FIRE PROTECTION BRANCH

RESEARCH REPORT

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EFFECTIVENESS OF FUEL-REDUCTION BURNING

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C O N T E N T S

SUMMARY

The principle of fuel-reduction burning is that the resulting decrease in fuel quantity will slow or stop the spread of a fire which originates inside, or spreads into, a fuel-reduced area. That a decreased fuel quantity leads to a reduced rate of fire spread, and therefore fire intensity, has been clearly demonstrated by studies of fire behaviour in eucalypt forests.

Fuel-reduction burning is conducted within strategic areas to hinder the development of major fires, and also to provide close protection for specific high-value assets. The most dramatic examples of the impact of fuel-reduction burning can be found where fires have spread to barriers created by intensive burning. Such burns, usually of relatively small area, have played a vital role in settlement protection in particular.

Large fuel-reduced areas have also provided substantial assistance during fire control operations although, because the total fuel quantities left are usually greater than after a small-scale operation, their effectiveness is more closely linked with fire intensity. They have frequently helped to minimise the spread of lightning-caused fires and therefore assist fire control in often difficult and remote terrain. However, under conditions of very high to extreme fire danger, where a fire has entered on a broad front, such areas have sometimes had little impact on spread rates. Because it is clear that the present standard of fuel-reduction is not always adequate, operational techniques which achieve greater reductions in fuel quantity need to be implemented.

INTRODUCTION

Fuel-reduction burning[1] is a major component of the fire protection work undertaken in Victorian forests and during the last few years there have been a number of investigations of the impact of particular fuel-reduced areas on fire suppression operations. Such investigations are difficult because wildfire[2] behaviour, the level of fuel-reduction achieved and the impact of suppression activity are difficult factors to quantify. However, the investigations conducted (Case Studies 1-10, appended) have provided useful information and they form the basis for comments on the effectiveness of fuel-reduction burning that are included in this report.

BACKGROUND INFORMATION

The principle of fuel-reduction burning is that a decrease in fuel quantity will slow or stop the spread of a fire which originates inside, or spreads into, a fuel-reduced area. The effect of reduced fuel quantity on fire behaviour can be illustrated by a look at predictions of fire behaviour made using the Forest Fire Danger Meter (McArthur, 1967). The Meter integrates a number of the factors which affect fire behaviour into a single index of fire danger. This Fire Danger Index (FDI) can then be combined with the known quantity of fine (<6 mm diameter) fuel on the ground to estimate the likely rate of forward spread, flame height and spotting distance of a fire.

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1. The practice of fuel-reduction burning is described by Luke and McArthur (1978).

2. The term wildfire is used to indicate a fire other than a planned fire. It does not imply any particular level of fire intensity.

The variation in fire behaviour that can occur with different fuel quantities, if for example the FDI is 50[1], is shown in Table 1 and it is apparent that the level of fire activity is substantially reduced in areas with lower fuel quantities. In this example a fire burning in fuel quantities greater than 10 t/ha would be very difficult to control using direct-attack methods, even if access into the fire area was good.

TABLE 1 - FUEL QUANTITY AND FIRE BEHAVIOUR (FDI = 50)

Fuel Weight (t/ha)	Rate of Spread (m/hr)	Flame Height (m)	Spotting Distance (m)
5	280	3.5	800
10	560	8.5	1 700
15	850	14.0	2 800
20	1 200	Crownfire	3 800

1. A FDI of 50 can be produced by a temperature of 35°C, relative humidity of 20%, wind speed of 40 km/h and a drought factor of 10.

The length of fire perimeter on which control work is required determines, to a large degree, the difficulty associated with suppression operations. Using the same conditions as for Table 1, Table 2[(1)] shows the minimum lengths of control line requiring construction after a fire has burnt unhindered for two hours or four hours. Again the possible benefits to fire control of reduced fuel quantities are apparent.

TABLE 2 - FUEL QUANTITY AND FIRE PERIMETER (FDI = 50)

Fuel Weight (t/ha)	Perimeter (km) at 2 and 4 hours from origin	
	2 hrs	4 hrs
5	1.3	2.6
10	3.4	7.0
15	5.1	10.6
20	7.2	17.4
25	9.0	21.8

Fuel-reduction programs are planned to enhance the protection of settled areas and private property adjacent to forested land, people visiting or working in the forest and forest values. The increased protection is usually provided through a combination of broad-area burning, to give in-depth protection to both the forest and surrounding private property, and more intensive burning, usually on a smaller scale, adjacent to particular high-value areas such as townships, settlements and softwood plantations. Burning to provide a high level of protection

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1. This table was derived from Table 2 in Fire Control Notes, Forests Commission Victoria (1984 edition).

immediately adjacent to valuable assets may be on a rotation as short as three years and designed to reduce fuel quantities over a very high proportion of the area. In the larger areas chosen to provide in-depth protection, burning in areas of high priority is often planned on a four to seven year rotation, while longer rotations are planned in other areas. Large areas usually include considerable variation in both fuel properties and terrain, and these factors combine to make it impossible to achieve a relatively uniform reduction in fuel over the whole area. The proportion of the treated area which is burnt will often be less than 50% and the result of one operation is shown in Figure 1. Note that only the more exposed and therefore drier ridges and slopes have been fuel-reduced with, under the conditions prescribed, fires not being sustained on the moister slopes or in gullies.

The extent of fuel-reduction burning over the last ten years has ranged from 62 350 hectares in 1982/83 to 477 160 hectares in 1980/81 with the average area treated each year being 224 500 hectares (Table 3). The large differences between years in area treated are related to seasonal conditions and the capacity to do the necessary work in the limited periods of suitable weather.

TABLE 3 - GROSS AREAS TREATED BY FUEL-REDUCTION BURNING

Year	Area (ha)	% of forest treated*
1974/75	165 920	2.2
1975/76	204 820	2.7
1976/77	188 870	2.5
1977/78	164 760	2.2
1978/79	98 950	1.3
1979/80	345 050	4.6
1980/81	477 160	6.4
1981/82	167 140	2.2
1982/83	62 350	0.8
1983/84	370 000	5.0
Average	224 500	3.0

* Total forest area is 7 450 000 ha (approx.).

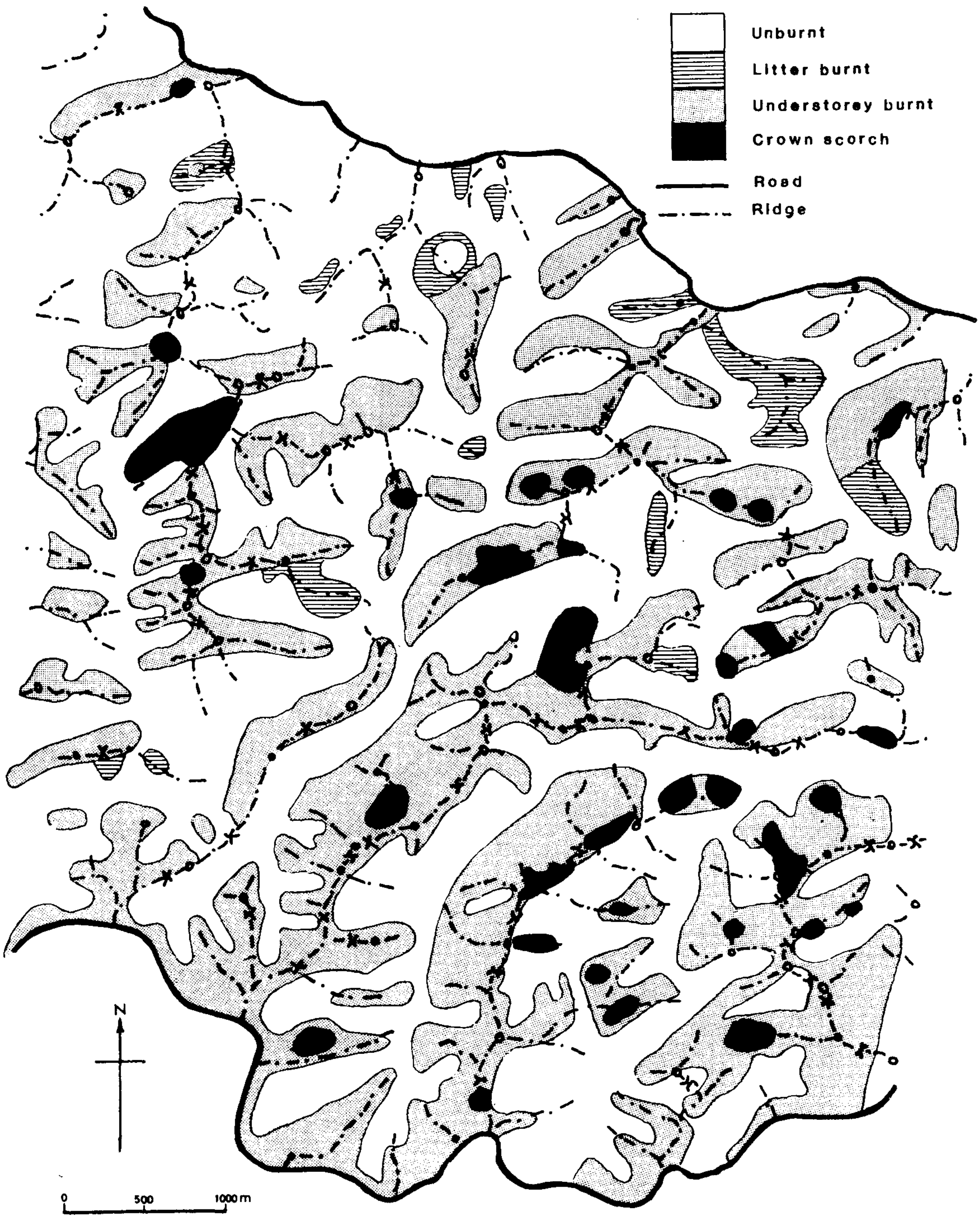

Figure 1: An example of the pattern of burning which can occur in a large-scale fuel-reducton operation. (Based on an operation in Heyfield Forest District in 1972).

The effectiveness of a fuel-reduced area will substantially depend upon the proportion of the total area which is burnt, the extent to which fuel quantities and other hazardous fuel properties have been reduced on the burnt sites and the distribution of burnt sites. For example, Figure 1 shows a relatively even distribution of burnt sites. A fire entering or originating in the area often will encounter areas of low fuel quantity. However, the ultimate impact of a fuel-reduced area will also depend on the intensity and size of the wildfire, the size of the treated area and the time since fuel-reduction was undertaken. The potential effectiveness will decrease as fuel quantities gradually increase after burning.

THE EFFECT OF FUEL-REDUCED AREAS ON FIRE SPREAD

There have been a number of recent instances where areas previously burnt by wildfire, which still contained low fuel quantities, have slowed or stopped the spread of a subsequent wildfire. A good example occurred near Cann River when an area burnt in 1978/79 remained substantially unburnt by another fire, which originated on 4 March 1983, despite the severe weather conditions which prevailed (Figure 2). As the level of fuel-reduction achieved in a prescribed fire of low intensity is markedly different from that which occurs in an intense wildfire, it is not possible to infer that areas fuel-reduced by low-intensity fire will have similar effects. However, the example clearly illustrates the potential for areas of low fuel quantity to impede fire spread.

Relatively small fuel-reduced areas have provided substantial assistance to fire control operations on a number of occasions and some of these are documented in the appended Case Studies. Of particular note are the circumstances described in Case Studies 1-5 where private assets under direct threat were saved when firefighting was assisted by the presence of fuel-reduced areas. Some areas stopped fire spread, and allowed the firefighters to concentrate on other sections, while others provided an

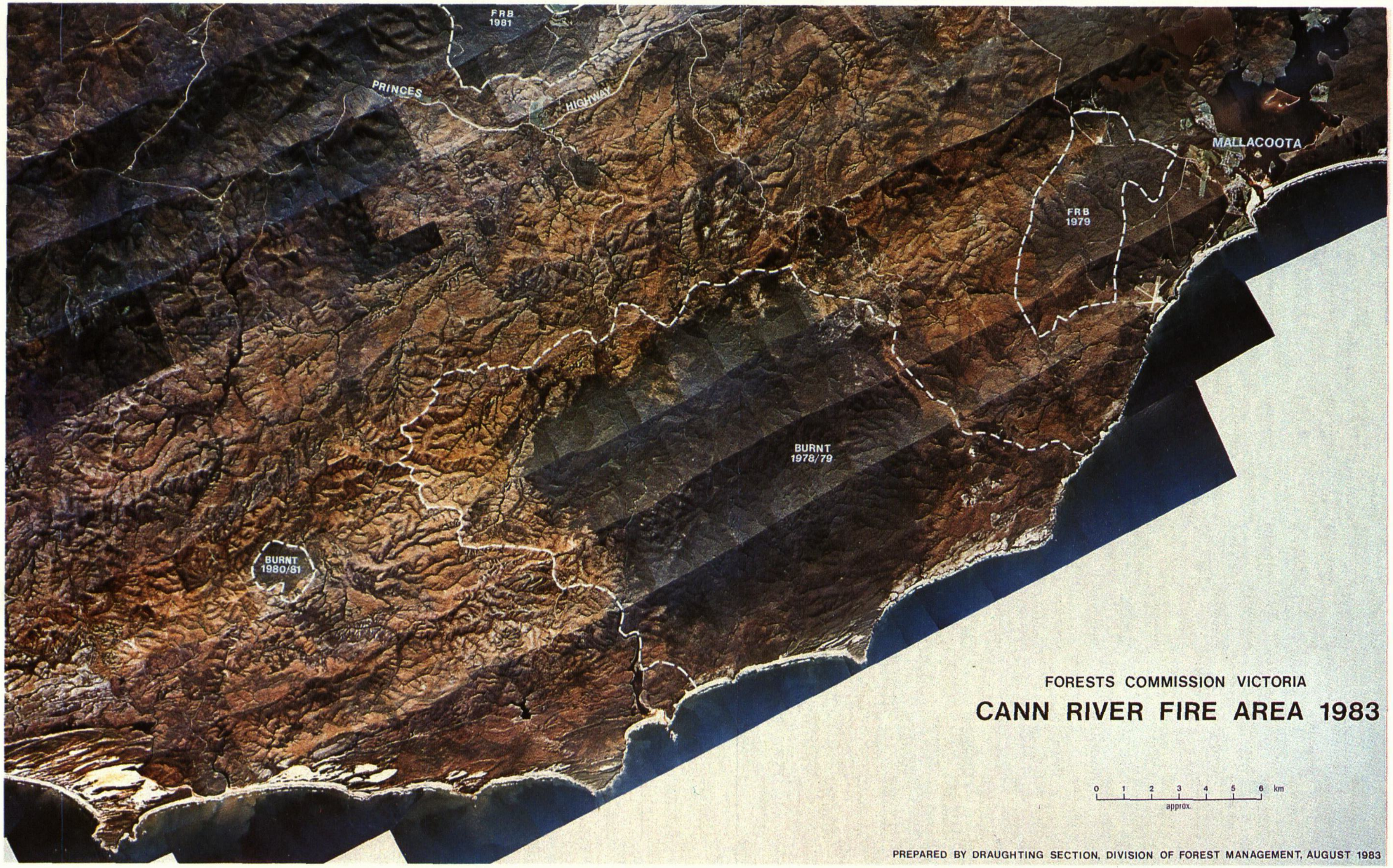

Figure 2: The impact of the 1978-79 fire on the spread of the Cann River Fire (March 1983)

opportunity to work close to valuable assets and protect them even though the fire was uncontrollable in areas that had not been fuel-reduced.

The impact of larger-scale fuel-reduction operations is harder to quantify although they have been important in a number of different circumstances. Lightning is a major cause of forest fire in Victoria being responsible for approximately 25% of fires and 51% of area burnt (Rees, 1984). Multiple fire situations often occur as a result of thunder-storm activity; for example, on 15 January 1978 more than 60 lightning-caused fires originated in the Eastern Highlands. Such fires frequently occur at remote locations and in difficult terrain where access may take many hours and cause the fire suppression resource to be severely extended. Extensive fuel-reduced areas are known to have minimised the spread of fires under these circumstances, thereby significantly assisting control.

The presence of large fuel-reduced areas has also assisted the control of fires under conditions of moderate to high fire danger and there were examples of this during the Cann River fires of 1982/83. This assistance may take two forms. The first is the direct impact on spread which can allow control work to take place close to the fire edge. The second is the provision of areas which can be used, with safety, to establish control lines when indirect attack and backburning methods are required (Figures 3 and 4).

Fire behaviour was extreme throughout much of the 1982/83 fire season. For example the Dean Marsh-Lorne fire of Ash Wednesday (16 February 1983) had, in one period, an average rate of forward spread of 10 km/h while the East Trentham-Macedon fire of the same day covered 16 km in 1.5 hours after a violent wind change to the southwest. (Rawson et. al. 1983). Even where conditions were not as bad as on Ash Wednesday, but spread rates still averaged 2-4 km/h, the evidence is that some of the larger fuel-reduced areas did not have a substantial impact (Case Studies 9 and 10). The reasons for this are probably related to an

Figure 3: An area near Mallacoota not burnt for a long period. Access and visibility for firefighting are severely restricted.

Figure 4: An area near Mallacoota fuel-reduced in 1979-80. Access and visibility are improved. (1983 photograph).

unsatisfactory level of fuel-reduction achieved in the first instance.

CONCLUSION

The theory of fuel-reduction burning has a sound basis in the research which has been conducted into the relationship between fuel quantity and fire behaviour and the results of fuel-reduction burning have assisted fire control operations under a wide range of conditions. However, at the highest levels of fire danger the amount of fuel-reduction achieved in larger-scale operations has proved to be inadequate on occasions. The problem of achieving a higher level of fuel-reduction over broad areas could be approached either by burning under drier/warmer conditions, or through the use of multi-stage burning techniques. The first option is not practical because of the control problems likely to be encountered. The second option, which uses a succession of burns within the same area to progressively increase the network of fuel-reduced sites, is viable and likely to be applied more often in future.

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CASE STUDY 1 - LORNE, ANGLESEA (1983)

On Ash Wednesday (16 February 1983) a fire in the Otway Ranges caused the deaths of three people and destroyed nearly 800 houses in burning an area of 41 200 hectares. Most of the property damage occurred in coastal settlements between Lorne and Anglesea.

The fire behaviour was extreme with spread rates up to 10 km/h and intense spotting over distances up to 10 km. Under these circumstances firefighters concentrated their efforts in and around settled areas and in some locations their work was assisted by the presence of forested areas in which fuel quantities had been reduced.

Lorne

Lorne is a popular summer holiday resort where the demand for housing has led to the development of several sub-divisions which encroach on the surrounding forest. In these areas, and others on the edge of the town, houses have been built in forest settings with a minimum of vegetation clearing and access. Fire protection relies heavily upon the provision of fuel-reduced areas, complemented by the presence of a number of other physical barriers such as the golf course (Map 1).

On Ash Wednesday the fire spread towards Lorne from the north-west and at 1620 hours, approximately 1.5 hours after ignition, spot fires were burning close to North Lorne at distances up to 15 km from the origin.

At about 1630 hours houses in North Lorne in Dorman Street and along the Great Ocean Road were threatened. Dorman Street was shielded from the main fire to some extent by an area which had been fuel-reduced in 1981/82 (Area A, Fig. 1 and Map 1), but spot fires started in scrub close to the beach and along Stony Creek and Little Stony Creek. They spread rapidly through overgrown house blocks and only a few houses, well protected by tidy surrounds, survived. The fuel-reduced area was eventually burnt but, as Fig. 1 shows, at a much reduced intensity.

On the road between Little Stony Creek and the cemetery (Area B, Fig. 1 and Map 1) firefighters, assisted by good access and the shelter provided by the Golf Course, saved many houses. Houses further to the south were also shielded by the Golf Course but poor access and overgrown house blocks again hampered operations.

The threat to most of Lorne was eased by a strong south-westerly wind change at 1900 hours. Prior to this the south-western flank posing the most immediate threat to the rest of Lorne was slowed by an area (Area C, Fig. 2 and Map 1) which had been fuel-reduced in 1980/81.

The planning and subsequent implementation of fire protection works around Lorne substantially assisted firefighting operations. Firefighters were able, in some areas at least, to work behind fuel-reduced areas and other buffers in conditions where they were able to concentrate on spot fires developing in residential areas.

Coastal Settlements between Lorne and Anglesea

Apart from Aireys Inlet most of these settlements comprised low density housing with no reticulated water supply and poorly developed access. With few exceptions little clearing or reduction of fuels had been undertaken close to houses or in the areas of scrub or forest-covered private property surrounding these settlements.

Fire protection works on public land were not extensive and limited by poor access. Some fuel-reduction burning had been carried out near Fairhaven, as well as to the west of Fairhaven (Map 2). Slashed firebreaks behind Eastern View and a powerline clearing through to Big Hill (Map 2) provided the only protection and access around some of the areas west of Fairhaven. The area of Moggs Creek had virtually no protection.

By 1800 hours on Ash Wednesday most of the coastal forest between Lorne and Big Hill had been burnt. With the wind change at 1900 hours the fire spread very rapidly towards Aireys Inlet and by 2000 hours it had burnt through Fairhaven and there were spot fires in Aireys Inlet.

At Fairhaven a series of narrow fuel-reduced strips and an area burnt by wildfire in October 1981 sheltered a small group of houses while most others were destroyed (Fig. 3 and Area D, Map 2). Further fuel-reduction burning near Fairhaven had been planned for the years 1982/83 to 1984/85 (Map 2) but, even if it had been completed at the time of the fire, much of Fairhaven would have remained vulnerable because of the high fuel loads on private lands. The value of reduced fuel quantities close to houses was clearly demonstrated in a number of instances, and Fig. 4 shows some houses near Moggs Creek which survived because they had some clearance from high fuel accumulations.

Anglesea

In Anglesea the demand for housing has resulted in a sprawling urban development with many houses on the fringes of the town being built on scrub-covered blocks.

Fairly extensive fuel-reduction burning had been carried out around the town by Country Fire Authority brigades, and the protection these areas provided was complemented by the Golf Course to the northwest and the Alcoa works area to the north (Map 3). An obvious weak link was a large stringybark and scrub-covered area of private property on the southwest boundary (Area E, Fig. 5 and Map 3) which had not been burnt for a long time.

At about 2100 hours on Ash Wednesday the fire was threatening the town from the southwest on several wide fronts. It burnt rapidly through the private property referred to earlier and into residential areas where it destroyed houses (Fig. 5). In other sectors however, the protection works assisted firefighters by breaking up fire fronts and reducing fire intensity (Area F, Fig. 6 and Map 3) and, although spot fires did occur within the town, the main part of Anglesea was protected.

Figure 1: Fire area near North Lorne

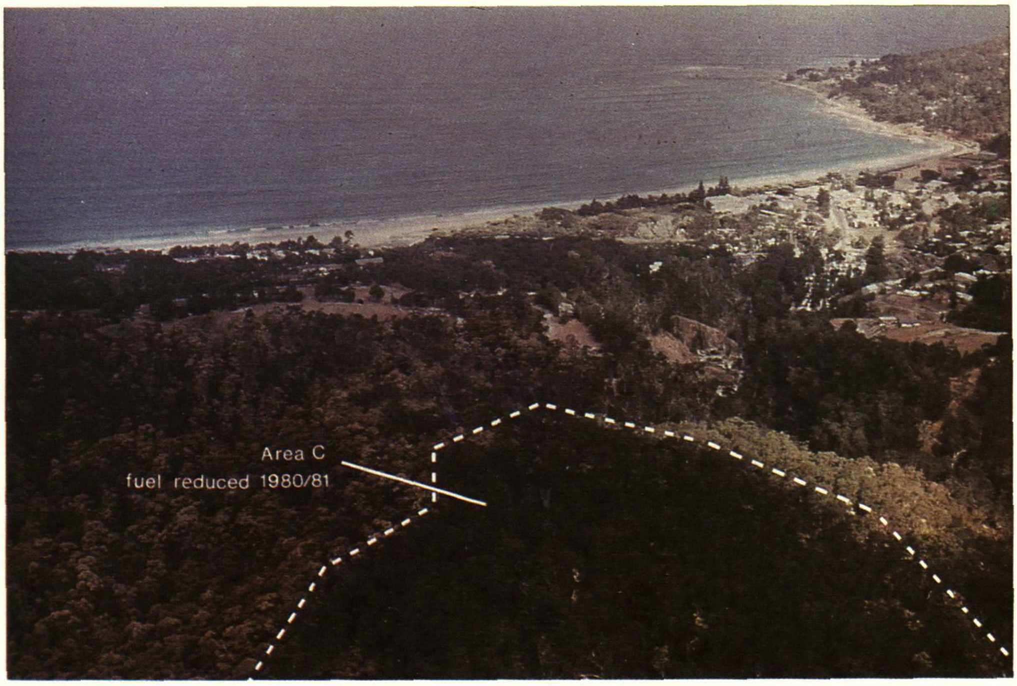


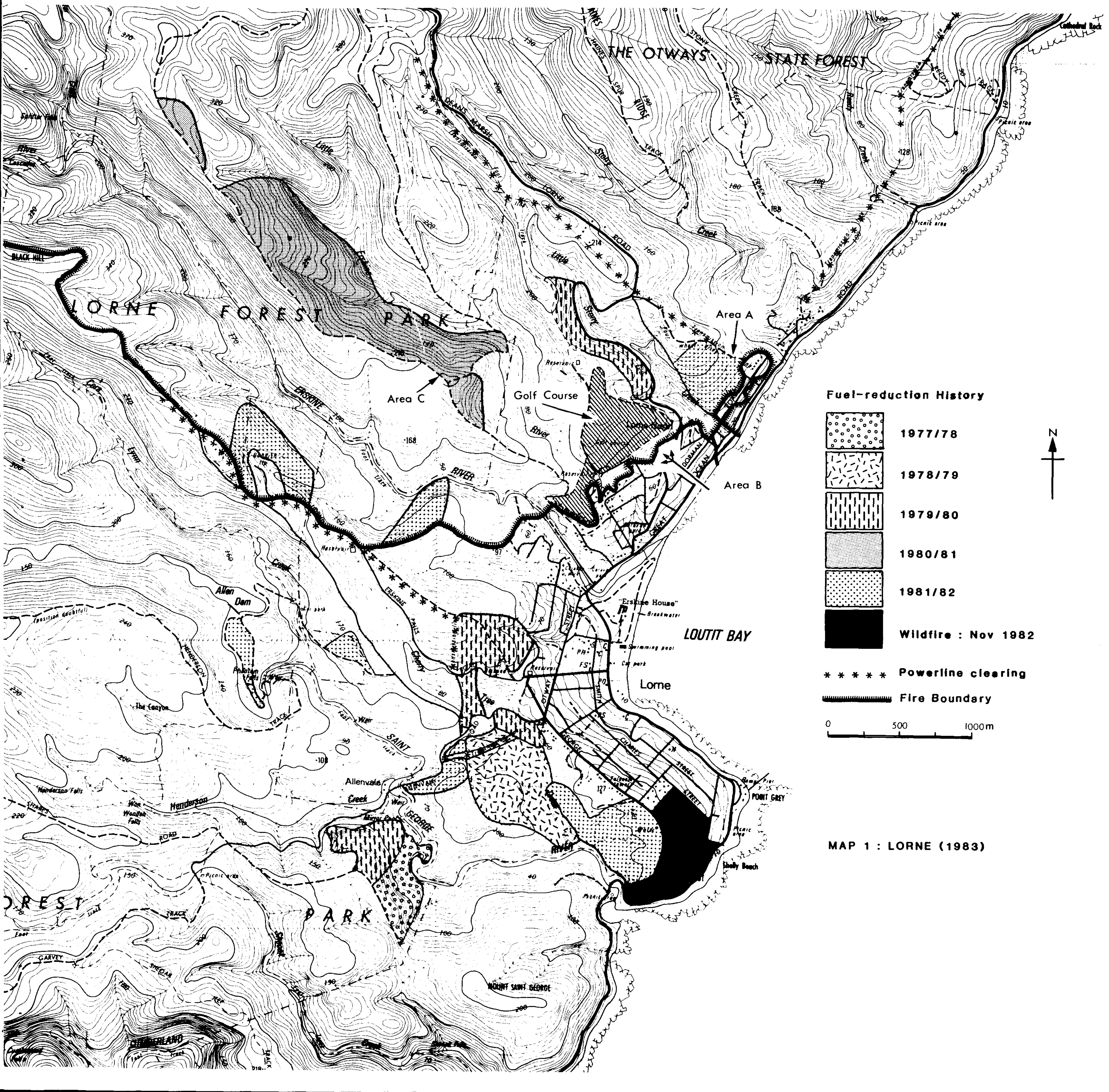
Figure 2: Fuel-reduced area near Lorne

Figure 3: Houses near Fairhaven protected by previously burnt area.

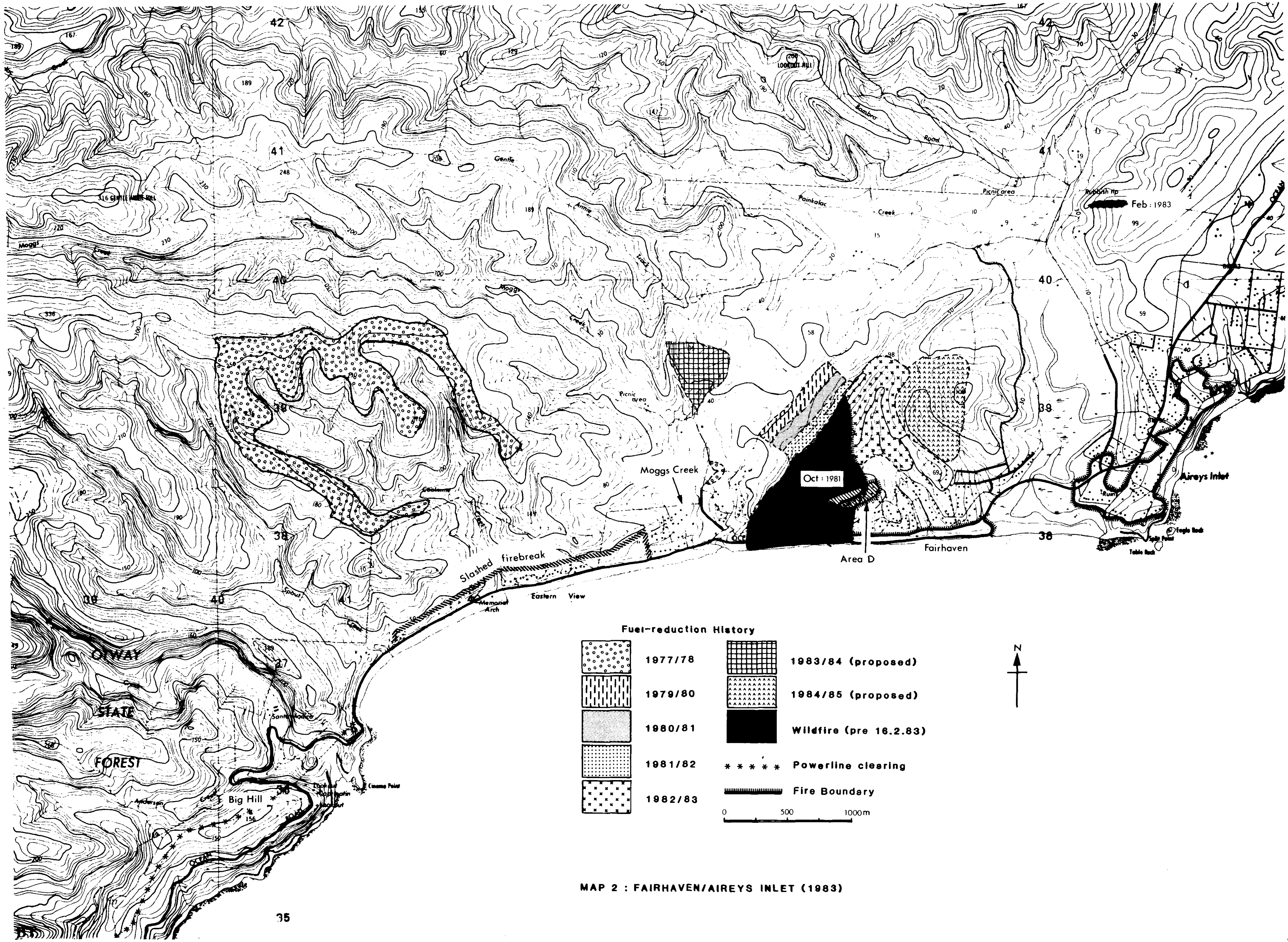
Figure 4: Unburnt Houses - Moggs Creek

Figure 5: Private property southwest of Anglesea

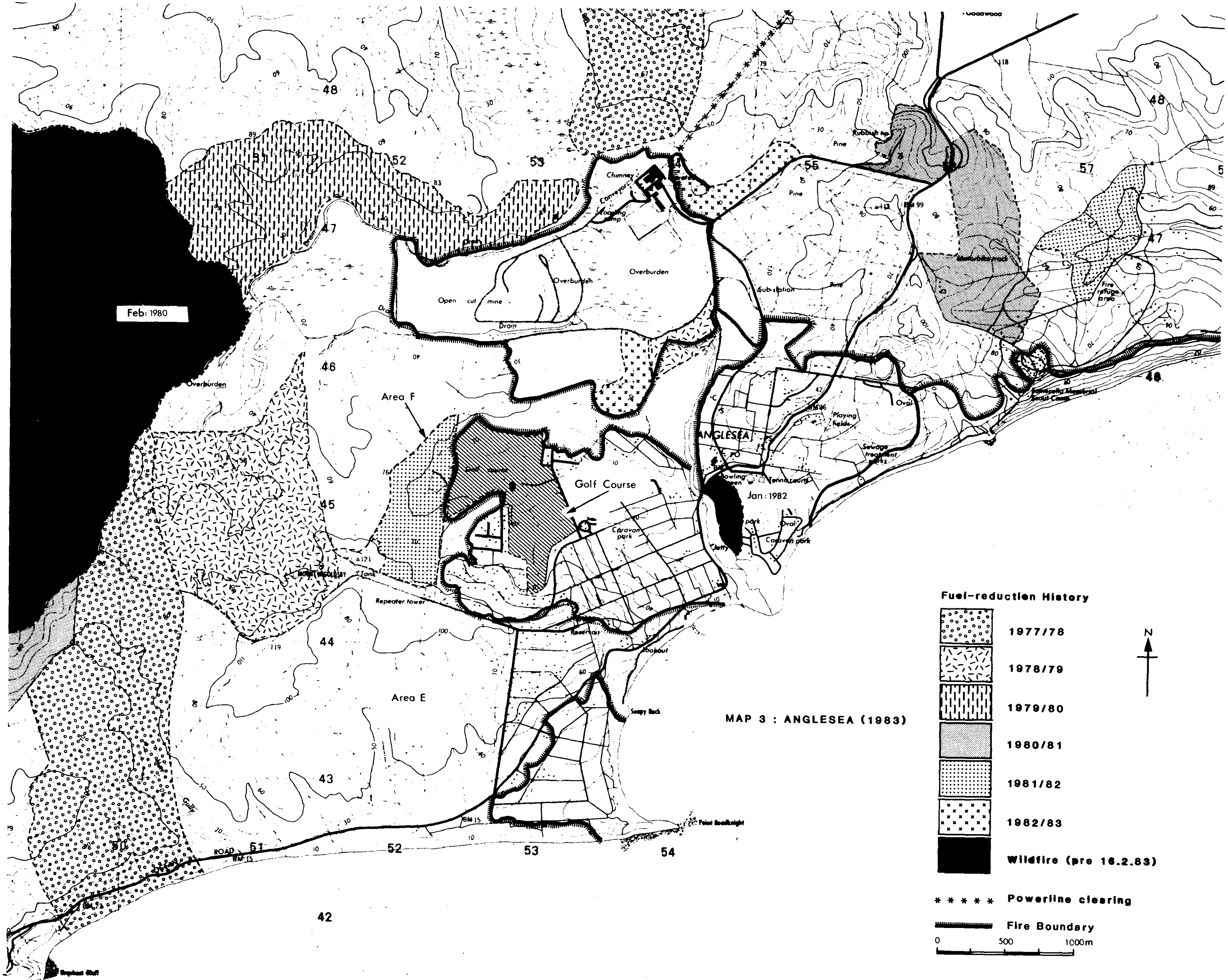
Figure 6: Fuel-reduced area near Anglesea



MAP 1 : LORNE (1983)



MAP 2 : FAIRHAVEN/AIREYS INLET (1983)



MAP 3 : ANGLESEA (1983)

CASE STUDY 2 - MT MACEDON (1983)

Braemar College near Mt Macedon has approximately 460 students. It is surrounded by forest dominated by messmate (*Eucalyptus obliqua*) and blue gum (*E. st. johnii*), much of which had not been burnt for at least 25 years prior to 1 February 1983. As a consequence fuel quantities in some places reached 20 t/ha. The only access to the College is by a road through forest leading in from the northeast and, to improve security if a fire occurred, an area of about 15 hectares adjacent to the College was fuel-reduced in September 1982 (Map 1).

At 1245 hours on 1 February 1983 a fire started to the southwest of the College. With the FDI close to 50[1] the fire spread rapidly uphill fanned by the strong north to north-westerly wind. Crown fire occurred in some areas and the spotting process became well established.

The College was being evacuated as Forests Commission and Country Fire Authority crews arrived at about 1300 hours. During the afternoon these crews were able to save the main buildings although several out-buildings were burnt as the fire spread across the slopes above the College. The situation became critical with a wind change to the southwest after 1700 hours. This spread the fire to the slopes below the College and north of the fuel-reduced area. This area then prevented the fire from burning rapidly upslope into the College, and it enabled crews to work safely in circumstances where they would otherwise have been in great danger. The impact of the reduced fuel quantity is clearly illustrated in Figures 1, 2 and 3.

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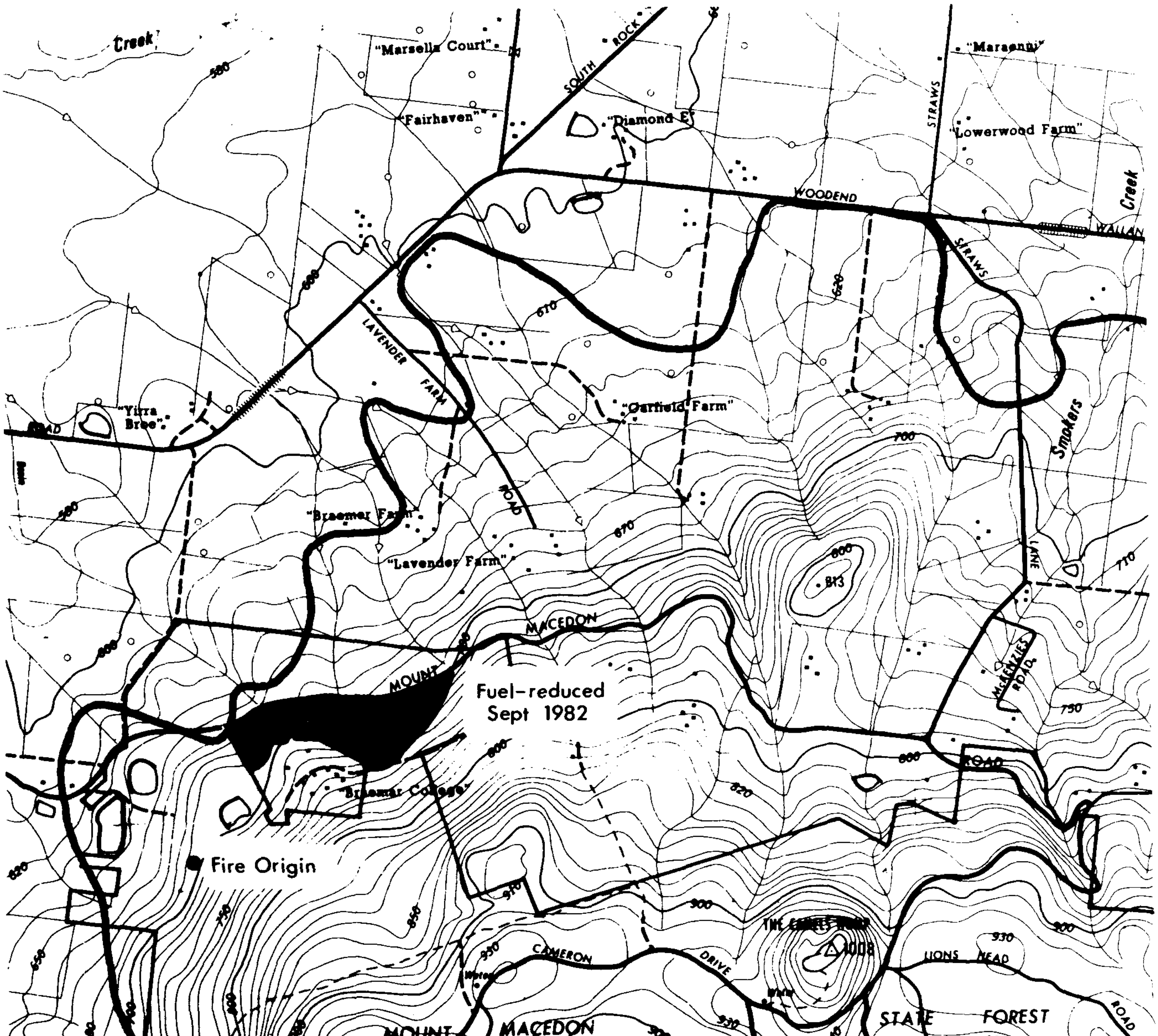
1 At Macedon (1200 hrs) conditions were: T = 38°C, RH = 15%, Wind 25 km/h



MAP 1 : MT MACEDON (1983)

Many other properties in the area were not as well protected. Generally these properties had poor access with houses located in forest settings with little or no attempt to reduce fuel levels. There were often deep litter layers and heavy fuels right up to the houses and eucalypts overhanging the roofs, choking the gutters with leaves, twigs and bark. It was not possible to provide protection under such circumstances and, in the total fire area of 5500 hectares, 24 houses were destroyed.

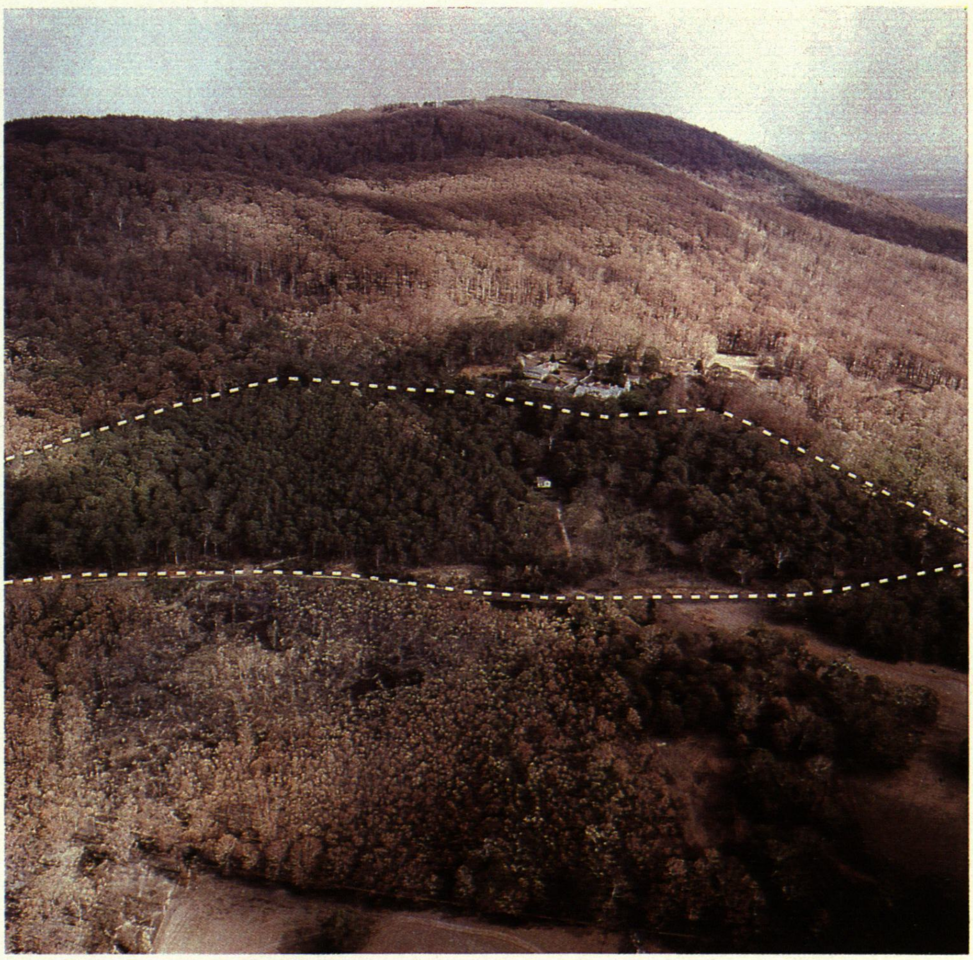


Figure 1: Fuel-reduced area near Braemar College.

Figure 2: Fire near Braemar College in fuel-reduced area (1800 hours)

Figure 3: Fire near Braemar College in area not fuel-reduced (1800 hours)

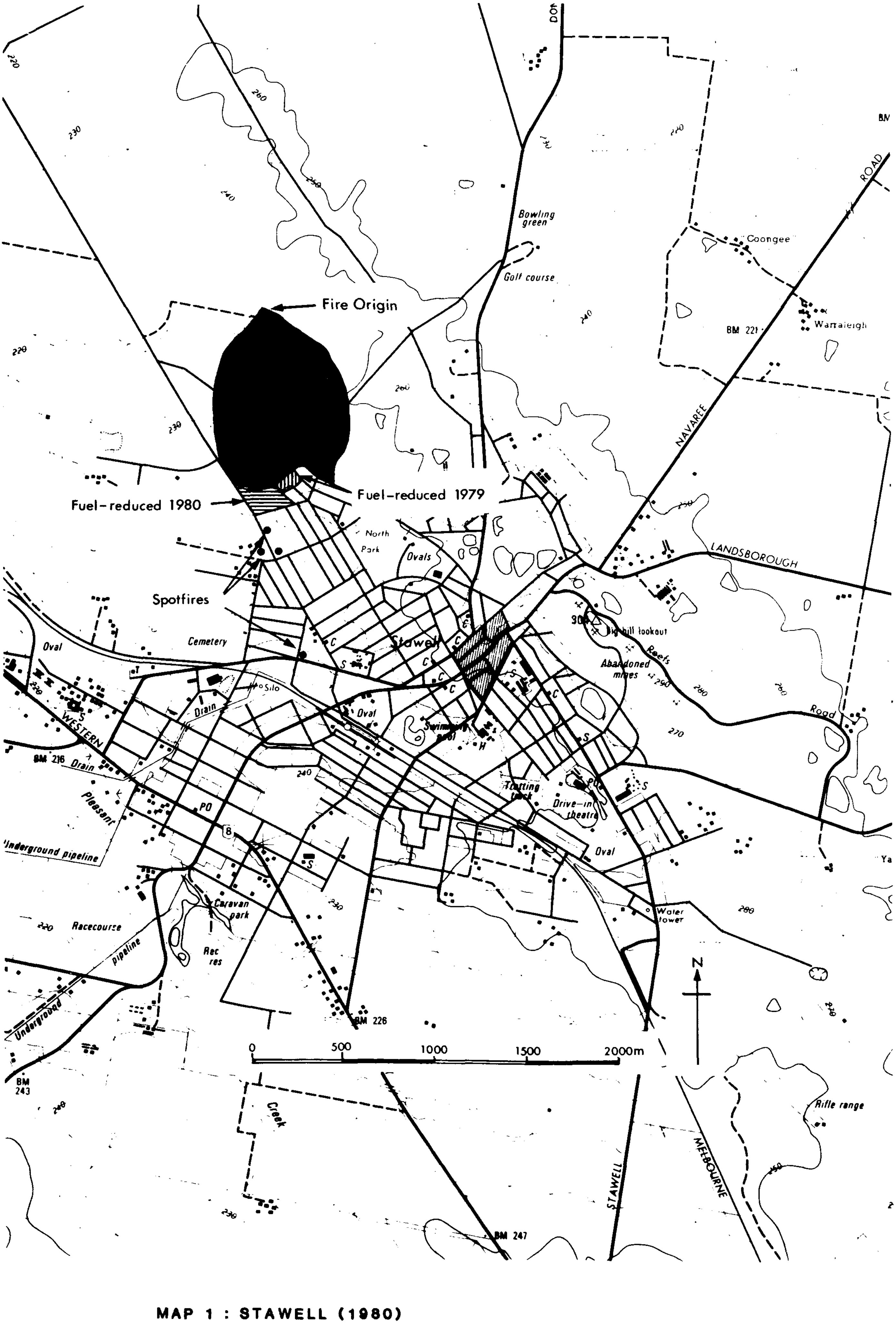
CASE STUDY 3 - STAWELL (1980)

On 21 December 1980 a fire started in grassland north of Stawell under conditions of extreme fire danger. Although the fire spread rapidly, fuel-reduced areas in forest on the outskirts of the town (Map 1) allowed firefighters to achieve control before any extensive damage to private property could occur.

Stawell is virtually surrounded by forest and the protection plan therefore includes provision for fuel-reduction burning. In this instance two areas were involved, with the first of 1.5 hectares being fuel-reduced in 1979 and the second, of 5 hectares, in 1980. Both areas are very close to houses on the edge of the town and in forest dominated by red ironbark (E. sideroxylon) and yellow gum (E. leucoxylon). Fuel quantities in unburnt forest were up to 10 t/ha while on cleared private property there was a dense cover of tall dry grass. Within the fuel-reduced areas fuel quantities remained low and were estimated to be less than 3 t/ha.

The fire started at approximately 1320 hours about one kilometre from the edge of the town. It was reported at 1325 hours and crews were on the scene within minutes. The FDI was extreme (52 at 1330 hours - Table 1) and fire development so rapid that the large suppression force of approximately 200 men, using 15 tankers and a bulldozer, was limited to a flanking attack and the protection of houses in the path of the fire.

In the first 30-40 minutes the average rate of forward spread was nearly 2 km/h, so that by 1400 hours houses on the edge of Stawell were under threat. Spot fires had also started up to one kilometre downwind on vacant blocks within the town and these were further hampering control operations. Fortunately, at this time the two fuel-reduced areas stopped the spread of the main front and firefighters were then able to concentrate on controlling the flank and spot fires and protecting houses. Further spread was stopped by 1500 hours even though the FDI remained extreme.



MAP 1 : STAWELL (1980)

TABLE 1 - WEATHER CONDITIONS

Time (hrs)	Temp (°C)	Relative Humidity (%)	Wind (km/h)	FDI
1200	29	23	N 25	27
1300	35	15	N 30	48
1400	37	13	N 30	54
1500	38	13	N 25	50
1600	38	13	N 25	50

There is little doubt that without the fuel-reduced areas the fire would have entered Stawell and caused substantial losses on private property. As it was losses in the 65 hectares burnt were confined to a few old out-buildings, some fencing and some farm machinery.

CASE STUDY 4 - BARKSTEAD (1980)

At 1400 hours on 17 January 1980 the faulty exhaust of a log skidder caused a fire in logging slash, west/northwest of Barkstead, within the Wombat Forest (Map 1). The FDI was high[(1)] and over the next 3.5 hours the rate of forward spread averaged 800-900 m/h as the fire spread towards Barkstead.

In November 1979 an area of approximately 60 hectares, on the western and northern boundaries of Barkstead, was fuel-reduced as part of the protection plan for the settlement. The fire was stopped when it reached this area at 1730 hours and no suppression action was required on 1.2 km of fire edge. The area was up to 400 m wide and this was sufficient to catch all the spotting activity from the main front except for one spot fire which occurred in Barkstead at 1730 hours.

If the fuel-reduced area had not been present a major suppression effort would have been required to hold the fire on the western edge of Barkstead, and it is doubtful whether a sufficiently strong force could have been mounted in time. In those circumstances properties would have been under severe threat and losses may have occurred.

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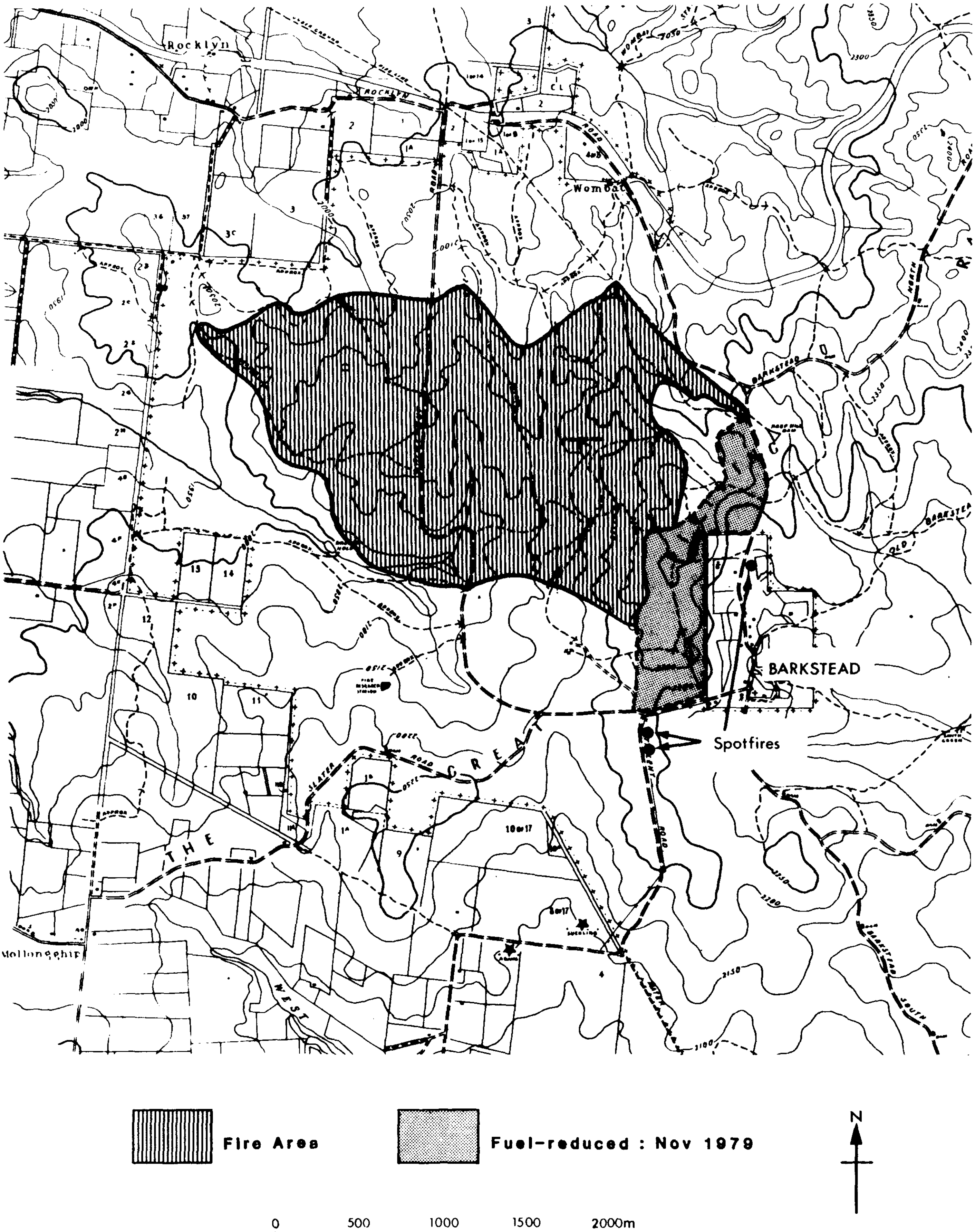
1 FDI at Daylesford (1500 hours) = 16 (T = 28°C, RH = 33%, wind - WNW 10-20 km/h)



MAP 1 : BARKSTEAD (1980)

CASE STUDY 5 - DIMBOOLA (1980)

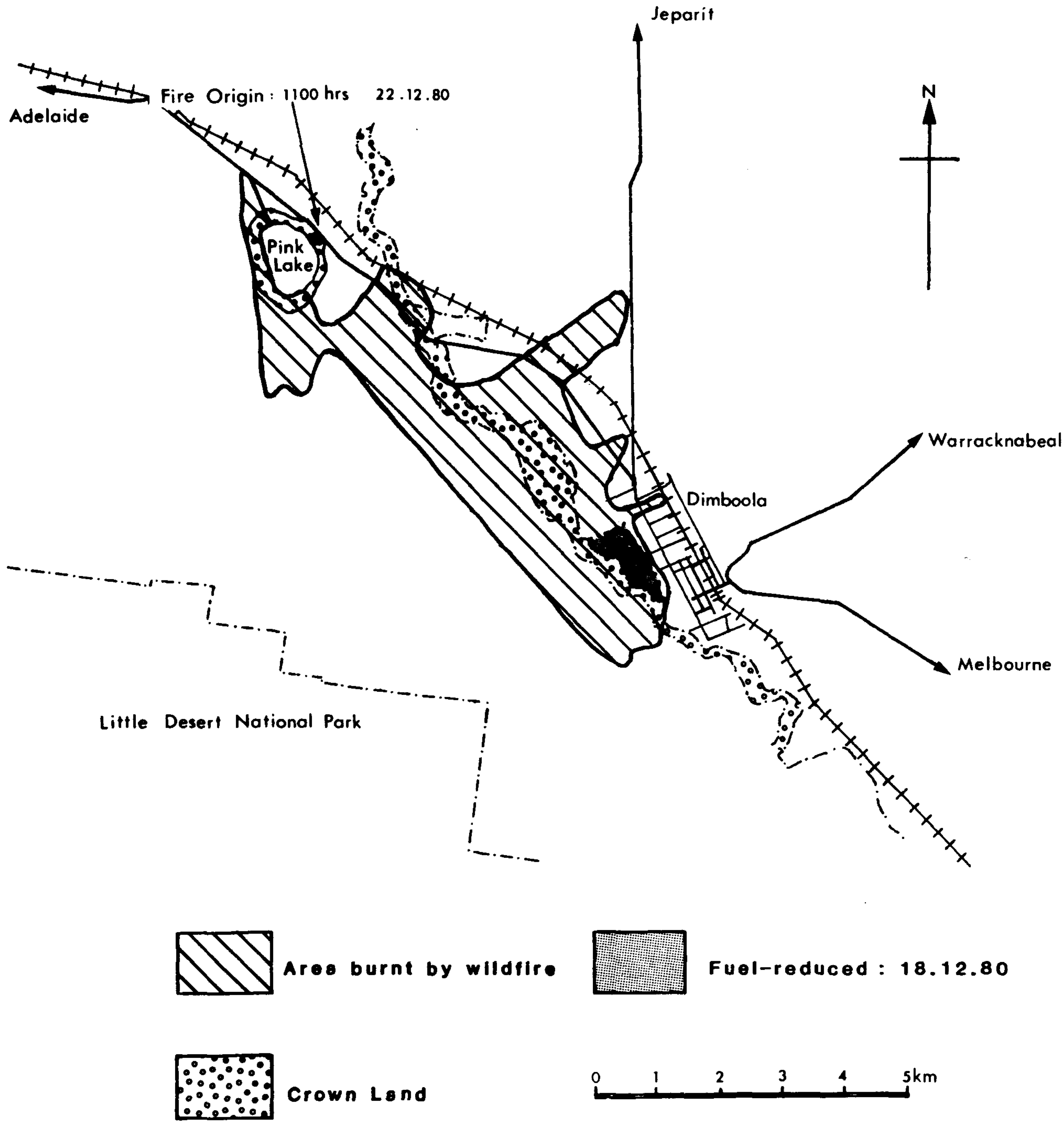
On 22 December 1980 the town of Dimboola was threatened by a fire which started at 1100 hours near Pink Lake (Map 1), 8 km northwest of Dimboola. An area which had been fuel-reduced four days earlier helped to protect the town in what was protentially a very dangerous situation. The area, approximately 100 hectares of Crown Land along the Wimmera River, was west of, and immediately behind, the main business area of the town.

The fuel quantity over most of the fire area was estimated at 8-10 t/ha and comprised fully cured grasses up to 0.5 m high with some branchwood and leaf litter. Along the Wimmera River scrubby vegetation increased fine fuel quantities to more than 20 t/ha.

At 1100 hours the FDI was in the mid-20's and the fire spread quickly through scrubby fuels around Pink Lake. Although the fire was very intense and difficult to attack it was checked by 1245 hours at an area of 200 hectares even though the FDI had risen to 30.

Weather conditions continued to deteriorate and at 1330 hours the strong northwest wind caused sparks from a burning stump to start a breakaway on the eastern flank when the FDI was close to 40. On reaching the Wimmera River the fire burnt fiercely in the heavier fuels along the river frontage and spread at approximately 5 km/h towards Dimboola. The situation worsened when the wind changed to the southwest at 1500 hours and the wind speed increased to 40 km/h, giving a FDI greater than 50. The north-eastern flank of the fire moved away on a front more than 6 km long.

Much of this front was burning along the river where access was poor, and it seemed there was little chance of preventing the fire entering the town. However the fire did not spread through the area that had been fuel-reduced. To the north, where fuel-reduction burning had not been carried out, the fire spread from the river frontage and crossed the Western Highway, threatening houses and out-buildings in this part of the town.



MAP 1 : DIMBOOLA (1980)

If the fuels in the area of approximately 100 hectares had not been reduced the fire would have entered Dimboola on a wide front from the southwest. An effective attack on this sector would not have been possible because of the heavy fuels and access problems along the Wimmera River frontage. With many vacant blocks within the town covered in long dry grass the fire would have continued to spread and threaten more buildings, and under those circumstances it is likely that substantial property losses would have occurred.

The fuel-reduced area effectively protected most of the town and allowed suppression forces to concentrate to the north and reduce the area burnt following the wind change. As a consequence, private property losses were minimised.

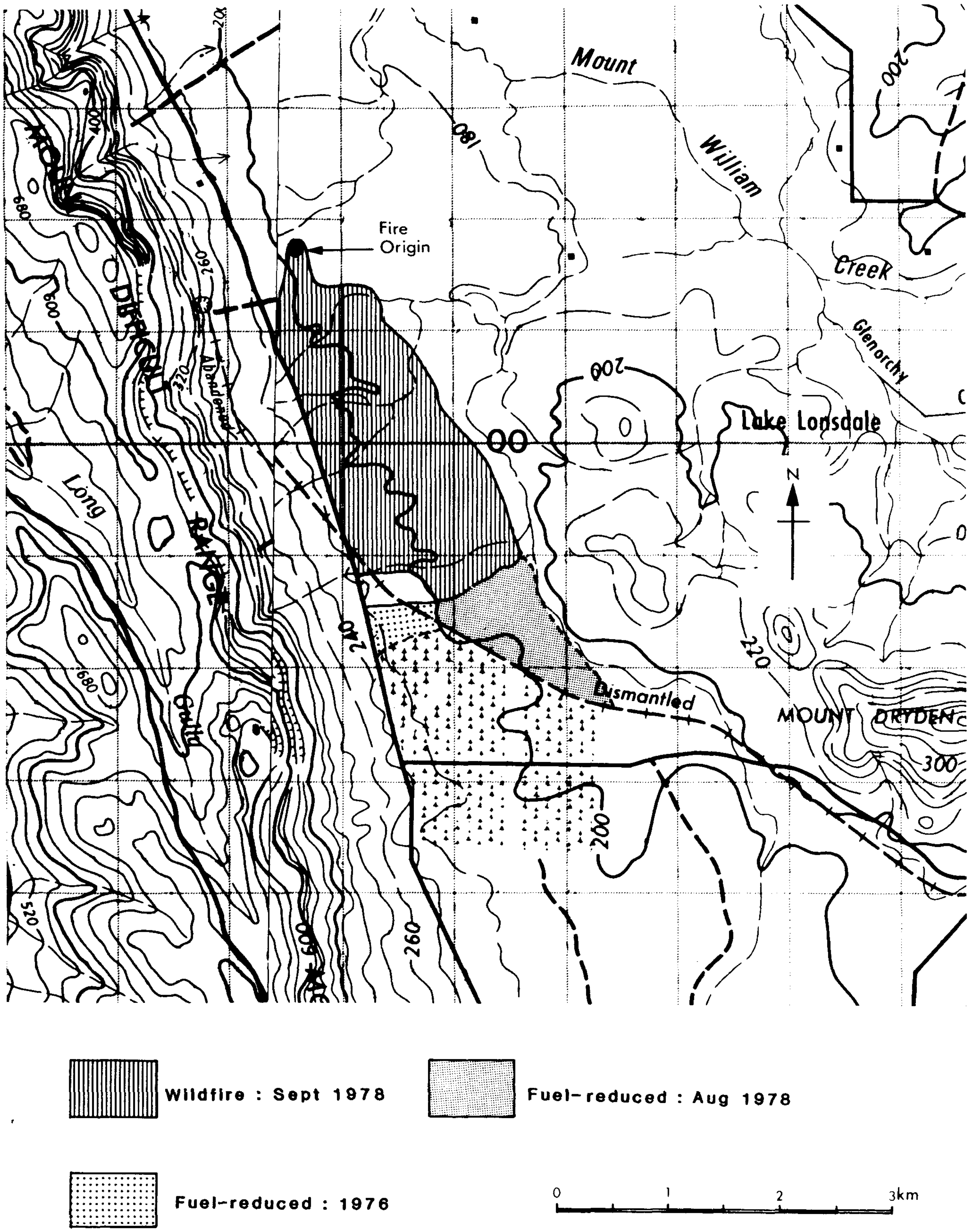
CASE STUDY 6 - GRAMPIANS (1978)

On 9 October 1978 a fast-spreading fire threatened the Mt Difficult Plantation (Map 1). It was reported at 1530 hours after it escaped from private property and spread into dense stringybark heaths in the Grampians State Forest. A strong north wind spread the fire at approximately 1 km/h and produced intense short distance spotting. The fire was too hot for a direct attack and much of the area was inaccessible due to wet ground conditions.

The vegetation cover comprised a dense open heath up to one metre tall with scattered brown stringybark (E. baxteri) 15-20 m tall. Fine fuel quantities were generally 15-20 t/ha although quantities of more than 25 t/ha occurred in a nearby area which had not been burnt for many years. Fuel quantities over an area of 80 hectares were reduced by low intensity fire during August 1978 as part of the protection plan for the Mt Difficult Plantation. The area was north of the plantation and scheduled for fuel-reduction every 5 years.

The fire spread into the recently fuel-reduced area and this sector of the fire required no further action, although suppression forces were unable to prevent the western flank crossing the Roses Gap Road in several places because of the high fire intensity and intense short distance spotting. With the onset of cooler evening conditions the western edge was controlled and a direct attack to secure the south-western flank was successful. The area burnt was 348 hectares.

Under a moderate FDI of 10 this fire burnt with a high intensity and spread rapidly. Poor access, caused by wet ground conditions, hampered suppression efforts and for much of the time the fire was too intense and spreading too quickly to be controlled using direct-attack methods. Without the extensive northern break created by fuel-reduction burning, the Mt Difficult Plantation would almost certainly have been burnt.



MAP 1 : GRAMPIANS (1978)

CASE STUDY 7 - GRAMPIANS (1981)

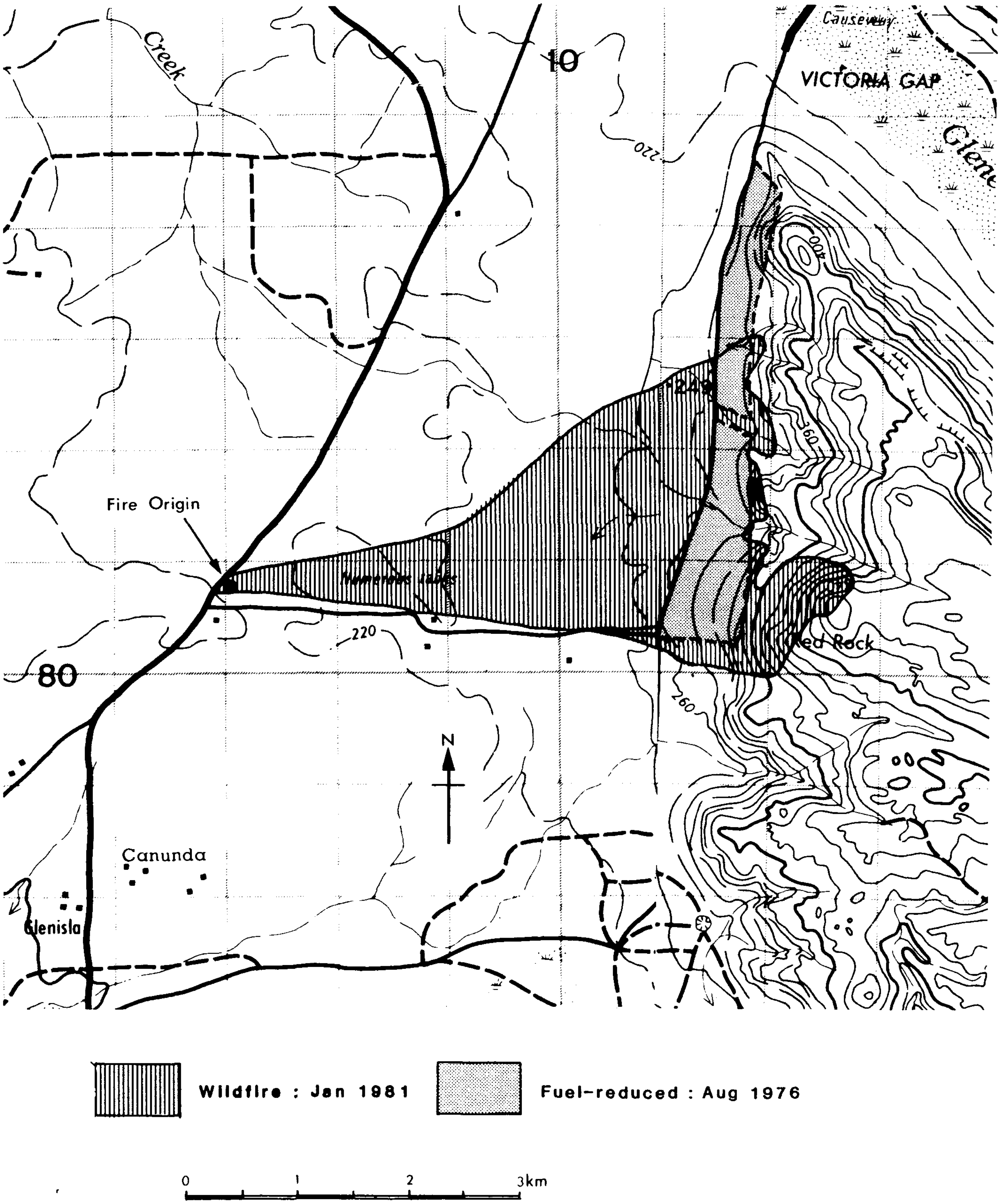
On 18 January 1981 a fire originated near the Henty Highway at 1415 hours when the FDI was close to 30 (Map 1). It spread across open grassland at about 4 km/h under the influence of a strongy westerly wind, reaching the boundary of the Grampians State Forest in one hour on a 700 m front which was too intense for direct attack.

The area was last burnt during a wildfire in 1962. The overstorey was predominantly brown stringybark and yellow box (*E. melliodora*) up to 15 m tall with a scattered understorey of heath species. Fine fuel quantities generally ranged from 10-15 t/ha although in some areas of denser vegetation quantities were up to 25 t/ha.

A strip of 130 ha between Red Rock and the Victoria Range escarpment was fuel-reduced in spring 1976. This strip was directly in the path of the fire and it temporarily held the fire as the front became fragmented and the spread rate and intensity were reduced. The southern flank eventually spread around the area and upslope towards Red Rock. Spotting also occurred across the area in several places at distances of more than 200 m.

A wind change to the south and moderating conditions further reduced the fire intensity and the accessible edges of the fire were quickly controlled. Access to the fire around the Red Rock escarpment was difficult, and the following day this section was controlled by hand-trailing and firebombing. The area burnt was 600 hectares.

The fuel-reduced area prevented the fire from spreading on a broad front onto the rugged Victoria Range and this significantly reduced both the area burnt and the suppression cost.



MAP 1 : GRAMPIANS (1981)

CASE STUDY 8 - GRAMPIANS (1980)

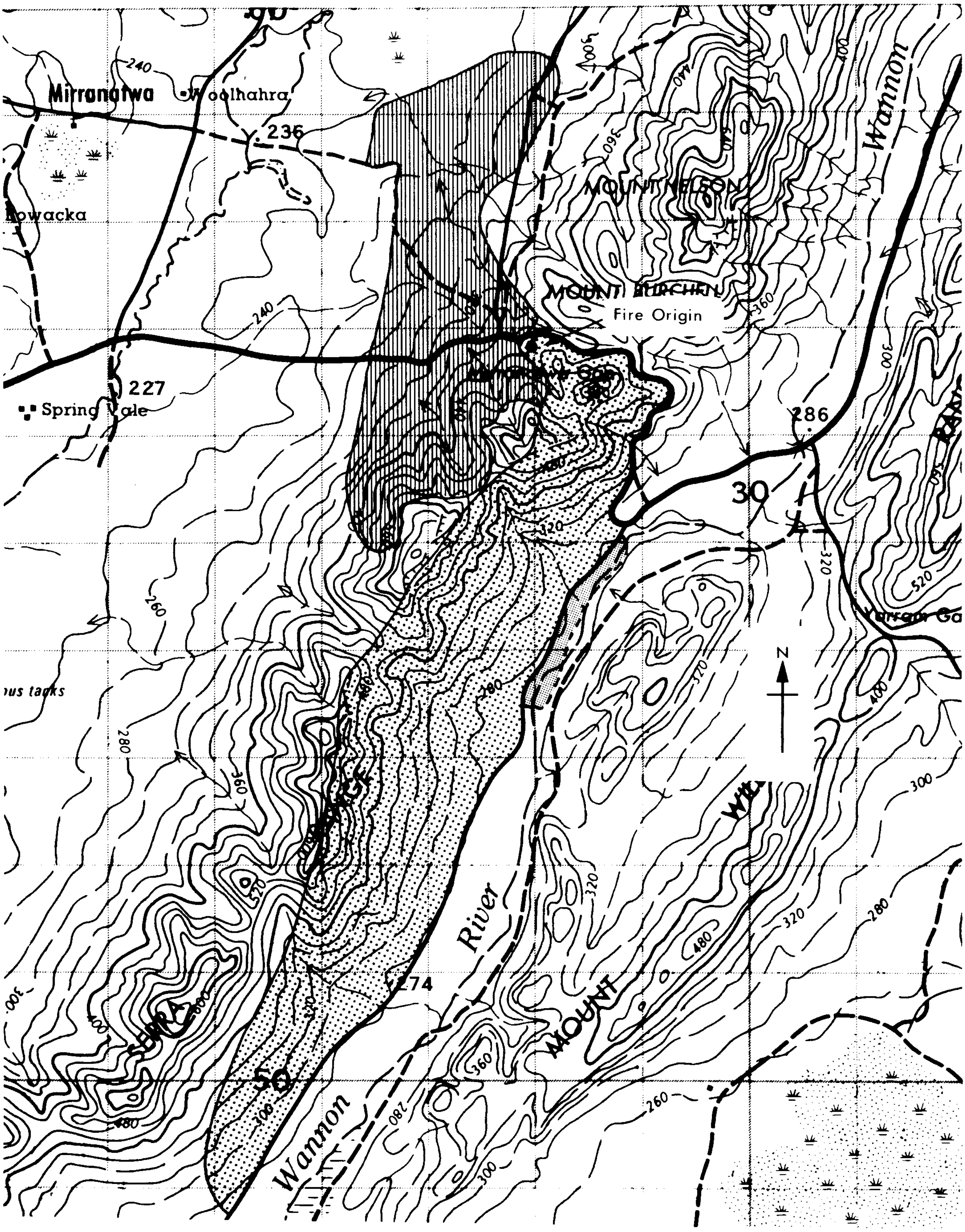
At 1300 hours on 26 October 1980 a fire was reported one kilometre west of Mirranatwa Gap in the Grampians State Forest (Map 1). The FDI was 20 and the fire spread quickly upslope fanned by a strong northerly wind. It burnt into poorly accessible terrain along the Serra Range, and then into the Wannon Valley, spreading at a rate of approximately 800 m/h.

The fire was spotting more than 100m when it reached the Halls Gap - Dunkeld Road. On the eastern side of the road an area of 40 ha had been fuel-reduced in 1979, and it prevented spread into the swamps and heaths around the Wannon River. Before 1979 the area had not been burnt for more than 20 years and fine fuel quantities were 20-25 t/ha. The vegetation consisted of scattered brown stringybarks up to 15m full and a dense heath understorey.

When crews arrived the fire was burning fiercely in a southerly direction along the road and subsequent back-burning kept the fire on the western side of the road. As conditions moderated the head of the fire was attacked and a wind change at 0400 hours on the following morning assisted control. The area burnt was 750 hectares.

Had the strip of 40 hectares not been fuel-reduced the previous year this fire would have certainly crossed the road and spread rapidly through very flammable heaths and swamps around the Wannon River. It is likely that had this occurred the fire would then have burnt across the Mt William Range and threatened private property south of Yarram Gap.

Because of the saturated ground conditions tankers and dozers were unable to operate in the heath areas and a direct attack was therefore impossible. As the fuel-reduced area stopped the fire spreading into inaccessible and highly flammable fuel types, suppression forces were able to work very effectively from the road and keep the area burnt to a minimum.



Wildfire : Oct 1980

Wildfire : 1976

Fuel-reduced : May 1979

0 1 2km

MAP 1 : GRAMPIANS (1980)

As a comparison a fire in September 1980 at Cassidy Gap (15 km further south), in very similar fuels and under almost identical weather conditions, burnt 2325 hectares including 25 hectares of private property and some fences.

CASE STUDY 9 - MT. DISAPPOINTMENT (1982)

At 1245 hours on 24 November 1982 a fire originated in private property on the western side of the Mt Disappointment forest (Map 1). The FDI at the time of detection was 45-50 (very high to extreme) with a temperature of 40°C, relative humidity of 10%, and wind speeds averaging 15-20 km/h[1].

The fire spread rapidly in an easterly direction and by 1900 hours the main front was estimated to be 11 km from the origin, giving a mean rate of forward spread of 1.8 km/h. Significant spotting occurred within this period. The fire continued to spread in an easterly direction until a south/south-westerly wind change around 0200-0300 hours on 25 November spread the northern flank to the north and northeast. After the wind change the fire began to encounter fuel-reduced areas and areas burnt in previous wildfires.

The effectiveness of any fuel-reduction burning program will depend firstly on the level of fuel-reduction achieved, and then upon the extent of the program and the location of burning operations in relation to assets. The study reported below was concerned only with determining if the levels of fuel-reduction achieved, in the separate areas encountered by the wildfire, were adequate.

Method

The positions of fires occurring from 1974/75 to 1981/82 inclusive were located (Map 1), and investigations of their impact on fire spread undertaken by a combination of ground inspection and interpretation of aerial photographs taken soon after the fire.

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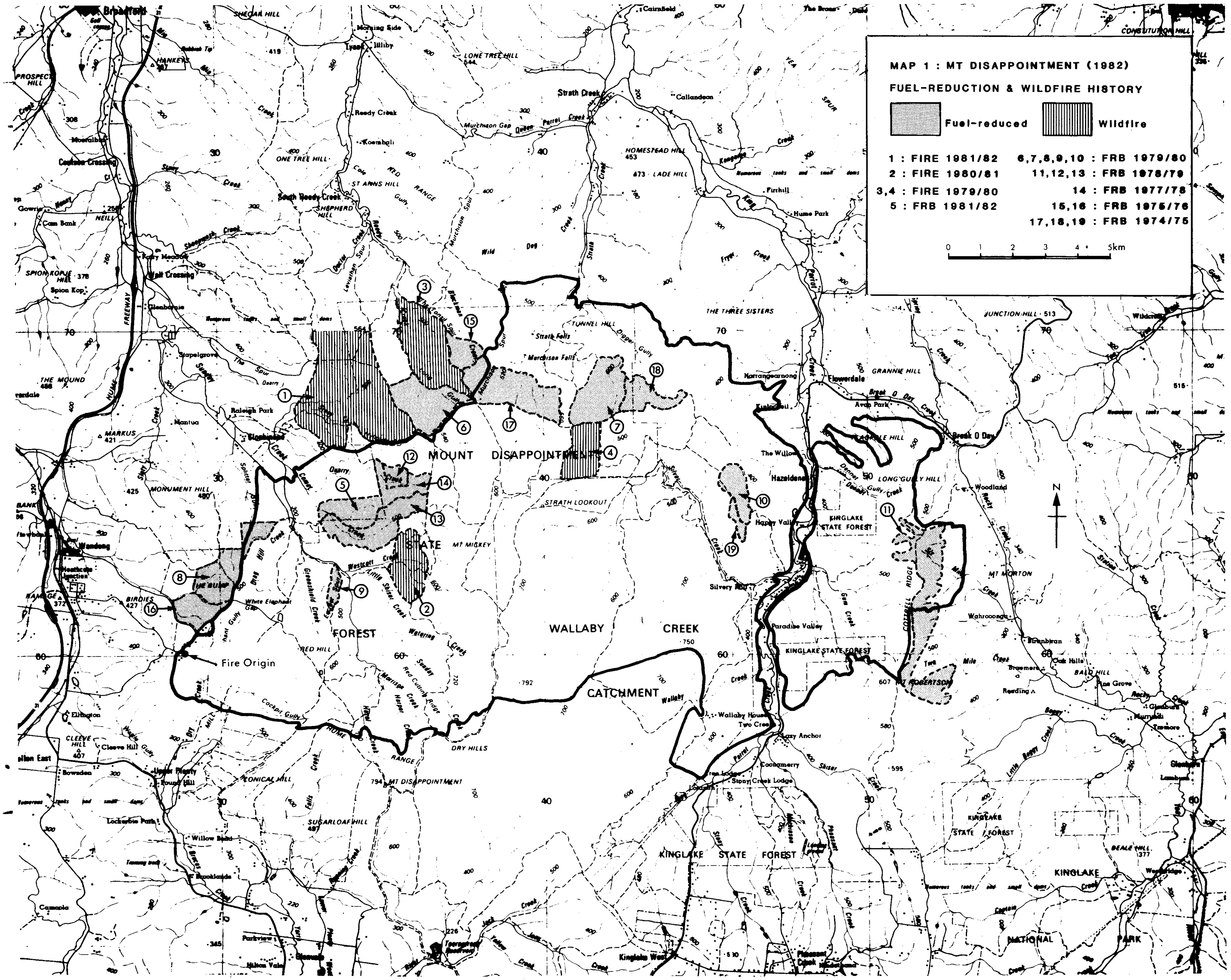
1 Temperature and relative humidity from Broadford, wind speeds from Melbourne Airport, Tullamarine.


MAP 1 : MT DISAPPOINTMENT (1982)
FUEL-REDUCTION & WILDFIRE HISTORY
Fuel-reduced
Wildfire
1 : FIRE 1981/82
2 : FIRE 1980/81
3,4 : FIRE 1979/80
5 : FRB 1981/82
6,7,8,9,10 : FRB 1979/80
11,12,13 : FRB 1978/79
14 : FRB 1977/78
15,16 : FRB 1975/76
17,18,19 : FRB 1974/75
0 1 2 3 4 5km
Fire Origin
MOUNT DISAPPOINTMENT
STATE FOREST
WALLABY CREEK CATCHMENT
KINGLAKE STATE FOREST
KINGLAKE NATIONAL PARK

Fire intensities were classified according to the extent of crown damage observed. Three intensity classes were defined as follows:

1. Crowns burnt - all leaves burnt from the tree crowns.

2. Crowns scorched - leaves killed by the fire but remaining on the trees.

3. Crowns green - at least the upper crown levels remained unscorched.

The percentages of each intensity class found within the previously burnt areas were estimated from the aerial photographs and comparisons made with the wildfire intensities apparent outside each area.

Limited sampling outside the boundary of the wildfire was used to indicate the quantities of fine fuel likely to have been present prior to the fire.

Results

A summary of the results is given below. More detailed information appears in Appendices 1-7.

1. 1974/75, 1975/76, 1977/78

The areas concerned were dominated by messmate (*E. obliqua*), broad-leaved peppermint (*E. dives*) and red stringybark (*E. macrorrhynca*) with stand heights between 15-25m.

Although some areas retained green crowns the same intensity patterns were found in adjacent areas not fuel-reduced but subsequently burnt by the wildfire. The reason why there was no measurable effect becomes apparent when fuel weights are compared. At the time of the fire fuel quantities had returned to levels similar to those found in untreated areas.

2. <u>1978/79 - 1981/82</u>

Eight areas fuel-reduced in these years were wholly or partly included within the wildfire boundary. Only two were judged to retard fire spread.

(a) Area 11 was dominated by messmate and broad-leaved peppermint with a stand height of 15-25 m, and fuel-reduced in 1978/79. Epicormic development indicated the section east of Cottrell Ridge was fuel-reduced with a fire of relatively high intensity, and limited sampling gave fuel quantities of 3-4 t/ha prior to the wildfire. High intensity wildfire was sustained in the western sector where the fuel-reduction intensity had been lower.

(b) Area 7 was dominated by messmate, broad-leaved peppermint and stringybark with stand heights of 15-25 m, and fuel-reduced in 1979/80. Comparisons with adjacent areas indicate the wildfire intensity was considerably reduced by the fuel-reduction burning, although the old wildfire (Area 4) to the south may have assisted by protecting the area from the full force of fire spread. No fuel quantity estimates were obtained.

Discussion

It is generally accepted that a good fuel-reduction burn can still provide a measure of protection for up to 5 years. The evidence presented for 1974/75 - 1977/78 is therefore not of concern. However, the majority of burns conducted within 5 years of the wildfire were ineffective and even the one year old burn was ineffective.

The reasons for the failure of most of these fuel-reduced areas to have a measurable impact on fire spread will concern the level of fuel-reduction that was achieved. Unfortunately this limited study highlights some problems but does not provide sufficient information on which to base more suitable standards for future operations.

Appendix I - Summary for 1974/75

Area Numbers/Fire Type (Ref. Map 1); 17, 18, 19

Fuel-reduction in all areas.

Forest Types

E. dives, *E. obliqua*, *E. macrorrhynca* association in general with *E. dives*, *E. macrorrhynca* usually being dominant on the northern slopes.

Stand heights:	Areas 17 and 18	- 15-20 m
	Area 19	- 15-25 m
Topography:	Areas 17 and 18	- undulating country with slopes 0-5°.
	Areas 19	- steep west slope dissected by gullies. Slopes 5-10°.
Fine Fuel Quantity:	8 samples taken from the section of area 17 which remained outside the wildfire ranged from 5.2-9.6 t/ha and averaged 8.4 t/ha.	
Fire Intensity:	Area 17	- Crowns scorched 67%
		- Crowns green 33%
	Area 18	- Crowns scorched 40%
		- Crowns green 60%
	Area 19	- Crowns burnt 5%
		- Crowns scorched 95%

Comments

Area 17: This area was burnt by the wildfire at approximately 1200 hours on the second day (25/11/1982) when the fire front was moving northeast. Fire intensities which did not completely scorch tree crowns were found in the gullies and on steep slopes where the fire spread was downhill.

Area 18: This area was burnt at about 1300 hours on 25 November 1982 when the fire spread was to the northeast. It was burnt with varying intensity, continuing a pattern started south of area 18 and continued north of the area. Lower fire intensities, leaving green crowns, occurred mostly in steep-sided gullies and on most southerly aspects.

NB: There was an obvious difference in intensity between this area and the adjacent 1979/80 fuel-reduced area (Area 7), along the Link 3 Road.

Area 19: This area was burnt at about 1100 hours on 26 November 1982. The major influences on the fire behaviour were the south-westerly wind, and the steep westerly slopes. These two factors allowed the fire to move rapidly at high intensity in an easterly direction up slope. The intensity was only reduced after crossing the ridge and then moving downslope, out of the fuel-reduced area.

Summary

The effect of these fuel-reduced areas on fire spread as not great enough to be measurable.

Appendix II - Summary for 1975/76

Area Numbers/Fire Type (Ref. Map 1); 15, 16

Fuel-reduction in both areas.

Forest Types: Area 16 - undulating country interspersed with several steep-sided gullies.

Area 15 - undulating country.

Fine Fuel Quantity: 4 and 5 samples were taken from parts of areas 15 and 16 respectively which remained outside the wildfire area. Fuel quantities ranged from 5.8-10.5 t/ha with an average of 8.4 t/ha.

9 samples taken from areas not fuel-reduced adjacent to area 15 showed a range of 4.1-9.2 t/ha and an average of 7.3 t/ha.

Fire Intensity: Area 15 - unburnt.

Area 16 - only 2 hectares of the area were burnt. Crowns scorched 100%.

Comments

Area 15: Was not burnt during the wildfire but it provided a useful comparison with adjacent unburnt country of similar forest type.

Area 16: The fire crossed the Main Mountain Road into area 16 but was stopped by a dozer trail. The fire in most of this small area was as intense as the main fire.

Summary

There was no measurable effect on fire spread.

Appendix III - Summary for 1977/78

Area Number/Fire Type (Ref. Map 1) 14

Fuel-reduction.

Forest Types	An *E. obliqua/E. dives/E. macrorrhynca* association with *E. viminalis* and *E. cypellocarpa* present in the deep gullies.
Topography:	Slopes 5-20°.
Fine Fuel Quantity:	No estimates available.
Fire Intensity:	Crowns scorched 82%
	Crowns green 18%

Comments

This area was burnt by the wildfire at about 0400 on 25 November 1982 when the fire front was moving northeast. Higher intensities occurred predominately in the western area where steeper slopes allowed rapid fire spread. This contrasts with the gentler slopes on the eastern side where areas of green crown remained. The pattern of lower fire intensity occurs both north and south of this eastern side where the topography is similar.

Summary

This fuel-reduced area had no measurable effect on fire spread.

Appendix IV - Summary for 1978/79

Area Numbers/Fire Type (Ref. Map 1); 11, 12 and 13

Fuel-reduction in all areas.

Forest Types:	Area 11:	Characterised by a *E. obliqua*, *E. dives* complex, with *Leptospermum spp.* scrub patches on poorly drained sites.
	Areas 12, 13	Characterised by a *E. dives*, *E. obliqua* and *E. macrorrhynca* association with *E. viminalis* occurring in the gullies.
Stand height classes:	Area 11:	- 15-25 m
	Areas 12 and 13:	- Upper slope - 10-15 m - Lower slope - 15-25 m
Topography:	Area 11:	Undulating country, slopes 0-5°.
	Area 12:	This small area was on the western slope of a large gully forming a branch at Quarry Creek.
Fine Fuel Quantity:	Area 11:	2 samples taken from the unburnt area gave values of 3 and 4 t/ha. Visual estimation indicated that the fuel was evenly spread over the unburnt area. However, leaf fall from the wildfire comprised at least a quarter of this

litter, making accurate results difficult to obtain. Ground observation showed that the fuel loadings on the fuel-reduced areas were significantly less than the surrounding non-fuel-reduced areas.

Areas 12, 13 - No estimates available.

Comments

Area 11 - This area was burnt by the wildfire at about 1600 hours on 25 November 1982 when the fire front was heading east. Low fire intensities were encountered in the fuel-reduced area on the east side of the Mt Robertson Road, except on the exposed northern slopes. The wildfire was sustained at high intensity in the western sector of the fuel-reduced area. The eastern sector contrasts with the crown-scorched areas opposite.

The fuel-reduction burn was of high intensity on the eastern side, as evidenced by the epicormic shoots on the trees within the area.

East of the estimated boundary of the fuel-reduced area, the intensity of the wildfire was greater than within the fuel-reduced area. This effect is complicated because of the extensive backburning carried out further east, along the private property boundary.

Areas 12 and 13 - This area was burnt by the wildfire about mid-morning on 25 November 1982 when fire fronts were heading north and east. Crowning occurred on several ridges and north running spurs. The small area where crowns remained unscorched was in an area of backburning. All other parts sustained a high intensity fire, causing crown scorch.

Fire Intensity:

Area 11 -	Crowns burnt	2%
	Crowns scorched	38%
	Crowns green	60%
Area 12 -	Crowns scorched	100%
Area 13 -	Crowns burnt	7%
	Crowns scorched	81%
	Crowns green	12%

Summary

In Area 11 the wildfire intensity was reduced in thos sections where the fuel-reduced burn had been most intense. Areas 12 and 13 had no measurable effect on fire spread.

Appendix V - Summary for 1979/80

Area Numbers/Fire Type (Ref. Map 1); 3, 4, 6, 7, 8, 9 and 10

Areas 3 and 4 - Wildfires.

Areas 6 - 10 - Fuel-reduction burns.

Forest Types

Areas 3 and 6 - *E. obliqua*, *E. dives* association with *E. rubida*, *E. viminalis* in the wetter areas and *E. macrorrhynca* occurring on some of the drier sites.

Areas 4, 7 and 10 - *E. obliqua*, *E. dives*, *E. macrorrhynca* association with *E. rubida* occurring in the slightly wetter areas.

Area 8 - *E. obliqua*, *E. dives* association with *E. goniocalyx* occurring on the dry northern slopes in place of *E. obliqua*.

Area 9 - *E. dives*, *E. macrorrhynca* association on a dry north-west aspect.

Stand Height Classes

Areas 3 and 6	15-25 m
Area 4	> 25 m
Areas 7 and 10	15-25 m
Area 8	10-15 m
Area 9	10-15 m

Topography

Areas 3, 4, 6, 7 and 10	- Undulating country, slopes 0-5°
Area 8	- Undulating country, slopes 0-10°
Area 9	- Steep slopes, 20°+

Fine Fuel Quantity

Area 6 - 11 samples taken from this area, which remained outside the wildfire, ranged from 3.9-7.8 t/ha with a mean of 6.1 t/ha.

Area 8 - 8 samples taken from sections remaining outside the wildfire area ranged from 5.5-7.5 t/ha with a mean of 6.4 t/ha.

No other estimates were available.

Fire Intensity

Area 3	-	Not burnt.	
Area 4	-	Crowns green	100%
Area 6	-	Not burnt.	
Area 7	-	Crowns scorched	3%
	-	Crowns green	97%
Area 8	-	Crowns burnt	10%
	-	Crowns scorched	85%
	-	Crowns green	5%

Area 9	-	Crowns burnt	25%
	-	Crowns scorched	75%
Area 10	-	Crowns burnt	2%
	-	Crowns scorched	71%
	-	Crowns green	27%

Comments

Areas 3 and 6 - Both areas were outside the wildfire boundary.

Area 4 - In areas where the previous wildfire was intense, penetration of the new firefront was a maximum of 10 m. Where the previous wildfire had not been intense a low intensity fire was sustained. This area was burnt about 1000 hours on 25 November 1982.

Area 7 - This area was burnt between 1300 and 1400 hours on 25 November 1982. Higher intensities occurred only on higher, more exposed sites. Comparisons between this area and those to the south, west and east of it indicate that the fire intensity was considerably reduced within this area.

Area 8 - This area burnt after the cool change, with its associated wind change, about 0100 hours on 25 November 1982. The topography, with gullies running north/south, allowed rapid movement of high intensity fire through the area even though the fuel-reduction burn was considered, at the time, to have been effective.

Area 9 - This area was burnt about 2100 hours on 25 November 1982, when conditions were extreme. Furthermore, the uphill, north-west slope in direct line of the fire movement allowed a high intensity burn to be sustained.

Area 10 - This area was burnt about midday on 25 November 1982. Low intensity fire was only sustained in the deeper gullies and on the eastern slopes. High intensities occurred in all other areas, with crowning occurring on the more exposed ridges.

Summary

(a) Apart from Area 7, the fuel-reduced areas had no measurable effect on fire spread.

(b) The wildfire area (Area 4) sustained a fire of very low intensity within its boundaries.

Appendix VI - Summary for 1980/81

Area Number/Fire Type (Ref. Map 1); Area 2

Wildfire.

Forest Types

The major associations here are:

1. *E. obliqua*, *E. dives*, *E. macrorrhynca* on the northern slopes, and

2. *E. obliqua*, *E. cypellocarpa* on the southern slopes and in the gullies.

Stand heights: Association 1 15-25 m

Association 2 > 25 m

Topography: Steep country with several moist gullies on the western side.

Slopes up to 25°.

Fine Fuel Quantity: Estimated at 1-2 t/ha in areas of crown scorch from previous fire.

Fire Intensity: Not applicable.

Comment

This area did not burn again except on the western edge where the fire penetrated up to 30 m.

Summary

The lack of fuel meant the fire could not be sustained in this area, despite the severity of the conditions at the time.

APPENDIX VII - SUMMARY FOR 1981/82

Area Numbers/Fire Type (Ref. Map 1); 1 and 5

Area 1 - Wildfire.

Area 5 - Fuel-reduction burn.

Forest Types:

Areas 1 and 5: The dominant association is *E. macrorrhynca*, *E. dives*, *E. goniocalyx* with *E. obliqua* on the damper slopes.

Stand height class 10-15 m.

Topography:

Areas 1 and 5: Steep country dissected by gullies. Slopes up to 25°.

Fuel Quantity:

Not available for Area 5.

Area 1 estimated to be 1-2 t/ha.

Fire Intensity:

Area 1: Not burnt.

Area 5:

Area 5:	Crowns burnt	9%
	Crowns scorched	74%
	Crowns green	17%

Comments

Area 1: This area was not burnt because of the lack of fuel.

Area 5: This area was burnt between 0100 hours and 0500 hours on 25 November 1982, following the wind change. The factors contributing to the high intensity burn were the steep terrain, and the high velocity winds moving upslope.

Summary

The fuel-reduced area had no measurable effect on the fire movement.

CASE STUDY 10 - MT. ELIZABETH (1982)

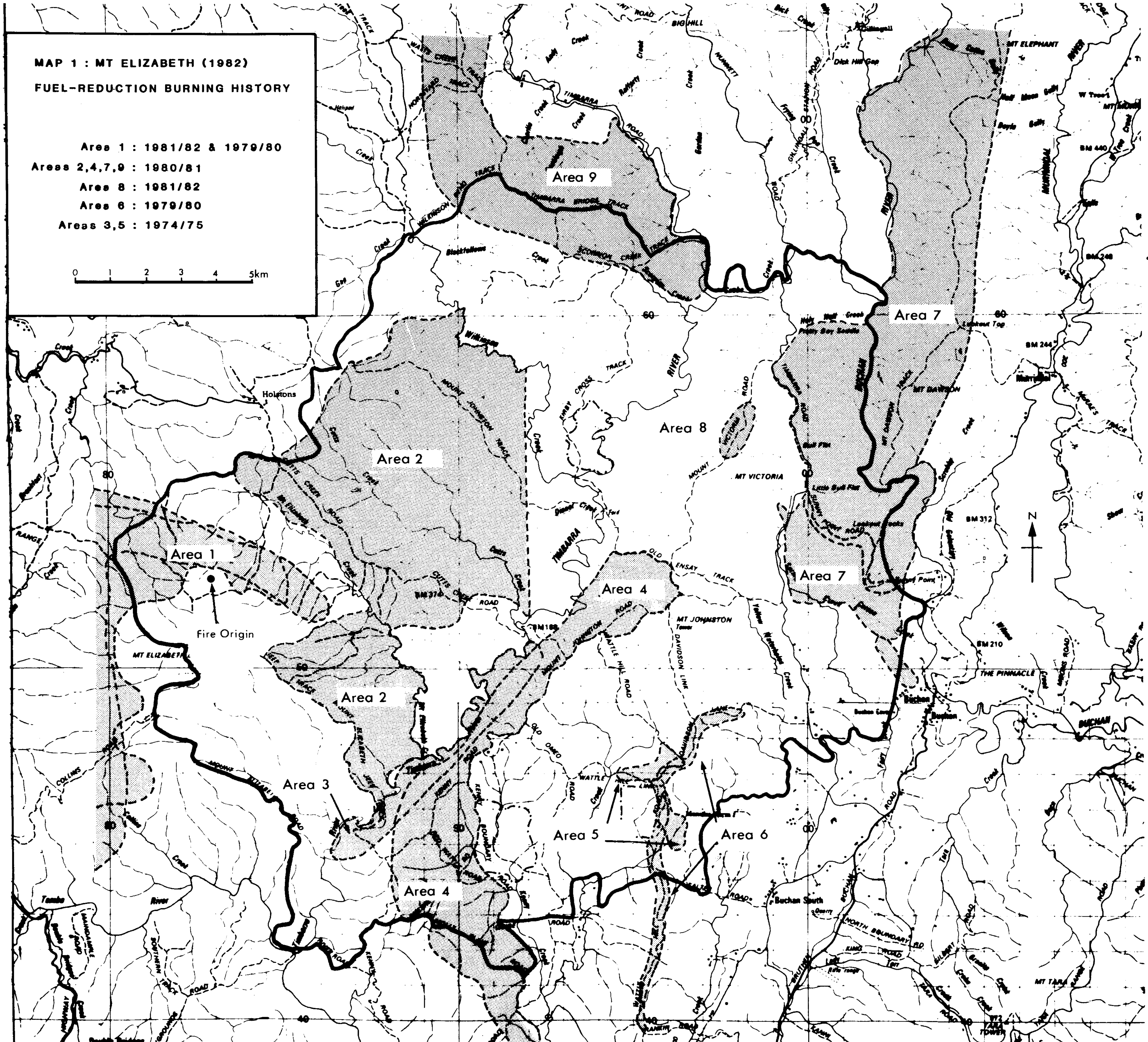
At 1225 hours on 23 November 1982 a fire was detected near Mt Elizabeth and over the next few days it burnt, often under conditions of very high to extreme fire danger, an area of approximately 27 000 hectares.

Some of the area burnt had been fuel-reduced in the previous few years (Map 1, Table 1).

TABLE 1: FUEL-REDUCED AREAS

Year	Area	
	(ha)	% of wildfire area
1981/82	810	3.0
1980/81	11 830	43.8
1979/80	260	1.0
1974/75	240	0.9

The fire started in logging slash and within two hours of detection it burnt into an area which had been fuel-reduced in both 1979/80 and 1981/82 (Area 1). Spread continued to the north through this area with an average rate of forward spread of 0.7 km/h. Spot fires were started above the northern boundary and it is believed these originated before the fire reached Area 1.


MAP 1 : MT ELIZABETH (1982)
FUEL-REDUCTION BURNING HISTORY
Area 1 : 1981/82 & 1979/80
Areas 2,4,7,9 : 1980/81
Area 8 : 1981/82
Area 6 : 1979/80
Areas 3,5 : 1974/75
0 1 2 3 4 5km
Area 1
Fire Origin
Area 2
Area 2
Area 3
Area 4
Area 4
Area 5
Area 6
Area 7
Area 7
Area 8
Area 9
N
MT ELIZABETH
MT VICTORIA
MT JOHNSTON
MT DAWSON
THE PINNACLE
Buchan
Buchan South
Holstons

On the second day the major run of the fire was to the east/southeast and during the period 1300-1900 hours it travelled approximately 15 km, at an average rate of forward spread of 2.5 km/h, burning through the major fuel-reduced area (Area 2) within the fire boundary. Throughout the third and subsequent days the main direction of fire spread was to the north and northeast.

Inspection of aerial photographs taken after the fire showed that the overall intensity was probably less within Area 1 than in the surrounding areas that had not been fuel-reduced[1]. The classifiction of intensities within Area 1 was as follows:-

Crowns burnt	12%
Crowns scorched	54%
Crowns green	34%

A similar analysis for Area 2 showed:-

Crowns burnt	29%
Crowns scorched	51%
Crowns green	20%

The forest types[2] concerned were mostly Open Forest II and III with some Open Forest IV within Area 1.

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1 Crowns burnt - all leaves burnt from the tree crowns.
Crowns scorched - leaves killed by the fire but remaining on the trees.
Crowns green - at least the upper crown levels remained unscorched.

2 Open Forest IV - (> 40 m) mountain ash, messmate, mountain grey gum.
Open Forest III - (27-40 m) white stringybark, mountain grey gum,yellow stringybark, messmate.
Open Forest II - (15-27 m) red stringybark, red box.

Despite the fact that Area 2 was considered to have been satisfactorily fuel-reduced it had no measurable influence on fire behaviour. Between 1400-1500 hours on Day 2 the fire spread 3.3 km and spot fires were started over distances up to 11 km.

The evidence shows that areas fuel-reduced as late as 18 months previously had little or no measurable effect on fire spread under conditions of very high to extreme fire danger (the FDI ranged from 15-60). Areas 7 and 9 (both burnt in 1980/81) were assessed to slow the fire edge but the FDI was less than 10. Snow damage did occur in parts of the fire area during 1982, but the resultant increased fuel quantities were not considered to have significantly reduced the effectiveness of the fuel-reduced areas.

The 1982/83 fire season was particularly severe because of the drought and the frequent occurrence of days of very high to extreme fire danger. However,this does not mean we should treat the above evidence lightly by indicating the experience is unlikely to be repeated in an average year. Our broad-scale fuel-reduction burning program must be designed to have an impact on fires burning under severe conditions.

There is no doubt that fuel-reduction burning can effectively slow or stop wildfire spread if both the percentage of area burnt and the extent of fuel-reduction on the burnt area is substantial. The evidence from this fire indicates that a review of our standards is required.