to suggest that fire has not been a factor in the ecology of many natural communities in the Australian environment for many thousands of years.

Direct evidence such as charcoal in river deposits, charred wood in the ground and early records of bushfires[91] coupled with logical deductions based on the likely concomitant occurrence of dry fuel with an ignition source, either lightning or aborigines[92] render such a viewpoint untenable.

The preponderance of evidence suggests that under the constraints imposed by edaphic and climatic conditions, the fire history in a given area plays a major role in determining the general structure and species composition of a plant community both by its interaction with the life cycle characteristics of individual plant species and indirectly by its influence on soil characteristics.

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90 The effect of fire on plant communities and ecosystems in general is an extremely complex field of investigation and space does not permit a comprehensive review within the body of this thesis. A general review has been done by B.Page dealing with the effects of fire on some aspects of natural communities and the extent to which this knowledge can be used to predict the ecological consequences of hazard reduction burning. This review was used as a basis for much of this section.

91 Hodgson, A. & Heisler, A., 1972; *Some Aspects of the Role of Forest Fire in South-Eastern Australia*, Forestry Commission of Victoria Bulletin 21.

See also McArthur, A.G., 1970: *Historical aspects of fire*, Paper presented at Second Fire Ecology Symposium, Monash University.

92 Mount, A.B., 1969: Eucalypt Ecology as related to fire, *Proceedings of Tall Timbers Fire Ecology Conference*.

Insofar as the fire history affects the structure and composition of the vegetation on an area, it will also affect the species composition and abundance of wildlife as the fauna is ultimately dependent on the vegetation for the provision of specific habitat types.

The fire history is normally thought of as representing a fire regime, consisting of fire intensity, fire frequency and the season in which a fire occurs and their relative combination over time.

Infrequent fires have probably occurred in wet sclerophyll forests phasing into more frequent fires in the dry sclerophyll forests.

Advocates for area hazard reduction burning often tend to allay fears over the possibility of adverse effects arising from such a technique in dry sclerophyll by favourably comparing the regime with the 'natural' patterns of burning that has been a feature of these forests for thousands of years.

However the point needs to be emphasized that the historical evidence does not permit anything but a very broad picture of the fire regimes operative in the past. Large variations in the frequency and intensity of fires are likely so have occurred over space and time.[93]

### 4.3.2 The Impact of Hazard Reduction Burning

Responsible land management implies that the consequences of a particular course of action are known before such action is blandly accepted. This is necessary both to the evaluation of the effectiveness of the action in achieving its objective and to enable its impact on other values to be determined. The responsible use of hazard reduction burning necessitates a knowledge of its short and long term ecological consequences in natural communities against which its benefits to fire control can be determined relative to its impact on other resource values.

To what extent are the ecological consequences resulting from hazard reduction burning known or can be confidently predicted?

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93 Gill, A.M. 1975; Fire and the Australian Flora: A. Review, *Australian Forestry, Vol. 39, No. 1, p. 7.*

### 4.3.3 Effect on plant communities

Hazard reduction burning as a fire regime can be defined by:

1. fire intensity - generally low
2. fire frequency - high and regular
3. season of fire - usually spring or autumn

Sufficient research has been done to predict that the high frequency and low intensity characteristics of the hazard reduction burning regime will have significant effects on the species composition and structure of plant communities.

Thus low fire intensities have been observed to cause significant reductions in the number of leguminous species[94] and high fire frequencies often give rise to a preponderance of non-woody plants which either have a short life cycle or a very effective means of vegetative recovery and spread.[95] Differences in species occurrence, dominance and total ground cover were apparent between dry sclerophyll forest regularly burnt on a five year cycle and an adjacent site unburnt for forty years in W.A.[96]

The extent to which the application of a given hazard reduction burning regime to a site will result in changes in the species composition and structure in the relatively short term will reflect to a large extent the local fire history and the life cycle characteristics of the locally occurring plant species. On this basis, the degree of change in species composition and structure can be expected to be least in the drier forests where the past fire frequency has probably been higher than in the wetter communities.

Nevertheless hazard reduction burning by virtue of its high frequency, regularity and consistently low intensity is a fire regime highly unlikely to occur in natural situations. Vegetation changes are inevitable even in the drier forests.

There is a practical need to be able to predict the direction and extent of any changes likely to result from the imposition of the hazard reduction burning regime on specific plant communities.

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94 Van Loon, A.P., 1970: *op.cit.* p. 2 and Peet, G.B., 1971, *op.cit.*
95 Gill, A.M., 1975; *op.cit.* p. 10.
96 Christiansen, P.E., and Kimber, P.C., 1975: Effect of Prescribed Burning on the Flora and Fauna of South-West Australian Forests, *Managing Terrestrial Ecosystems*. Proceedings of the Ecological Society of Australia Vol. 9, pp. 85-106.

This position is far from being approached and this lack of practically applicable knowledge raises the following areas of concern.

1. *high fire frequencies on some sites may result in the replacement of the original understorey type with a more inflammable vegetation cover.*

Frequent burning of wet sclerophyll associations may result in promotion of a dense understorey of bracken, *Pteridium esculentum* (Plate *4* ) or cutting grass, *Gahnia grandis*.[97]

Similarly frequent burning is considered to play a large part in the maintenance of grass dominated understories in the drier forests,[98] (Plate 5 ) although sedges and *Lomandra longifolia* may be encouraged in preference to grasses on some sites.[99]

The promotion of any of the above understories and the elimination or reduction of shrubs results in an increase in the inflammability of the forest[100] and hence is counterproductive to the hazard reduction objective.

The particular combinations of fire frequency and intensity which can result in the above changes to the understorey composition are not known in practical terms. Research is badly needed into this aspect of hazard reduction burning to ensure that an increase in understorey inflammability is not incurred.

2. *some plant species and community structures may be progressively eliminated by the adoption of a rigid fire regime on a systematic basis.*

The 'critical limits of a fire regime' within which a plant species may exist are unknown for most species [101] and this fact coupled with the lack of a detailed inventory of plant species and their distribution presents the very real danger of eliminating some species by the systematic application of a 'blanket prescription' fire regime.

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97 Mount, A.B. , 1969; *op.cit.*, p.97.

98 Hogg, A. and Kirkpatrick, J.B., 1974: The phytosociology and synecology of some Southern Tasmanian eucalypt forests and woodlands. *Journal of Biogeography 1*, p. 243.

99 Personal observations indicate that sedges and *Lomandra longifolia* are likely to result from frequent firing on mudstone and sandstone sites and grasses on doleritic sites.

100 Rates of spread in these fuels are very high, particularly for grass and bracken (see part 2.3.4). Removal of the shrub layer also will open up the ground fuels so drying influences.

Gill, A.M.; 1975; *op.cit.*, p. 21.

Plate 4: Possible bracken understorey encouraged by frequent hazard reduction burning.

Plate 5: Grassy understorey of drier forests.

Likewise various types of community structure, particularly the more mature shrub strata may be eliminated by frequent burning. This possibility is particularly likely in wet sclerophyll communities but can also occur in dry sclerophyll particularly for high fire frequencies.

### 4.3.4 Effects on wildlife

The effects of fire on wildlife must be looked at in terms of the impact of the fire itself and secondly on the impact of the fire regime on habitat in the short and longer term. [102]

The mild fires of hazard reduction burns are unlikely to cause significant mortality amongst adult specimens of birds and other animals due to their mobility, burrowing or arboreal habits. However, the eggs and young of bird species which nest close to the ground such as the superb blue wren, would be virtually assured of destruction if such burns occurred during the nesting season. Nevertheless, even this loss must be put in the perspective of species survival. Most bird species have the ability to rapidly build up their numbers after a 'natural' disaster such as fire provided suitable habitat conditions remain. [103]

Therefore, the provision of suitable habitat is the important consideration. Most species are reasonably distinctive in the type of habitat within which they may survive. Ecologically, animals and birds are tied to the vegetation in an area and any changes that occur in the structure and composition of the vegetation will cause changes in the composition and abundance of wildlife in that area.

Continued prescribed burning in the forests of W.A. has been shown to have a significant effect on populations of *Antechinus flavipes* which are resident in the burn areas. Presumably the five to seven year burning of the forest has created conditions unsuitable for this animal. [104]

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102 Cowley, R.D., 1971; Birds and forest management, *Australian Forestry* 35, pp. 234-50.

103 *Ibid.*

104 Mason, M.L., 1974; Fauna in the Northern Jarrah Forest, *Forest Notes*, Vol.12, No.2, Forests Department, Western Australia.

Butcher [105] emphasizes the need to examine the effects of a fire regime at the species level and to date there exists an extreme paucity of knowledge of habitat requirements of most species of birds and animals so that even if changes to the vegetation could be adequately predicted in response to given hazard reduction burning programme, this could not confidently be related to the requirements of many wildlife species.

This situation is further exacerbated by the lack of faunal censuses for most areas so that even if habitat requirements were known in considerable detail there would still be no basis on which to judge the potential impact of hazard reduction burning on the wildlife populations, or its importance to the total wildlife resource at the regional or national level.

As with its effect on vegetation, the impact of a particular hazard reduction burning regime on wildlife is fraught with uncertainty.

### 4.3.5 Effect on Soil Characteristics

The soil and its resident microfauna and microfaunal population represents an important functioning component of the total forest ecosystem. Changes to this component through fire could have a profound effect on the structure and productivity of the plant and animal communities.

Hazard reduction burns remove a significant part of the organic layer. The loss of nutrients, particularly Nitrogen and Sulphur held in these layers is cumulative and will lead to a reduction in total nutrient levels unless the replacement rate from rainfall, weathering and legume fixation is at least as high [106]. Lower foliage levels of Nitrogen and Phosphorous in some regularly burnt areas suggest that depletion rates are higher for some sites and burning frequencies.[107]

Fires of variable intensity have been shown to have significant effects in reducing the structure of the surface soil and in promoting the formation of hydrophobic layers both of which significantly influence water

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105 Butcher, A.D., 1970; *Aspects of Wildlife Management*, Paper presented at Second Fire Ecology Symposium, Monash University.

106 Humphreys, F.R., 1966; Some effects of fire on plant nutrients, in *The Effects of Fire on Forest Conditions*, Technical Paper No. 13, Forestry Commission, New South Wales.

107 Floyd, A.G., 1966; The effects of control burning on forests, in *The Effects of Fire on Forest Conditions*, Technical Paper No. 13, Forestry Commission, New South Wales.

infiltration into the soil[108]. Surface run-off is thereby increased and with it the potential for erosion on sloping surfaces.

The removal of the protective vegetation and litter layers by fire will accentuate the process. The cumulative effect of repeated fires could be the progressive removal of surface layers of soil by this mechanism resulting in loss of site productivity and water run-off quality.

Studies done on soil microfauna and flora after control burns are contradictory. Bornemissza[109] found that microfaunal populations recovered rapidly after a fire, however, Springett[110] found that the diversity and density of microfauna are much reduced and do not recover in the five to seven years before the next control burn. If the latter study holds for even some situations then control burning could have considerable implications to the forest ecosystem. Springett provides food for thought by mentioning that a diverse and active litter layer of organisms in the forest is important to the control of Phytophthora cinnamomi.

The above points strongly suggest the possibility that at least in some instances, decidedly adverse effects on soil characteristics may be incurred by regular, frequent burning.

Although much in general is known about the role of fire in the ecology of many Australian communities, there is a strong element of uncertainty in extrapolating this general knowledge to the ecological consequences likely to result from the imposition of the hazard reduction burning. The fact that fire has played a large part in the ecology does not mean that all fire regimes are desirable or can be adequately absorbed by manual communities without adverse effects occurring.

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108 Krammer, I.S. and de Bono, L.F., 1965; Soil wettability; a neglected factor in watershed management, *Water Resources Research, 1,* pp. 283-6.

109 Bornemissza, G.F., 1969; *Re-invasion of burnt areas by insects and mites,* Paper presented at a Seminar on the Effects of Forest Fire, Ecological Society of Australia, Canberra Group.

110 Springett, J.A., 1976; The effect of prescribed burning on the soil fauna and litter decomposition of West Australian forests, *Australian Journal of Ecology: 1*, pp.77-81.

The possibility of adverse effects on the soil and the potential for changing the understorey to a more inflammable type by certain burning frequencies and intensities necessitates a conservative approach in the use of hazard reduction burning.

The existence of considerable uncertainty as to what vegetative changes will occur in response to a hazard reduction burning coupled with an inability to relate vegetation type to specific faunal habitat makes the conservative approach in the use of hazard reduction burning also desirable for the conservation of a diversity of flora and fauna.

## 5. TOWARDS A RATIONALIZATION OF WILD FIRE MANAGEMENT IN THE HOBART SPECIAL FIRE AREA

The point has been made previously in this report, either directly or indirectly, that Hobart exists in a potentially fire hazardous environment. This fact may be confirmed by reference to the historical record of past fires as well as by a consideration of the physical and meteorological parameters that contribute towards creating a fire hazardous environment.

Such a fire hazard does not occur because of the existence of these fire conducive characteristics alone. It is not just the environment that creates the fire problem. Rather the problem stems from the way that this environment and man interact, and the problem is given more dimensions and further complicated by the fact that there is not just a single aspect of interaction, there exists a whole range of ways in which man's activities interact with the fire environment. The work of developing a fire management programme for the area under study then will need to deal not only with the single aspects of the problem but also need to consider the ways in which these single aspects are integrated to form a total fire hazard.

There exist basically three general approaches to an amelioration programme that if pursued singularly to an extreme would probably prove totally effective in eliminating the fire hazard. Firstly one could work towards eliminating the fuel on which the fires feed; by extensive frequent controlled burning it would be possible to approach a situation where there is insufficient fuel to support a wild fire. Secondly one could work towards eliminating fire ignition points; since man is largely responsible for initiating fires it should be possible by regulatory powers and pecuniary punishment to reduce such ignitions to an insignificant or absent level. Thirdly one could ensure that dwellings are constructed such as to mitigate against the entry of fire and only exist within an immediately totally fuel-free environment; again by regulation and threat it could be established that every dwelling, either newly constructed or already existing, should conform to a code of construction and be surrounded by a totally fuel-free environment.

For a good many reasons it is obviously not possible to attempt a practical implementation of any of these extreme amelioration programmes. What is demanded is a compromise between these three extremes that goes towards protecting life and property from fire and yet works within the practical limits imposed by the community and the environment. The present amelioration programme practised within the H.S.F.A. is an example of one such compromise; it is of course not the only compromise that is possible.

Depending upon the weighting and consideration that one gives to community limits and values and environmental limits and values then it is possible to arrive at a different compromise that still goes towards achieving the aim of protecting life and property. It is our intention in this section to consider ways in which present practices may be altered or re-emphasised in an attempt to accommodate particular community and environmental values and still achieve an effective amelioration programme. Each particular aspect that we feel in need of comment will here be individually detailed.

## 5.1 Uses of the Hobart Special Fire Area

It would seem that when undertaking the management of a particular area for a particular purpose there exists the very real danger that one may become very single-minded in pursuing the desired goal of the programme. Whether such a single-mindedness has its impetus within the generally framed guidelines of the statutory directives or within the individual interpretation and application of these directives as practised by officers within the organization is rather a moot point. However, the point which needs to be made is that such a single-minded approach to the development and implementation of a management programme may well find itself in conflict with other values and uses with the area. Such conflicts may well be avoided if the managers of an area would extent their responsibilities beyond the immediate attainment of management goals or extend their management goals.

Such a point needs to be made with respect to the H.S.F.A., for although it complicates the development and implementation of any fire management programme, it is necessary to appreciate that the area concerned is more than just a fire hazard.

The area provides recreational and hobbyist facilities to diverse groups of Hobart's citizens from bush-walkers and bird watchers to family picnicers and trail bike riders and contains many parks and reserves (Figure 24). The timbered areas surrounding Hobart also provide an ever-present background to many a view in the city so even if a person does not physically use the area he must almost inevitably look at the area. Of course the aesthetic amenity of any vista depends on the viewer; however it needs to be remembered that such visual use is inevitably made of the area.

Any planning needs to be based on the multiple uses to which the area is put, both at present and in the future, for the existence of wooded areas in such close proximity to a large centre of population creates a potential for recreational development. Such present and possible future uses suggest that the area needs to be treated with care and forethought in order that present and future options may be maintained.

## 5.2 The Role of Broad Area Hazard Reduction Burning

Broad area hazard reduction burning is one of the major elements of the fire protection policy within the H.S.F.A. at present. Figure 25 shows the extent of areas within which the Rural Fires Board considers that the technique can be effectively applied and Figures 17 and 18 (presented earlier) suggest that this plan has been actively pursued by the relevant authorities.

Essentially the areas which can be hazard reduced by burning in the opinion of the Rural Fires Board excludes only cleared and built-up areas and sites in excess of 800 m in altitude because of the "less fire resistant tree species in these areas."[111] Some constraint has therefore been made to the broad scale application of the technique due to the possibility of serious conflict with other values above 800 m.

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[111] Tyson, R.G., 1974; *A review of the requirement for a more highly trained and efficient fire fighting and hazard reduction force,* Unpublished Internal Report of Rural Fires Board.

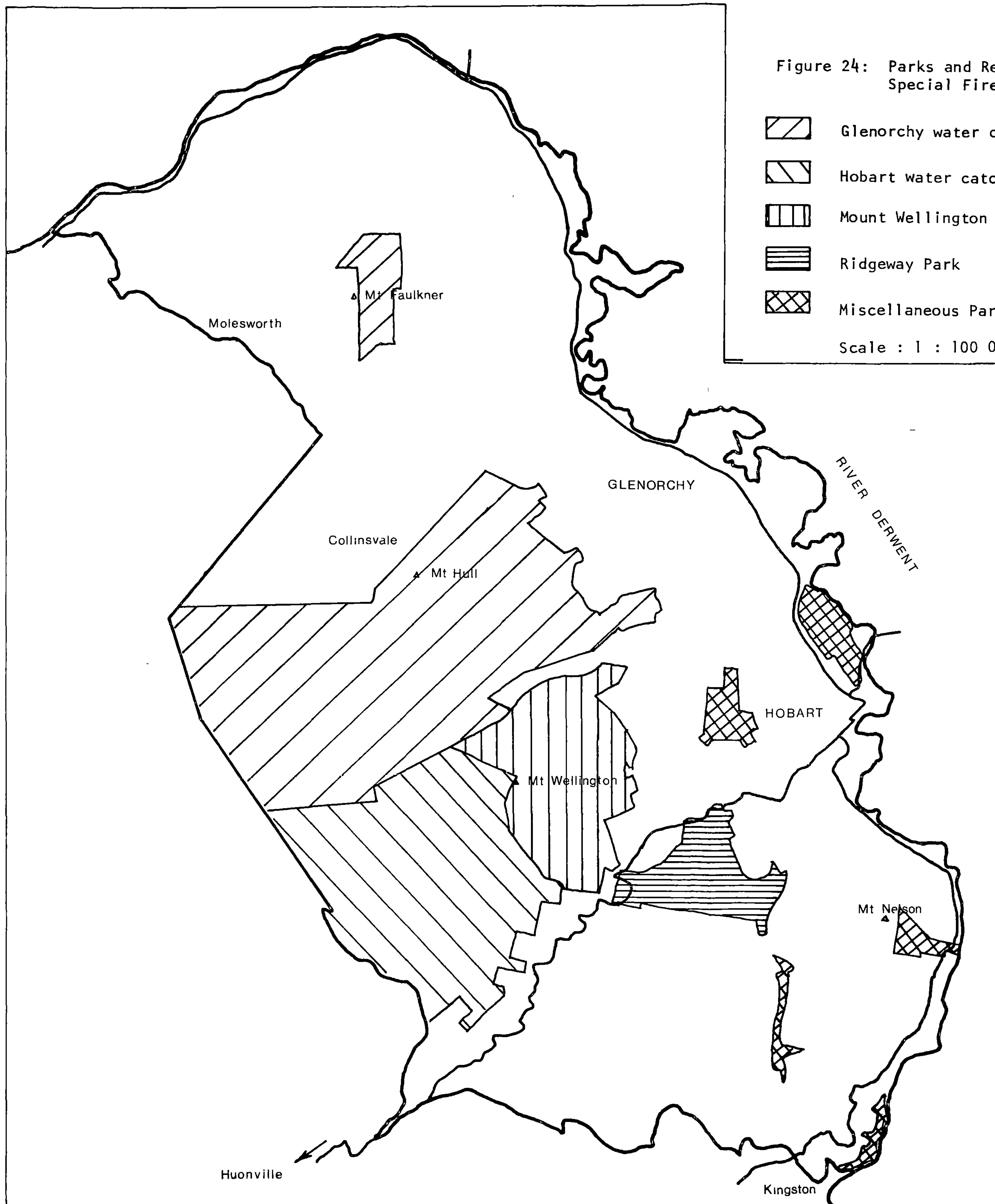


Figure 24: Parks and Reserves Within the Hobart Special Fire Area

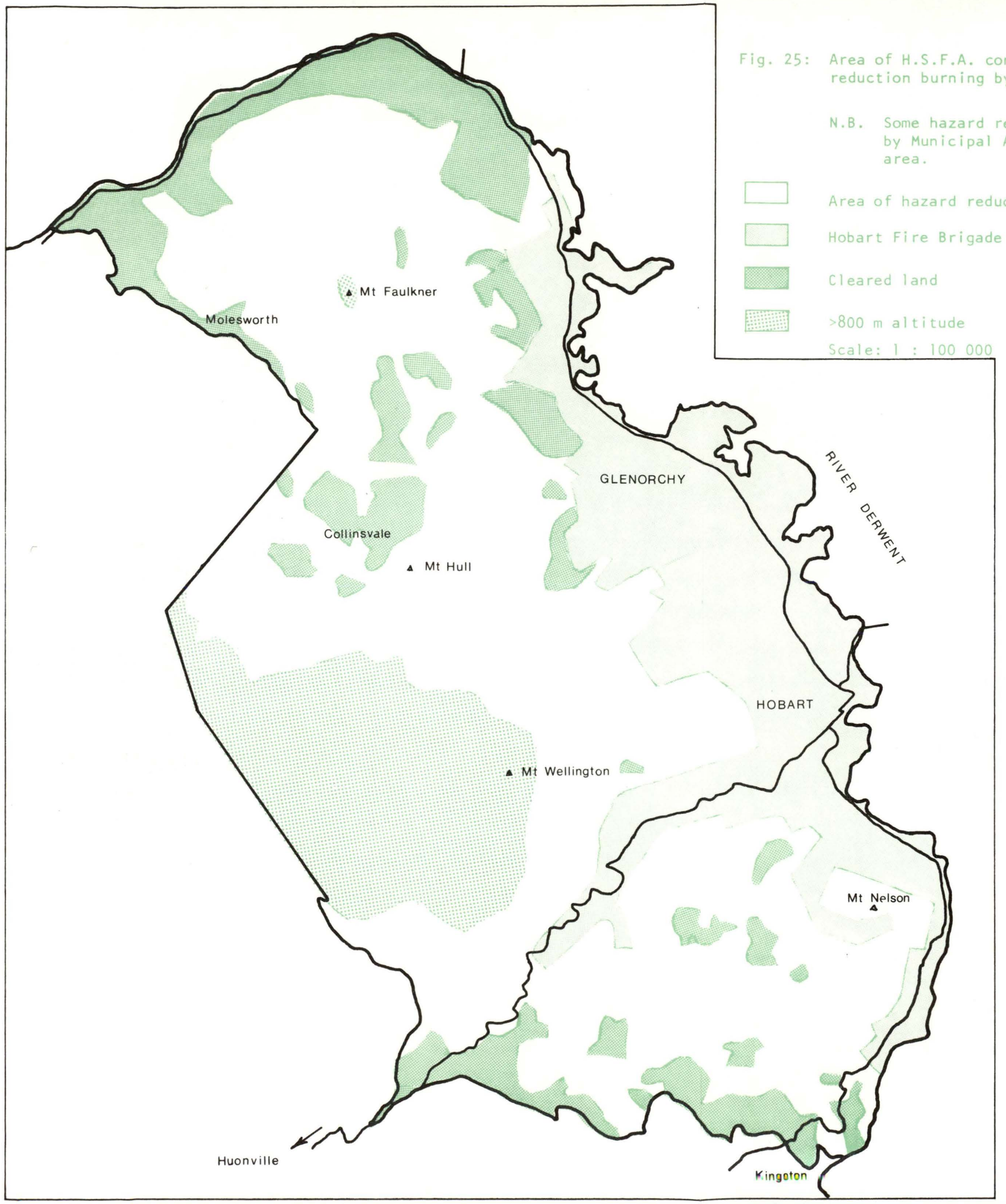


Fig. 25: Area of H.S.F.A. considered amenable to hazard reduction burning by Rural Fires Board

N.B. Some hazard reduction burning is carried out by Municipal Authorities within Fire Brigade area.

Area of hazard reduction burning

Hobart Fire Brigade Area

Cleared land

>800 m altitude

Scale: 1 : 100 000

The lack of any further constraint on the area subject to the technique suggests a general acceptance by the authorities that the benefits to fire protection derived from hazard reduction burning over the rest of the area far outweigh any disadvantage and conflict with other values.

The status of research into the ecological consequences of hazard reduction burning on specific communities is insufficiently advanced as to be able to make such a general assumption.

The possibility of considerable conflict with watershed values and the maintenance of floral and faunal diversity cannot be discounted at the present time.

Even the benefits to be derived from hazard reduction burning in some community types are open to question due to the possibility of understorey change to a more inflammable type[112] or due to a very rapid recovery of fuel levels.[113]

Quite clearly the possibility for rational decision-making into where and when hazard reduction burning should be used to advantage is severely prejudiced by the lack of specific research.

We consider that such an atmosphere of uncertainty necessitates that any scheme of fire protection should have the minimization of hazard reduction burning consistent with the provisions of a reasonable level of protection rather than its widespread application as one of its primary constraints.

A de-emphasis of broad area hazard reduction burning in the fire protection strategy in the H.S.F.A. is therefore strongly recommended at least until further research provides more exact information on its effects on potential and actual land-use.

The first and most obvious area in which de-emphasis can be profitably

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[112] Mount, A.B., 1969; *op. cit.*
[113] Van Loon, A.P., 1970; *op. cit.*

achieved is in the wet sclerophyll communities. The uncertainty of ecological effects arising from a frequent burning regime is relatively high in such communities owing to their generally accepted low fire frequency history. These communities by virtue of exhibiting much higher fuel moisture contents than their dry sclerophyll counterparts except under relatively severe drought conditions also represents a lower fire risk. The opening up of these forests to drying influences by frequent burning, the high possibility of the conversion of the wet sclerophyll understorey to more inflammable components as a result of frequent burning, perhaps at less than ten year intervals and the difficulties of applying low intensity hazard reduction burns to wet sclerophyll[114] all tend to make the technique of doubtful benefit.

The justification for this reduction of hazard reduction burning in the drier forests is less definitive than in the case of the wet sclerophyll communities as frequent fires are generally considered to approach the 'normal' fire history in these communities. Nevertheless, there is no evidence to suggest that the frequent fire regime of hazard reduction burning has ever been experienced regularly over time at any one place and this coupled with the possibility of an understorey change to a more inflammable type such as grasses or sedges by certain burning frequencies and intensities necessitates a conservative approach to the application of hazard reduction burning.

In our opinion hazard reduction burning may be reduced in scale without seriously detracting from the level of protection of life and property afforded by the current broad area plan by restricting its location to strategic areas where it will prove most effective in

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[114] Mount, A.B., 1965; *The Vegetation as a Guide to Prescribed Burning in Tasmania,* Unpublished Paper presented at Hobart Conference of Institute of Foresters of Australia.

affording protection to life and property over the H.S.F.A.

In the context of protection to life and property a wild fire does not constitute a danger until it actually threatens life and property and hence the absolute necessity to extinguish the fire on every square metre of land does not exist due to the simple fact that property is discontinuous in space.[115]

We consider that an adequate level of protection can be achieved by the implementation of the following strategies:

1). the facilitation of fire control within the general environs of a settled area,
2). the provision of effective protection from wild fire in the immediate environs of property.[116]

The factors affecting fire behaviour and their variation over the H.S.F.A. have previously been dealt with from which several points emerge:

1). Fire control on northern and western slopes will usually be more difficult than in other situations due to lower fuel moisture contents and high exposure to strong north-westerly winds.
2). Spotting well ahead of the fire front is particularly prolific as fires reach the upper northern and western slopes and ridge tops and funnel burning embers and bark into the wind stream. Thus a fire can rapidly travel by spotting from ridge to ridge.

Fire control in an area may then be facilitated by a reduction in fuel loading on upper northern and western slopes and ridge tops. Such a pattern of hazard reduction burning, whilst also providing buffer zones wherein a fire may be supressed if control elsewhere proves

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115. This does not mean that attempts should not be made to control all wild fires at all times. This should still remain a highly desirable objective.

116. Dealt with in more detail in 5.3.

difficult, would give a reduction in the fuel loading in those areas most likely to exhibit severe fire behaviour under a wide spectrum of Fire Danger Indices and cause a drastic reduction in the capacity of a fire to rapidly spread to successive ridges by the spotting process.

The question remains as to which ridge tops and northern and western slopes be subject to such fuel reduction.

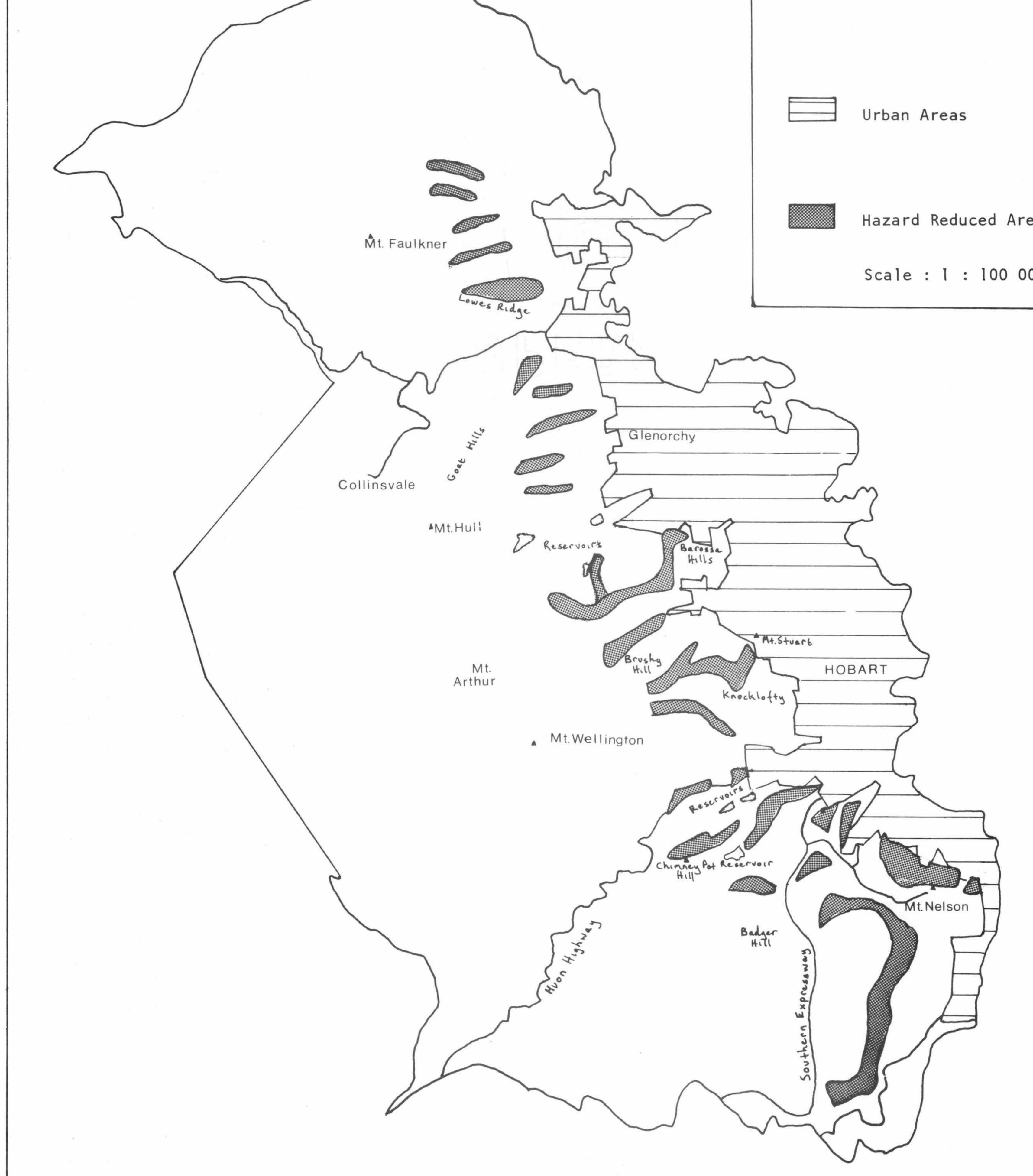
We see little justification to extend hazard reduction burning to all such situations over the H.S.F.A., since quite clearly the risk to property presented by a fire is a function of its proximity. The maximum benefit would be gained by the adoption of hazard reduction burning on those areas proximate to settled areas. Figure 26 shows the areas which we suggest should be subject to area hazard reduction burning.

The suggested areas have been restricted to dry sclerophyll and grassy woodland communities. Further to this, they have been chosen not only on the basis of relative proximity to settled areas but also bearing in mind the form which such settlement takes in different areas. Thus settlements such as Collinsvale by virtue of a high proportion of cleared land are considered relatively safe from wild fire devastation and a similar argument can be made for scattered small farms over the rest of the area.

Within these areas the time interval between successive burns should ideally be related to actual fuel accumulation rates. Nominal burning intervals between 5-10 years are suggested with the longer interval applied to poor mudstone sites carrying little ground cover phasing into five year intervals where high eucalypt crown cover and dense understorey vegetation predominate. Adjacent burns should exhibit variable fuel ages to create localized patterns of habitat diversity.

Each of the hazard reduction burns in addition to fulfilling a fire

Figure 26: Suggested Sites for Area Hazard Reduction Burning



protection role should be regarded as providing a basis for research into the ecological effects of the hazard reduction burning regime and the rates of fuel accumulation in different communities. Only via such research can the hazard reduction burning regime be properly evaluated as an ecological factor and its use rationalized appropriately.

To this end there is a need to keep detailed records of the history of hazard reduction burns in each area and as the season of the burn is an unknown variable in terms of its ecological significance, each burning unit should be burnt in a constant season, i.e. either spring or autumn.

It should be mentioned that attempts by the authors to determine both rates of fuel accumulation and some ecological effects were prevented largely due to the paucity of detailed fire history available in the H.S.F.A.

We consider that the restriction of area hazard reduction burning to the areas suggested in the above scheme coupled with considerable attendant research is a more responsible approach in relation to both environment and property than that undertaken at present and that combined with the additional strategies dealt with in the following sections, this will impart an adequate level of protection to life and property.

## 5.3 The Role of Localized Protection and Responsibility

Any de-emphasising of hazard reduction burning needs to be accompanied by an emphasising of the need for localized protection if an adequate level of protection of life and property is going to be maintained. The impetus for such a programme undoubtedly rests with the government agencies concerned but needs to be directed towards establishing the large degree of self-help that is possible in mitigating any direct fire hazard. Aspects of such a programme that may be profitably pursued are here detailed.

As previously noted a considerable degree of protection may be afforded a building by excluding the entry of sparks and embers to any part. Such exclusions may be achieved by adopting particular building techniques, e.g. fully enclosed eaves, fine mesh on external vents, etc. A degree of protection could well be given to all new construction then by requiring, via regulation, that such building techniques be employed. For those buildings already constructed every encouragement should be given to owners and residents to make whatever alterations may be necessary to achieve a "fire tight" building. Considering financial limitations such encouragement may be limited to educating owners of the simple techniques required and the considerable benefits to be gained from such an exercise.

An educational programme may also be of value in instilling into the minds of residents the ways in which life may be protected or endangered in a wild fire situation. This aspect along with the afore mentioned building protections coupled with the third factor of maintaining an immediate low fuel zone around buildings, could form the basis of an education programme designed to illustrate to residents the considerable amount of effective amelioration that can be achieved on a personal, small scale basis. It would be of greatest benefit of course if every member of the public could be reached by such a programme and this undoubtedly would be an eventual aim. However, considering the shortages of finance and resources, such is not possible, and it may be of greatest value to be rather mercenary in allocating the educational dollar. Obviously the place to receive the greatest attention should be the place most likely to be threatened. We feel that a good deal of effective amelioration of the wild fire threat to life and property could be achieved by educating people in the simple self-help techniques available and further that such a programme be initially directed towards those people who live in high fire risk areas, such areas being defined by occurrence of previous bush fire damage.[117] Such an education and regulation approach seems the only viable avenue open to stimulate self-help. Another considered avenue of differential insurance premiums is unavailable due to the

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117. Since such an educational programme would be assuming considerable importance in protecting life and property within the H.S.F.A., it is felt that considerable care and research should be given to the development and implementation of such a programme and due cognizance given to the body of knowledge that exists in relation to public education and advertising, viz.
Martineau, P., 1957; *Motivation in Advertising;* McGraw-Hill Book Company Inc., New York.

attitudes of insurance companies. In an attempt to minimize costs such companies are keen to simplify procedures, hence the recent adoption of a blanket fire insurance covering all houses in all areas. Payouts on buildings destroyed by external fire represent such a small fraction of business that companies would lose more money than would be gained by introducing differential insurance premiums.[118]

It is also felt that a degree of community responsibility exists in ensuring that low fuel buffer zones are maintained in the immediate environs of buildings. Such a responsibility manifests itself in the form of abatement notices served to people who are neglectful of reducing the immediate fuel hazard around buildings and in the form of maintaining a low fuel verge that extends for a short distance (say 50-100 metres) into the bush along a bush-urban interface. Such a verge may consist of a managed park or grassed area (Plate 6), or fuel reduction may be achieved by mechanical clearing and/or burning; the particular technique(s) employed being dependant on the limitations present in each individual situation. It may also be possible to extend this concept of buffer zone creation to encompass new housing developments so that wherever possible the immediate juxtaposition of building and bush does not occur and that areas of low fuel are interposed; these areas may include playing fields, grassed parklands or roadways.

## 5.4 The Role of Fire Prevention and Suppression

Emphasis has so far been placed on the measures necessary for the protection of life and property in the event of a wild fire. Another aspect of fire management that complements these measures is that of attempting to ensure that wild fires do not occur.

No one would seriously suggest that this is a practically achievable aim in its entirety, nevertheless the potential for maintaining the occurrence of wild fires at a very low level does exist and should be actively pursued. Virtually all past wild fires in the H.S.F.A. have been of human origin,[119] thus the prevention of wild fires largely

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118. Personal communication from Mr. Spinks, Vice-Chairman of the Tasmanian branch of the Insurance Council of Australia.
119. See section 2.1.

Plate 6: A grassed buffer zone between housing and bush.

rests with the modification of human behaviour.

The present system of restricting the lighting of fires according to the prevailing fire danger conditions[120] appears reasonable; however a certain amount of tightening-up on the issue of permits seems desirable. There is the need to make people aware that fire is a potentially dangerous tool and the allowance of excessive freedom in its use is decidedly counterproductive in this context. It is therefore suggested that permits to burn off be required at all times with the difficulty of obtaining these permits being increased as the fire danger worsens.

During periods of low fire danger such permits should be freely given but nevertheless recording of the relevant details of the burn by the local permit officer should still be required. During declared fire danger periods permits should be issued only after the permit officer has satisfied himself that all necessary precautions have been taken to prevent the fire from escaping. A copy of all permits detailing the location and area of the burn should be forwarded to the Rural Fires Board headquarters.

With such a permit system controlling the lighting of fires the probability of a fire occurring on or immediately prior to a day of high fire danger is obviously low. Some illegal fires will nevertheless occur and need to be immediately controlled and suppressed to further reduce this probability.

The need for such stringent measures restricting the lighting of fires and/or their immediate supression and control during a fire danger period is exemplified by reference to the 1967 disaster where numerous fires had been burning freely prior to the 7th February without any concerted attempts to control them until control in fact proved impossible on that day.

The point has been made on a number of occasions in the preceding pages that the development and implementation of a fire management programme

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120. See section 3.1

for an area such as the Hobart Special Fire Area is a very involved and very difficult problem. It is a problem to which there is more than one answer, none of which may be absolutely correct. What has been presented in the foregoing pages is a resume of the factors involved in the fire problem and the directions that the authors think the fire amelioration programme should be directed. It is a solution that we hope includes adequate cognizance of both environmental and community values.

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# APPENDIX A

## A STUDY OF FUEL ACCUMULATION IN DRY SCLEROPHYLL FOREST AND WOODLAND IN THE HOBART AREA

### 1. INTRODUCTION

The rate at which fuel accumulates after a fire is of practical importance to the formulation of fire prevention and supression plans, owing to the importance of the fuel weight to subsequent fire behaviour.

Hazard reduction is normally an ongoing process aimed at maintaining fuel weights over widespread or limited areas below what is considered to be safe limits so that effective control over a wildfire burning through such fuel can be achieved under most burning conditions.

The knowledge in quantitative terms of the rates of fuel accumulation in the forest is then fundamental in designing a hazard reduction programme.

Fuel accumulation models of variable sophistication have been derived by McArthur (1962), Hatch (in McArthur, 1967) and Peet (1971) mainly for jarrah and karri forests in Western Australia.

The relatively simple model developed by McArthur (1962) and shown in Figure 1 has undoubtedly been used as a practical guide to fuel accumulation throughout much of the dry sclerophyll forest in Australia.

These models deal primarily with the accumulation of dead material generally less than about 1 cm in thickness which constitutes, ignoring moisture content for the moment, the available fuel component, i.e. that fuel which most significantly contributes to the combustion process. No really satisfactory means of quantifying the contribution of living fuels to the total available fuel weight has yet been determined owing to the complexities involved, such as fuel discontinuity, and differential inflammabilities between species. In any case, the living vegetation, because of its high moisture content, will not burn unless considerably pre-heated by already burning dead fuel. Thus the accumulation of dead fuel is a prerequisite before living vegetation can add to the available fuel mass.

## 2. THE STUDY ITSELF

The present study was initiated in order to ascertain the extent to which the various models of fuel accumulation could conceivably be applied to dry sclerophyll forest and woodland in the Hobart area.

The study was necessarily limited in scope by time and the constraints imposed by uncertainty in relating fire history to particular areas.

### a) The Study Area

The area selected for the study was the Mt Nelson range bordered to the west by the Southern Outlet Highway which had been generally burnt in the 1967 fire and since which time a reasonably comprehensive fire history was available.

### b) The Forest Types Studied

One aim of the study was to see if practically different litter accumulation rates were exhibited by dissimilar eucalypt species in the broad dry sclerophyll and woodland classification and consequently two dissimilar eucalypt communities were selected for study, these being *E. obliqua* and *E. pulchella*. These two species are very different in their leaf and bark types with the latter generally occupying the more exposed drier sites.

Areas dominated by these species respectively which had been unburnt since 1967 were selected for possible study.

### c) General Methodology

Sampling plots were located in the above forest types with the selection of plots being based on estimated crown cover of the eucalypts. As far as possible, a range of crown covers was required to be sampled within each eucalypt type.

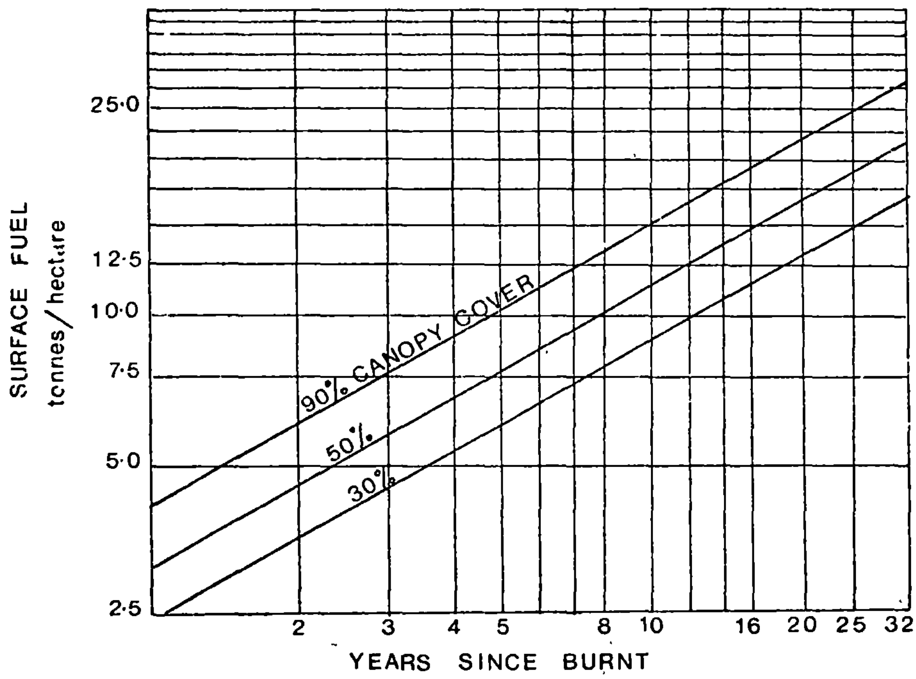
The actual field location of a sampling plot involved walking to an area which was likely to exhibit a desired eucalypt type and then establishing a plot within this general area.

The sampling plots were 30m x 30m in size within which two 50cm x 50cm quadrats were randomly located in each quarter of the plot. All dead material less than 1cm thickness was collected on each quadrat and weighed

FIGURE 1

Fuel Accumulation Model

(From McArthur, A.G., 1962; Control Burning in Eucalypt Forests, Forestry and Timber Bureau Leaflet No. 80, Canberra).




If shrub layer is present, increase fuel quantity as follows:

| Shrub cover % | Additional fuel (tonnes/hectare) |
|---|---|
| 10-30 | 2.5 |
| 35-50 | 5.0 |
| 55-75 | 7.5 |
| >75 | 10.0 |

with a sample of litter from each quadrat being collected for oven-drying. Segregation of the litter into grass component, Casuarina component and the remainder was done prior to weighing if significant proportions of these components were present on the plot.

The eucalypt crown cover of the plot was estimated by firstly locating the eucalypt trees on a plot diagram and then sketching in the crowns for each tree including those that overlapped onto the plot from trees outside it. The percentage crown cover was subsequently quantified by adding up the number of $1m^2$ units occupied by crowns relative to the total $900m^2$ units in the 30 x 30m plot.

As undoubtedly litter on the plot could also originate from crowns outside, the plot was located as far as possible in a generally homogeneous area with respect to crown cover.

No attempt was made to quantify the contribution to the fuel made by the shrubby understorey, although estimates of the average height and crown cover were made for the major ground and shrub understorey species on each plot for possible later use.

The litter samples taken from each quadrat were then oven-dried at $105^{o}C$ for 24 hours and the moisture contents determined from this were then used to adjust the total quadrat litter weights to an oven-dried basis.

A total of six plots were established and measured in the above way for both the *E. obliqua* and *E. pulchella* communities.

d) Results

Table 1 shows the results obtained from the field study. The litter weight referred to here is the oven-dried weight of dead material less than 1cm thickness.

Also included in this table apart from the plots established in 8 year old fuel, are the results from five plots established in an *E. pulchella* community which had been control burnt two years previously.

TABLE 1

Litter Accumulation Results for Two Dry Sclerophyll Eucalypt Types

| Eucalypt type | Years since burnt | Eucalypt crown cover | Grass cover | Casuarina cover | Litter weight (tonnes/ha) | | |
|---|---|---|---|---|---|---|---|
| | | | | | predom. euc. | Grass | Casuarina |
| *E. obliqua* | 8 | 23% | 30% | | 4.8 | | |
| | | 34% | | | 6.7 | | |
| | | 36% | | | 7.0 | | |
| | | 39% | 5% | | 8.4 | | |
| | | 44% | 5% | | 8.0 | | |
| | | 46% | 15% | | 7.8 | | |
| *E. pulchella* | 8 | 23% | 20% | 25% | 4.4 | 1.7 | 2.4 |
| | | 28% | 55% | | 4.5 | 2.6 | |
| | | 33% | 60% | | 6.6 | 2.4 | |
| | | 43% | 45% | | 7.8 | 1.8 | |
| | | 44% | 80% | | 9.0 | 1.0* | |
| | | 46% | 35% | | 8.9 | 0.5 | |
| | 2 | 21% | 65% | 5% | 2.4 | 2.4 | 0.1 |
| | | 30% | 65% | | 3.0 | 1.5 | |
| | | 46% | 60% | 10% | 3.6 | 0.8 | 0.3 |
| | | 51% | 10% | | 5.4 | | |
| | | 63% | 10% | | 4.1 | 0.1 | |

* This plot had been grazed.

e) Analysis of Results

It can be readily seen that the presence of a significant grass understorey or a *Casuarina* overstorey severely complicates the relationship of litter accumulation to eucalypt crown cover.

For the present, assume that we are dealing with a forest containing only the normal array of dry sclerophyll shrubs with the exception of Casuarina and specifically without a dominant grassy understorey. For this type of forest, the litter weights shown above as predominantly eucalypt can be reasonably expected to apply.

The data suggests a linear relationship between crown cover and litter weight over the range of crown covers that were sampled.

The linear regression of litter weight (y) on crown cover (x) for *E. obliqua* and *E. pulchella* for 8 years accumulation, was determined to be the following:

*E. obliqua* $y = 1.82 + 0.14x$ correlation coefficient: 0.91
*E. pulchella* $y = 0.74 + 0.21x$ " " : 0.97

A statistical comparison of the two regression coefficients 0.14 and 0.21 using the t test for 8 degrees of freedom, showed that the difference was decidedly not significant indicating that the rates of litter accumulation between the *E. pulchella* and *E. obliqua* communities were essentially the same.

The results for both eucalypt types were then combined into a single regression which gave

$y = 0.33 + 0.18x$ with a correlation coefficient of 0.94

The following table presents litter weights predicted from the above regression for the range of crown classes covered in the study and also includes the litter weights correspondingly predicted from other sources.

TABLE 2

Predicted litter weights using various fuel accumulation models

| Prediction source | Eucalypt crown cover | | | |
|---|---|---|---|---|
| | 20 | 30 | 40 | 50 |
| Above regression | 4.0 | 5.8 | 7.6 | 9.4 |
| McArthur (1962) | | 7.8 | | 10.0 |
| Hatch (in McArthur 1967) | | | | 10.1 |
| +Peet (1971) | 7.4 | 9.2 | 10.4 | 10.9 |

\+ The model developed by Peet (1971) for dry sclerophyll jarrah forest unfortunately is only applicable up to 5 years after the last burn.

The nature of this model defined by the following equation

$$y = (0.1932x_1 + 0.8067 \log x_2 - 0.6245)^2$$

where $y$ = litter weight; $x_1$ = years since burnt; $x_2$ = crown cover causes the input of the variable 'years since burnt' of more than 5 years to give absurd results for litter weight. For the 5 year period, however, the relationship of litter weight/age is close to being linear within each crown class. The results shown in the table above are derived by determining this linear function and then extrapolating to eight years since burnt within each crown class.

Owing to the fact that litter accumulation rates tend to decrease with time, this approach if anything yields a slight overestimate.

f) Discussion of Results

The results obtained from the field study do not show close agreement with those fuel accumulation rates predicted from other models. Our results being consistently below those from other studies, particularly for the lower canopy classes.

A large variety of reasons contributing to this divergence could be readily envisaged and owing to the limited nature of the study and small number of plots established, it cannot be confidently stated that a real different exists in litter accumulation rates between those observed in the forests from which the other models are derived and the dry forests in the Hobart area.

The high divergence of the results obtained in this study and those from other models at the lower canopy classes could possibly be due to the greater variation in litter weights over the plots at these low crown covers. The relatively small number of quadrats established could purely by chance have yielded much lower estimates of litter weights than could have been estimated using a higher sampling intensity of quadrats.

A reasonably close agreement between predicted litter weights from the various models does exist for 50% crown cover which tends to suggest that the models may in fact be comparable at these higher canopy classes.

From general observations and those taken during the field study, however, it would appear that much of the dry forest has canopy covers generally less than 50% and differences of the order exhibited between the field study and the other models at the lower canopy classes could be quite significant in determining the interval between successive hazard reduction burns.

A more intensive field study would be required however, before this observed difference could be definitely stated as being real and not due to sampling error or measurement bias.

The litter weights contributed by grasses and *Casuarina spp.* have up till now not been considered. McArthur specifically states that his model does not apply to forests with a predominant grassy understorey hence from the outset this component was dealt with separately.

It can be seen from the results in Table 1 that after 8 years a high percentage grass cover can contribute up to an additional 2.5 tonnes/ha and what is equally important, this additional weight can be reached after 2 years. This suggests that grass litter is readily decomposed and that decomposition rapidly balances accumulation after a maximum period of 2 years, thus the grass accumulation will rarely exceed 2.5 tonnes/ha, and this only under tree canopy covers less than above 50%.

Early observation had shown that *Casuarina spp.* particularly *Casuarina stricta* contributed significantly to the groundlitter wherever the species occurred by shedding prolific quantities of pine-like needles. The fact that its distribution over the dry forest was fairly sporadic prompted us to consider its contribution to the total litter weight separately, as otherwise considerable variation in litter weight could occur between otherwise similar eucalypt crown cover. The results obtained suggests that the contribution to the litter by this species is certainly practically significant; an approximate 25% cover yeilding 2.4 tonnes/ha in 8 years. Denser stands could conceivably yield twice this quantity.

## CONCLUSIONS

The ground litter accumulation after 8 years obtained by a limited study on two dry sclerophyll eucalypt types, *E. obliqua* and *E. pulchella*, in the Hobart area was not significantly different between the two eucalypt types.

The results obtained, however, showed a consistently lower litter accumulation relative to eucalypt crown cover than was predicted from the McArthur fuel accumulation model (1962) or from those from other sources: Peet (1971).

The differences were most marked at the lower eucalypt crown cover classes whereas for the 50% crown cover class, a similar litter weight was predicted in all cases, i.e. approx 10 tonnes/ha.

The field study was not sufficiently intensive to state with certainty that litter accumulation rates in the Hobart area are below those predicted by the McArthur model; however, the results do tend to suggest this particularly for less dense forests. Further intensive study is needed to appraise this possibility fully and its subsequent implications to hazard reduction planning.

The presence of a grassy understorey can contribute up to 2.5 tonnes/ha of fine fuel under relatively open forest, perhaps in the first year after a burn but further accumulation probably does not occur due to an accumulation-decomposition equilibrium.

An understorey of *Casuarina* can contribute significant amounts of fine fuel. Crown covers of 50% may contribute up to 5 tonnes/ha in 8 years.

In the context of hazard reduction, the results considered together with the other fuel accumulation models suggest that a hazard reduction burning rotation of every 8 years would maintain the available fuel component of dead material below 12.5 tonnes/ha over virtually all of the dry forest of the H.S.F.A. with most of the forest carrying less than 10 tonnes/ha of available dead fuel.

## REFERENCES

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