FIRE AND STEM DAMAGE WITH PARTICULAR REFERENCE TO JARRAH (*Eucalyptus marginata*).

L. McCAW

1981.

FIRE AND STEM DAMAGE

with particular reference to Jarrah (Eucalyptus marginata)

SUMMARY

This report examines the factors contributing to cambial damage during a fire. The cambium is protected from the heat of a fire by the bark. The thickness of the bark is the major factor governing heat transfer to the cambium. Even in regularly distributed fuels, heat distribution around the stem is uneven. Further irregularities may be introduced by uneven fuel accumulation, particularly large fuels such as logs. Death of a section of the cambium will result in the formation of a scar.

Scars may downgrade the quality of a log, and permit the entry of destructive decay fungi and insects. It has proved possible to predict the extent of decay on the basis of the physical characteristics of a scar. Fire may also induce undesirable changes in cell characteristics resulting in the formation of kino veins.

The importance of wood quality in future management of the Jarrah forest is briefly discussed.

A) INTRODUCTION

Jarrah is a highly fire resistant eucalypt - a factor which probably contributes to its dominance over such a large area of forest. Adaptions to fire include thick bark, concealed epicormic buds and the presence of a lignotuber.

Low intensity fires may kill small saplings and advanced growth but under normal circumstances will not damage larger established trees. More intense fires can cause damage to the crown and bole of the tree, but only the most intense fires will kill the larger trees. Fire will continue to be an important factor in the Jarrah forest environment, both as prescribed fires and the occassional wildfire. Recently, some attention has been focused on the use of higher intensity prescribed fire. Higher intensity fires can be used to stimulate legume regeneration and manipulate the structure of populations of Banksia grandis, both desirable in controlling the dieback disease caused by Phytophthora cinnamomi. Such fires may also stimulate the growth of Jarrah and have a general beneficial effect on the forest.

But higher intensity fires will cause more damage to the trees. In areas where wood production is to be an objective of management this may be undesirable. The aim of this report is to review the processes involved in fire injury to the cambium, and the effects of such damage on wood quality.

B) HEATING OF THE CAMBIUM DURING FIRE

1) Lethal Temperatures

The cambium is the critical tissue for stem survival as it is responsible for the growth of both bark and woody tissue in the tree. The effect of heat on plant tissue is related to the temperature and duration of exposure. It is generally accepted that temperatures exceeding 60^0c for periods of less than a minute are sufficient to cause the death of most hydrated plant cells. (Hare 1961, McArthur, 1968), Cremer (1962) cites 50^0c as the lethal temperatire for many plant cells, but this seems low in comparison with other estimates. Some variation exists in the heat tolerance of tissues from different environments and has been reviewed by Levitt (1972). However, Gill (1981) considers that the lethal temperature for moist bark cells is similar in all species of Eucalyptus.

Martin (1963) has proposed the following model to describe the relationship between temperature and the duration of exposure required for cell death.

$$t = a - b \ln T$$

where t = temperature
T = time of exposure
$\ln$ = natural logarithm
a,b = constants

Thus the temperature required for cell death is inversely proportional to the logarithm of the time of exposure at that temperature. Martin (loc cit.) proposes a technique whereby values from the cambial time-temperature curve are substituted into this equation to predict whether a given fire will cause injury.

This approach is based on the assumption that the effects of different temperatures are additive, but still seems superior to using a fixed temperature criterion.

Complete girdling of the cambium will result in death of the bole. For established Jarrah, exceeding say 20cm D.B.H.O.B. this would only occur in the most extreme fires. Death of a portion of the cambium will result in the formation of a scar. A fire scar consists of a core of exposed xylem bounded by intact bark and cambial tissue: hence the commonly accepted name of "dryside". Scars are often triangular in shape and are usually found on the lower sections of the bole. Extreme scarring may extend to the full length of the bole and Cremer (1962) reports scarring on the underside of horizontal branches of Eucalyptus obliqua many metres above the ground. On rough barked eucalypts scars may remain concealed for several years until the dry outer bark peels away or is removed by subsequent fire.

The extent to which the cambium will be heated during a fire depends upon the insulative properties of the bark and the thermal environment provided by the fire itself.

2) The Thermal Environment

The temperature in dense flames may exceed 1200^{O}K, but will be somewhat less for thinner flames (Packham and Pompe 1971). These temperatures were determined by the measurement of blackbody radiation, a method considered by Vines (1981) to be definitely superior to the use of thermocouples. The values are in accordance with those reviewed by McArthur (1968), and are not dissimilar to those obtained by Fahnestock and Hare (1964) using thermocouples exposed to naked flame. In any event, Vines (1981) stresses that it is the intensity (Bryam 1959) or rate of heat output, rather than temperature alone, which determines the damage caused by a fire.

The duration of flaming combustion at a specific point is known as the burn-out time, and may be up to several minutes in eucalypt litter fuels (McArthur and Cheney 1966). Flaming combustion may persist for considerably longer periods in heavy slash fuels (McArthur 1968). Vines (1968) recorded a burn-out time of approximately seven minutes in heaped Jarrah branches. However, trees may be subjected to heating for considerably longer periods than those associated with exposure to flames. In particular, smouldering combustion of large fuels such as logs and branch wood may continue for long periods. Jacobs (1955) considers that smouldering is enhanced by the flue action which develops between a tree and a log resting against its base. Fires in deep humus can be particularly destructive, as the burning material often completely encircles the butt of the tree. Cremer (1962) reports several instances where stands of Eucalyptus regnans had survived quite intense surface fires in logging slash but were killed by a smouldering humus fire.

Local experiments (Appendix 1,2) have shown the damaging potential of large fuels. In Experiment 345, almost 50 percent of bole injuries were directly attributed to the close proximity of logs or slash. A similar situation occurs with coppice stems growing from a stump, or where a multiple-stemmed tree has been thinned. The dry wood of the stump ignites even under mild burning conditions and with time invariably injures the remaining stems. The heat from a single fire may be insufficient to damage the cambium, but repeated burning will reduce the bark thickness and render the tree vulnerable. The presence of a log or stump will tend to enlarge and existing wound, and will prevent complete healing.

3) *The role of protective tissues*

Under normal circumstances, the temperature at the cambium will be close to ambient (Gill 1981). This may be important in determing whether lethal temperatures are attained during a fire of given intensity . Hare (1963) subjected Pinus palustris to a constant heat source and noted that trees initially at 2^0c took one and a half times as long to reach 60^0c as those at 21^0c. The cambial temperatures of shaded trees in a stand may be lower than that of exposed trees (Vines 1968), and on individual trees, aspect may be important in determining the susceptibility to injury (Hare 1961).

The decisive factor governing temperature rise at the cambium is bark thickness (McArthur 1968, Vines 1968). This observation may seem suprising in view of the wide variation in the physical characteristics of bark between species. The explanation lies in the importance of thermal diffusivity rather than thermal conductivity in determining the movement of heat through the bark. Considerable variation occurs in the values of the properties used to estimate diffusivity but overall they compensate one another with the result that diffusivity is constant for a wide range of density, moisture content and temperature (Martin 1963). Bark flammability can significantly affect the temperature rise at the cambium; burning of the dry outer bark will reduce the thickness of the insulating tissues and may prolong the heating effect of a fire. Gill and Ashton (1968) report that the rough, fibrous bark of E.obliqua allowed a more rapid rise of cambial temperature than the same thickness of smooth , gum bark of Eucalyptus cypellocarpa.- this was due to the combustion of the dry outer bark. The moisture content of the outer bark may also be an important consideration. Peet and McCormick (1971) report the height of bole char and incidence of scarring on Jarrah were considerably greater in autumn than in spring due to the drier outer bark. The temperature of moist outer bark cannot rise above 100^0c until evaporation has occurred and even then it will char rather than burn (Gill 1981). Thus the often reputed superior fire resistance of rough-barked eucalypts is due almost entirely to their greater thickness of bark - a conclusion supported by the data of McArthur(1968) and

and Gill and Ashton (1968).

Bark thickness varies with the age and size of a tree, and will be influenced by fire. Loneragan (1971) has determined the regression of bark thickness on girth for both old and second growth Jarrah. The proportionate increase of bark thickness with girth is much greater for second growth trees. Larger trees will have thicker bark and will be more fire resistant, and this has been documented for a number of experimental fires (Vines 1968, Burrows 1981, FD internal report, Appendix 1,2).

Conversely, reduction in bark thickness may adversely effect the fire resistance of a tree. Loneragan (1961) reported that severe summer fire reduced the bark thickness of Jarrah poles by approximately 12mm, or 40 percent of the preburn thickness. Recovery to equilibrium levels would take between 10 to 14 years. Similar trees lost 4mm thickness during mild fire, and recovery was expected to take 4-5 years. For the gum barked Eucalyptus dalrympleana Gill (1980) found a reduction of 10mm in bark thickness following spring wildfire. Seven years after burning, bark was still 6mm thinner than for unburnt controls. McArthur (1968) reports that four years after moderate fire, the bark of Eucalyptus rossii was still only 30-50% of its prefire thickness.

4) Location and Size of Fire Scars

The size and position of a scar are determined by the interaction of a number of factors, and may be influenced by bark thickness. Peet and McCormick (1971) report a significant correlation between the area of dry-siding on Jarrah poles and the thickness of bark. The importance of burning logs and stumps in this context has already been discussed. Irregularities in the bark surface may result in differential heating; Fahnestock and Hare (1964) observed lower temperatures and total heat values in bark fissures than on surface plates and concluded that the thinner bark in fissures was probably offset by reduced heating.

A number of investigations of the partitioning of heat around the bole have been made. Fahnestock and Hare (1964) studied the heating of pole sized trees during surface fires in pine litter and found that heating was considerably greater on the lee than on the windward side. Maximum heating on the windward side occurred at ground level and at between ground level and 30cm on the lee side. Headfires were found to have a greater heating effect than backfires.

Gill (1974) used laboratory models to examine the factors influencing heat distribution during a fire. Flames tended to persist on the leeward sides of trees, and flame height *was strongly related to tree diameter and wind speed. Subsequent field experiments by Tunstall et al (1976) confirmed these findings. In evenly distributed grass fuels, differential heating occurred in respect of both aspect and height above ground. Maximum heating was recorded at 40cm above ground on the lee aspect, a position corresponding with the apices of many fire scars in the surrounding districts. The results of this particular study cannot be applied directly to a forest situation because of the fuel type, and the absence of a closed canopy. The distribution of forest fuels tends to be uneven, particularly on steeper slopes where litter may accumulate on the uphill side of a tree. Regarding the effect of tree diameter and windspeed on heating, Gill (1981) states that the interaction depends mainly on the size of the tree in relation to the magnitude of the turbulent cells of heat and flame within the fire.*

For fires of similar intensity, the size of a wound will often be inversely related to the diameter of the tree (Peet and McCormick 1971; Burrows 1981). However, this statement can only be validly applied to trees which are previously undamaged and not subject to the influence of burning logs or other large fuels. It is necessary to apply similar constraints when considering the relationship between wound size and fire intensity. In general, more intense fires cause larger wounds. McArthur and Cheney (1966) examined the relationship between fire intensity and physical damage to the stand using data obtained from the Dwellingup fires. But unfortunately, their criteria for physical damage are not clearly defined and the information presented is of limited application. Data presented by Burrows (1981) shows that for trees of similar diameter, more intense fires caused larger wounds. Tree vigour may also be an important factor in determining susceptibility to injury - Loneragan (1971) noted that supressed and subdominant trees were damaged more often than the vigorous dominants within a stand.

The inherent variation in fuel distribution,fire behaviour and tree characteristics make it an almost impossible task to predict the degree of damage caused by a particular fire. In fact, each tree is a unique case. One of the main difficulties at present is that is is impossible to obtain an accurate estimate of fire intensity within larger fires. Work is currently being undertaken in an attempt to flame height and intensity to the height of bark char. This should allow a better stratification of fire intensity within large burns.

5) <u>Healing of scars</u>

The rate of healing of a wound is important in that it determines the length of time for which the tree is susceptible to attack by insects and decay organisms. For a given rate of callus tissue formation, wide wounds will be exposed for longer than narrow wounds. The rate of callus *formation is governed by the growth rate of the tree. Podger and Peet (1965) found a significant increase in the ring width of Jarrah Poles subjected to high intensity fires. This growth stimulus persisted for up to 4 years, and occurred in both fire scarred and undamaged trees. Kimber (1978) presents further evidence of fire related growth stimulus in Jarrah. Thus, intense fire may cause injuries, but will also encourage rapid healing. Factors of site, stocking and individual tree vigour will also affect the rate of healing. Wargo (1977) reports that defoliation adversely affected rates of wound closure by reducing radial growth. Jarrah may be subject to severe defoliation by the Leaf Miner Perthida glyphopa, with resultant loss of growth (Mazanec, 1974).*

The scar itself may influence the vigour of the tree - Rundel (1973) has shown a strong correlation between the area of basal scarring and the presence of snag tops. This was attributed to destruction of large amounts of active xylem.

The intensity and frequency of subsequent fires will influence wound healing, and the undesirable effects of log fuels have already been discussed in this context.

C) FIRE, WOOD DEFECT AND ECONOMIC LOSS.

Fire may have a major economic impact on wood production, directly affecting both the quantity and quality of timber obtained from a tree. It may induce undesirable cellular changes which adversely affect wood quality. Physical damage to a log can result in its downgrading or rejection and will permit invasion by destructive insects and decay organisms. Fire also has the capacity to affect the vigour and growth rate of a tree. Studies of fire damage and related defect in Australia have concentrated on exotic plantation conifers. This is probably due to their high value per hectare and their relative sensitivity to fire, in comparison with most eucalypt forests. Such studies have been undertaken by VanLoon (1967) French and Kierle (1969) and Nicholls and Cheney (1974). Yet the destructive aspects of fire in wood production in eucalypt forests should not be overlooked.

1) Cell Characteristics

Fielding (1967) has stated that even controlled burns may subject trees to high temperatures, and can definitely affect wood properties. However, for Jarrah, Nicholls (1974) reports that spring fires of less than 200 KW/m intensity caused no major alterations in wood characteristics; autumn fires of similar intensity resulted in a minor disturbance to the density profile of the past-fire seasons growth. Hotter fires may have a greater effect; Podger and Peet (1965) observed a reduction in springwood density following summer defoliation. Nicholls (1974) found that autumn defoliation of Jarrah poles resulted in a decrease in the maximum density and an increase in the minimum density of the wood formed in the year following fire. Overall, these affects appear to be shortlived and of little consequence to long term wood quality.

2) Kino Veins.

Of far greater importance is the formation of kino veins and pockets. Veins impair the visual quality of timber and if extensive can result in structural weakness. Experimental work by Jacobs (1938) revealed that kino formation occurred as a response to insect attack, branch shed and mechanical damage. Jacobs (loc. cit.) considered that fire did not directly cause veining but acted indirectly via injury to the periderm, reduction in bark thickness and by stimulating the formation of epicormic branches. Hillis (1978) reviews recent studies on kino veins, concluding that there is still considerable uncertainty as to the causes of formation.

Floyd (1966) discusses the effect on regular prescribed burning on kino vein production in a 47 year old stand of Eucalyptus pilularis 83 percent of trees on a regularly burnt firebreak displayed veining, compared with only 23 percent in an adjacent unburnt compartment. Henry (1965) presents conflicting evidence for the same species reporting that similar numbers of kinoveins were formed during equal periods of fire exclusion and regular control burning.

Jarrah is considered to be less susceptible to kino formation than many other species (Jacobs 1955). Podger and Peet (1965) examined stem sections cut from pole size Jarrah which had been subjected to fires of a range of intensities and found that very few sections contained kino veins. However, Loneragan (1971) observed that kino vein formation and sapwood discolouration had occurred following summer defoliation.

Nicholls (1974) has suggested that heat damage to the cambium stimulates the formation of soft parenchyma tissue, which is subsequently differentiated into kino veins. This differentiation is governed by auxins produced at the cambium and may be augmented by auxins from the regenerated epicormic crown. Thus veining may be more pronounced following spring , rather than autumn, defoliation. Even where kino is not deposited it is likely that the parenchyma tissue represents a zone of structural weakness which may subsequently fail under impact.

3) Economic loss as a result of scarring

Fire injury may result in economic loss because of primary degrade to the log. Excessive physical damage to a log will result in its rejection.

Scarring is usually most severe on the lower bole but this is also the portion of the tree with the greatest volume. Long-butting or rejection of a complete butt log will result in considerable volume loss. Peet and McCormick (1971) observed that intense autumn fire may scar up to 80% of the surface of the butt log from a Jarrah pole tree. Overall, however, it appears that the direct loss due to scarring is relatively minor. Studies by Greaves et al (1965, 1967) for two hardwood forests indicate that the loss due to fire rarely exceeds 5%. A mill study of fire-damaged <u>Pinus radiata</u> (Nicholls and Chency) 1974) revealed that although 11% of the boards exhibited damage the actual reduction in sawn volume caused by the fire was only 0.4 percent. Even where trees are killed outright, rapid salvage and correct storage procedures can reduce defect losses. (Wright and Grose, 1970).

Secondary degrade resulting from the entry of decay organisms through fire scars is a more serious concern. Kaufert (1933) made a detailed study of hardwoods in the South eastern USA and estimated that between 90 and 95% of decay had occurred as a direct result of fire scarring.

Detailed studies of the losses due to termites, decay and fire have been published for two Australian eucalypt forests. (Greaves et al, 1965 , 1967). In an alpine forest of <u>Eucalyptus delegatensis</u> the losses due to downgrading and rejection of logs were greatest in the virgin stands, which had been subject to a long history of uncontrolled fires. For some stands, losses exceeded 50 percent of the total royalty return. Royalty losses were considerably less in regenerated stands which had been actively protected from fire. Termites were responsible for most of the damage, up to 80 percent in some compartments, and the volume lost to decay varied between 13-36 percent of the total loss. Similar results were obtained for two coastal forests of <u>E.pilularis</u>. The royalty value lost to defect was much greater in virgin stands than those which had been regenerated and protected from fire. Termites were again found to be the most destructive agent, but the loss to decay was significantly less in the more durable coastal species. The importance of decay should not be underestimated, as it was a necessary pre-requisite for the establishment of termite colonies in both areas. The authors concluded that whilst fire caused less than 10 percent of the total volume lost to defect, fire scars permitted entry of decay organisms and termites which ultimately result in severe losses to the merchantable volume of the stand.

Floyd (1966) reports a further study of fire related defect in <u>E.pilularis</u>. 42 percent of trees on a regularly burnt firebreak had suffered termite attack and 18 percent of the total stand volume was lost to defect. In comparison, only 16 percent of trees in a nearby protected compartment had been attacked by termites, with an overall defect loss of 14 percent.

Cambial injury is a pre-requisite for the entry of many wood boring insects. Clark (1925) observed that the Lyxemelia pinhole borer Atractocerus kreuslerae Pasc. which attacks Jarrah, deposits its eggs on the exposed wood of injuries. Although the Lyxemelids are not symbiotically associated with fungi they can still cause prolific staining near galleries (Neumann and Harris 1974), and their galleries provide ideal entry points for decay organisms. A detailed study of the succession of insect and fungal attack following fire was made in Eucalyptus plantations at Bulolo, New Guinea (Wylie and Shanahan 1976). Attack was rapid under the tropical conditions and many trees were badly infected after only 3 months.

4) *Predicting future losses*

Traditionally, fire damage has only been assessed following major wildfires such as occurred in Victoria in 1939 and at Dwellingup in 1961. Peet and Williamson (1968) estimated the loss in timber value following the Dwellingup fire. Estimates were based on the volume of merchantable timber killed by the fire in conjunction with possible salvage options. Yet even in the most severely affected areas the average mortality was less than 10 percent of the volume per hectare.

Prescribed fires of up to medium intensity will not cause significant mortality of established crop trees, but can cause injury which subsequently results in serious wood degrade. In a forest managed for wood production it is desirable to have accurate forecasts of the quality and quantity of timber available in the future. Hence the need for a technique to predict the consequences of fire injury.

A series of studies of degrade following fire have been undertaken in the hardwood forests of the South eastern USA. Regression techniques have been used to predict the vertical extent of decay on the basis of readily observed wound characteristics. Hepting (1935) found significant relationships between rate of decay and tree age, percentage of circumference scarred, diameter at time of wounding present diameter and species of fungi present. Following a study of Oaks Quercus sp., Hepting (1941) developed an equation to predict the volume of cull on the basis of wound width and time since wounding. Investigations by Toole and Furnival (1957) and Toole (1959) in bottomland hardwoods showed that the height of the decay colum was strongly correlated with wound age and size, length of hollow and height of butt bulge. Loomis (1974) has used regression equations to predict the loss of merchantable volume in Oak-Hickory forests. Similar techniques have been applied to Lodgepole Pine , Pinus contorta in Alberta (Nordin 1958) and White Fir Abies concolor (Aho and Roth 1978).

Any model of this type will be specific to certain conditions. Factors such as species, site quality, stand condition and fire history will probably be important. For example, Hepting and Shigo (1972) report very considerable variation in the decay rate of Oak between North Carolina and Maine.

The information available from such a model would aid decision making in badly damaged stands, and would be applicable to the selection of fire regimes for future management. This type of model could also be readily incorporated in a computerized management information system.

D) DISCUSSION AND CONCLUSION

Wood quality is likely to be an increasingly important consideration in Jarrah forest management. The resource of wood from the old-growth forest is all but exhausted; however very considerable volumes of wood are contained in the pole stands which have regenerated following cutting. Many of these stands are now 50 - 60 years old and contain trees approaching a merchantable size. Because of its slow growth, Jarrah will be unable to compete for its traditional markets with plantation grown softwood. Yet opportunity exists to establish new, higher value markets for Jarrah. Recently, pilot studies have been undertaken to assess the potential for using small Jarrah logs for veneer slicing. It was found that even small logs could be efficiently utilized, providing there was little defect. If the production of high quality timber is to be an object of management for some areas of the forest then attention will have to be focused on the relationship between fire and wood quality in Jarrah.

Historically, large areas of the Northern Jarrah have been burnt wildfires at one time or another during this century. The trees in some stands are badly scarred. Yet there is very little known about the effect of such injury on wood quality. A pilot study will be undertaken in the near future in an attempt to define the extent of the problem (see Appendix 3).

L. McCAW
A.D.F.O.
Fire Ecology
DWELLINGUP.

1/12/81

LITERATURE CITED.

Aho, P.E. and Roth, L.F. (1978). Defect estimation for White Fir in the Rogue River National Forest. USDA Forest Service Res. Pap. PNW 240.

Bryam, G.M. (1959). 'Combustion of forest fuels'. IN K.P. Davis, ed., Forest Fire: control and use, pp 61-89. McGraw-Hill, New York.

Burrows, N. (1981) Jarrah forest fire - its behaviour and actions under dry fuel conditions. W.A. For. Dept. Internal Report.

Clark, J. (1925). Forest Pests - The Pinhole borer. (Atractocerus kreuslerae, Pasc.) W.A. Dept. Agriculture Leaflet 156.

Cremer, K.W. (1962). The effect of fire on eucalypts reserved for seeding. Aust. For. 26, 129-54.

Fahnestock, G.R. and Hare, R.C. (1964). Heating of tree trunks in surface fires. J. For. 62, 779-805.

Fielding, J.M. (1967). The influence of silvicultural practices on wood properties. In Romberger and Mikola, eds. International review of forestry research, Vol. 2, pp 95-126.

Floyd, A.G. (1966). The effects of fire on forest conditions. For Comm. NSW. Tech. Paper 13.

French, J.R.J. and Keirle, R.M. (1969). Studies in fire damaged Radiata Pine plantations. Aust. For. 33(3): 176-180.

Gill, A.M. (1974). Towards an understanding of fire scar formation: field observation and laboratory simulation. For. Sci. 20: 198-205.

Gill, A.M. (1981). 'Coping with fire'. In J.S. Pate and A.T. McComb, eds., The biology of Australian Plants, pp 65-87. Univ. of W.A. Press.

Gill, A.M. and Ashton, D.H. (1968). The role of bark type in relative tolerance to fire of three central Victorian eucalypts. Aust. J. Bot. 16, 491-8.

Greaves, T., McInnes, R.S. and Dowse, J.E. (1965). Timber losses caused by termites, decay and fire in an alpine forest in New South Wales. Aust. For. 29, 161-174.

Greaves, T., Armstrong, G.J., McInnes, R.S. and Dowse, J.E. (1967). Timber losses caused by termites decay and fire in two coastal forests in New South Wales. CSIRO Div. Entomol. Tech. Pap. No. 7, pp 4-18.

Hare, R.C. (1961). Heat effects on living plants. Occ. Pap. U.S. For. Serv. No. 183. (Southern For. Exp. Stn.)

Henry, J.P. (1965). Control burning in Blackbutt (E.pilularis) forests on Manning River National Forest No. 1. Aust. For. Res. 1(2). 3-7.

Hepting, G.H. (1935). Decay following fire in young Mississippi delta hardwoods. USDA Techn. Bull. 494.

Hepting, G.H. (1941). Prediction of cull following fire in Appalachian oaks. J. Agr. Res. 62(2). 109-20.

Hepting, G.H. and Shigo, A.L. (1972). Differences in decay rate following fire between oaks in North Carolina and Maine. Plnt. Dis. Rptr. 56(5), pp 406-7.

Hillis, W.E. (1978). 'Wood quality and utilization'. In W.E. Hillis and A.G. Brown, eds., Eucalypts for wood production CSIRO.

Jacobs, M.R. (1938). Field studies on the gum veins of the eucalypts. Comm. For. Bur. Bull. 20.

Jacobs, M.R. (1955). Growth habits of the eucalypts. 262pp Comm. Govt. Printer. Canberra.

Kaufert, F.H. (1933). Fire and decay innury in southern bottomland hardwoods, J. For. 31, 64-67.

Kimber, P.C. (1978). Increased girth increment associated with crown scorch in Jarrah. For. Dept. W.A. Res. Paper 37.

Levitt, J. (1972). Responses of plants to environmental stresses. 699 pp Academic Press. New York.

Loneragan, O.W. (1971). Second growth Jarrah (Eucalyptus marginata Sm). Forest Dept. W.A., Perth.

Loomis, R.M. (1974). Predicting the losses in sawtimber volume and quality from fires in Oak-Hickory forests. USDA For. Serv. Res. Pap. NC 104.

Martin, R.E. (1963). A basic approach to the fire injury of tree stems. Proc. 2nd Tall Timbers Fire Ecol. Conf. pp 151-62.

Mazanec, Z (1974). Influence of jarrah leaf miner on the growth of jarrah. Aust. For. 37, 32-42.

McArthur, A.G. (1968). The fire resistance of eucalypts. Proc. Ecol. Soc. Aust. 3, 83-90.

McArthur, A.G. and Cheney, N.P. (1966). The characterisation of fires in relation to ecological studies. Aust. For. Res. 2, (3). 36-45.

Neumann, F.G. and Harris, J.A. (1974). Pinhole borers in green timber. Aust. For. 37, 132-41.

Nicholls, J.W.P. (1974). Effect of prescribed burning in a forest of wood characteristics of Jarrah. Aust. For. 36, 178-189.

Nicholls, J.W.P. and Cheney, N.P. (1974). Effect of experimental and wild fires in pine plantations on wood characteristics. Aust. For. 36, 164-177.

Nordin, V.J. (1958). Basal fire scars and the occureence of decay in lodgepole pine. For. Chron. 34, 257-265.

Packham, D.R. and Pompe, A. (1971). radiation temperatures of forest fires. Aust. For. Res. 5, 81.

Peet, G.B. and Williamson, A.J. (1968). An assessment of forest damage from the Dwellingup fire in Western Australia. Paper to 5th Inst. For. Conf.

Podger, F.D. and Peet, G.B. (1965). Some effects of fire on the growth of Jarrah. Paper to 4th Inst. For. Conf.

Rundel, P.W. (1973). The relationship between basal fire scars and crown damage in Giant Sequoia. Ecol. 54(1), 210-213.

Toole, E.R. (1959). Decay after fire injury to southern bottomland hardwoods. USDA For. Serv. Techn. Bull. 1189.

Toole, E.R. and Furnival, G.M. (1957). Progress of heart rot following fire in bottomland Red Oaks. J. For. 55, 20-24.

Tunstall, B.R., Walken, J. and Gill, A.M. (1976). Temperature distribution around synthetic trees during grassfires. For. Sci. 22; 269-276.

Van Loon, A.P. (1967). Some effects of a wildfire on a southern pine plantation. For. Comm. NSW Res. Note. 21.

Vines, R.G. (1968). Heat transfer through bark, and the resistance of trees to fire. Aust. J. Bot. 16, 499-514.

Vines, R.G. (1981). 'Physics and chemistry of rural fires'. In A.M. Gill R.H. Groves and I.R. Noble, eds., Fire and the Australian Biota, pp 129-149. Aust. Acad. Sci. Canberra.

Wargo, P.M. (1977). Wound closure in sugar maple: adverse affects of defoliation. Can. J . For. Res. 7, 410-414.

Wright, J.P. and Grose R.J. (1970). Wood degrade due to fire. Aust. For. 34, 149-160.

Wylie, F.R. and Shanahan, P.J. (1973). Insect attack in fire damaged plantation trees at Bulolo in Papua New Guinea. J. Aust. ent. Soc. 14, 371-382.

APPENDIX 1

APB 25 HAKEA BLOCK

FIRE DAMAGE ASSESSMENT 13 MONTH PROGRESS REPORT

This report details the results of a fire damage assessment commenced in April 1981, 13 months after the burn.

(A) Method

(1) Pre fire

A sample of 319 trees (289 Jarrah and 30 Marri) with no previous fire damage were numbered with aluminium tags before the burn. The following were noted for each tree :-

- diameter (cm)
- height (m)
- crown class (DOM, CODOM, SUP)
- reproductive activity.

(2) Post fire (13 months)

Fire damage to individual trees was assessed by the following characteristics:-

- crown reshooting
- development of bole epicormics
- kino exudation
- bark cracking
- cambial rupture (dry siding)

To allow estimation of fire intensity:-

- scorch height (m)
- scorch percentage
- maximum height of entire bark char. (m)
- highest individual point of bark char. (m) were noted for each tree.

It was obvious that factors other than fire intensity alone had contributed to damage on a number of trees. This was noted in the field under the following categories:-

a) Logs and debris - causing localized 'hot spots' or heat pulses of extended duration
b) Scraping for number, which reduced bark thickness
c) Damage associated with multiple stems, or the stump of a stem which had been removed in thinning operations.

(B) Results

(1) Jarrah

Of the 289 numbered trees, 10 were below 10cm DBH, and DBH data was unavailable for a further 4. These trees have been excluded from the analysis.

Of the 275 trees analysed, only 1 had failed to reshoot from the crown.

Table 1 shows the number of trees within each size class which suffered cambial damage as a result of the fire, taking pre-disposing factors into account.

In Table 2 this data is expressed as a percentage of the number of trees within each size class.

(2) Marri

Table 3 shows the number of Marri with cambium damaged by the fire.

Discussion

JARRAH

The sample population is most extensive for trees in the range 15-36cm DBH, and this should be borne in mind when drawing conclusions.

a) The percentage of trees damaged decreases with increasing DBH (Table 2).

Trees exceeding 20cm DBH appear to be considerably more resistant, but a proportion of larger trees have still suffered damage.

b) Logs and debris appear to be a major factor in pre-disposing trees to cambial injury, either by causing localized hot spots, or through continued burning after the fire has passed. The presence of this material reflects to a large degree the cutting history of the area. This data reinforces the need for tops disposal following commerical operations, as the elimination of this component may significantly reduce the level of damage.

c) The presence of stumps or multiple stems also pre-disposes individual stems to cambial damage, although to a lesser extent than logs and debris. Apart from not actively promoting coppice at the expense of single stem trees, there is little scope to reduce this component of damage.

d) Bark scraping to facilitate numbering was responsible for a small degree of damage. However, it is an unnecessary component and could be eliminated by alternative techniques.

CONCLUSION

Assessment commencing 13 months after the burn found that a considerable proportion of previously undamaged trees have suffered cambial damage as a result of the fire.

FURTHER ACTION

Work is currently taking place in an attempt to relate the level of damage to different intensities within the burn, with a view to producing a more precise relationship between diameter and incidence of damage.

A further field assessment is to be conducted in April, 1982.

L. McCaw
Fire Ecology Section.

8/ 10/ 81.

TABLE 1. JARRAH; NUMBER OF TREES DAMAGED BY FIRE.

DBHOB (cm)	PRE BURN No. TREES	POST BURN NUMBER DAMAGED: FIRE ALONE	LOGS & DEBRIS	SCRAPING FOR No.	STUMPS AND MULTISTEM'S	TOTAL
10-14.9	14	-	3	1	1	5
15-19.9	57	9	4	1	4	18
20-24.9	79	3	9	1	5	18
25-29.9	46	4	5	1	1	11
30-34.9	38	3	3	-	1	7
35-39.9	14	-	-	-	1	1
40-44.9	11	1	2	-	1	3
45.	16	1	1	-	-	3
	275					66

TABLE 2. JARRAH; PERCENTAGE OF TREES DAMAGED WITHIN EACH SIZE CLASS.

DBHOB (cm)	PERCENT OF TREES DAMAGED: FIRE ALONE	LOGS-DEBRIS	SCRAPING FOR NUMBER	STUMPS AND MULTISTEMS	TOTAL
10-14.9	-	21	7	7	35
15-19.9	16	7	2	7	32
20-24.9	4	11	1	6	22
25-29.9	9	11	2	2	24
30-34.9	8	8	-	3	19
35-39.9	-	-	-	7	7

TABLE 3. MARRI; NUMBER OF TREES DAMAGED BY FIRE.

DBHOB (cm)	PREBURN No. TREES	POST BURN NUMBER DAMAGED: FIRE ALONE	LOGS & DEBRIS	SCRAPING FOR NUMBER	STUMPS MULTISTEMS	TOTAL
10-14.9	5	-	-	-	-	-
15-19.9	11	-	3	2	-	5
20-24.9	10	-	2	1	1	4
25-29.9	4	-	-	-	-	-
	30					

APPENDIX 2

NORTH EAST ROAD EXPERIMENTAL BURNS LE 311

FIRE DAMAGE ASSESSMENT

INTRODUCTION

The purpose of the experiment was to study the ecological effects of medium-intensity prescribed buring executed on a semi-operational scale.

Three experimental burn areas were located along the south-eastern side of N.E. Road in Cameron Block, Dwellingup Division (Fig 1). Burning was conducted between 7.3.79 and 9.3.79 as follows:

Experimental Burn 1: Area 120 ha.
Total crown scorch with complete browning but no defoliation at crop tree level.

Experimental Burn 2: Area 60 ha.
Light to full scorch with mild browning, no defoliation at crop tree level.

Experimental Burn 3: Area 110 ha.
Evening burn with varying 50-100% scorch but no crop tree defoliation.

Detailed fire behaviour data is available.

PRE FIRE ASSESSMENT

The area to be burnt was traversed by a series of 35 transect lines, 100m apart and oriented NW-SE. Lines were marked at roadside with numbered white pegs. Along each line, further pegs were located at 50m intervals to mark sampling points.

Two distinct methods were used (for details see Appendix 1,2).

Method 1: Strip assessments were conducted along sections of 6 lines, to 5m either side of centre. The position of individual trees was plotted to scale on graph paper, and size and condition were noted.

Method 2: Circular plots of radius 3m were located at 50m intervals along odd-numbered lines, except No. 35. Position of trees was plotted to scale on graph paper, and size and condition were noted.

Pre-fire assessment was conducted in Feb/March 1979.

POST FIRE ASSESSMENT

Examination and field checking of pre-fire data revealed certain shortcomings in the initial methods:

1) size classification appeared to be very subjective and categories too coarse for useful analysis.
2) it was not possible to determine the form or relative positions of the stems.
3) they did not accurately describe the type of injury or indicate possible contributing factors.

The post fire assessment was designed to overcome these problems. An example of a field data sheet is shown in Appendix 3.

Circular plots (Method 2) were re-assessed in August 1981 using pre-fire field sheets to determine the position and condition of trees, each tree being allocated a number. This was achieved with reasonable success, although a small number, approximately 60, were unaccounted for. The absence of this data is probably not important, as most of the missing trees were in the smaller sizes and dead before the fire.

The cause of fire damage was only noted in cases where there was no doubt as to its contribution; for example, the presence of drysides on the inside of coppice stems. Similarly, death was only attributed to a specific cause under circumstances where factors other than normal fire intensity had obviously been involved.

Transect lines 11,13 and 19 passed through more than one E.B., the distribution of circular plots to each being determined by scale measurement on a 1:12,500 plan.

<u>E.B. 1</u>:	Lines 21-35	all plots
	Line 19	plots 1-10
<u>E.B. 2</u>	Line 19	plots 11-15
	Line 17,15	all plots
	Line 13	plots 1-11
	Line 11	plots 1,2
<u>E.B. 3</u>	Line 13	plots 12-20
	Line 11	plots 3-21
	Line 1-9	all plots.

DISCUSSION

1) Table 1 shows that a substantial proportion of trees within the experimental area have been damaged in previous fires. Much of this damage may have been due to Dwellingup wildfire. It is noteworthy that the majority of stems below 10cm DBH are undamaged, but above 20cm DBH the reverse is true.

Tables 2,3 and 4 summarise the stem form and nature of damage for trees injured prior to the experimental burns, Table 5 shows the stem form of previously undamaged trees.

The majority of trees in the advance growth and sapling stage, below 15 cm DBH, exhibit multi-stemmed form with larger trees tending to a single-stemmed form. It is in fact unusual that a considerable number of lignotubers have developed several stems to relatively large size, (15cm DBH) without a single sapling attaining dominance. This observation may be related to past fire history, as this situation commonly occurred where a single dominant stem had been killed by previous fire, with a number of shoots from the lignotuber subsequently developing to similar dimensions.

2) Trees exhibiting only bark rupture are considered essentially undamaged, the main reason for noting this characteristic being future reference. Dissection of a sample of these trees may be a valuable exercise.

3) The extent of mortality and damage due to the experimental burning treatments is shown in Table 6A, B, 7. There is a paucity of data for trees in excess of 20cm DBH, aggravated if further broken down to allow comparison between treatments. It would be unwise to attempt to draw conclusions as to the level of damage associated with each treatment from the limited sample. Data is presented for inspection only.

Mortality curves are presented for trees less than 20 cm DBH. (Fig2,3). No trees in excess of 20 cm DBH were killed by the burns. As expected, the level of mortality in EB3, the night burn, was considerably lower than in EB1, the hottest burn.

A substantial proportion of trees in both treatments suffered cambial damage, the lower level in EB1 being offset by a greater mortality. (Table 7).

Several of the trees in EB3 had wounds which had healed to form a scar, but none were observed in EB1. It is possible that the wounding in the lower intensity fire was less severe, and more capable of occlusion.

4) Table 8 shows the factors contributing to the different types of damage. Lack of data again prevents valid conclusions for larger size classes. Multi-stemmed form appears to be an important cause of damage below 15 cm DBH. Coppice stems are also predisposed to damage - vis.

Pre burn - 49% damaged

Post burn 80% damaged or dead.

Thus any management technique which encourages the development of either form at the expense of single stems is undesirable from a fire damage point of view.

CONCLUSION

From this assessment it can be seen that a fire causing full crown scorch to the overstorey under autumn conditions, will kill or severely damage a substantial proportion of trees below 20cm DBH.

FURTHER ACTION

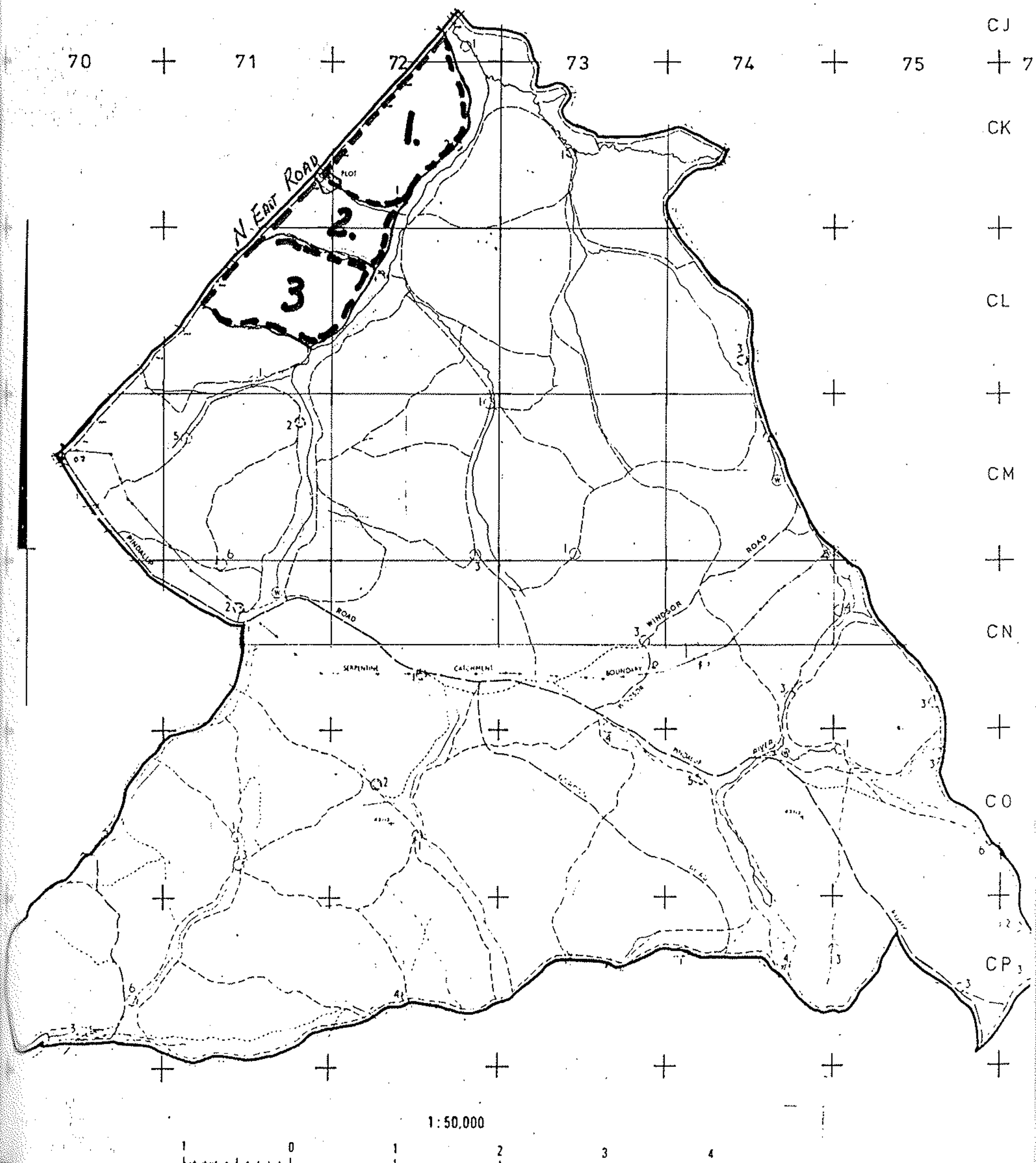
This study is limited by deficiencies in the initial design, which have been overcome to a certain extent in producing this report. However, there is little more that can be gained and no further re-assessment is proposed.

L.McCaw.
Fire Ecology
6/10/81.

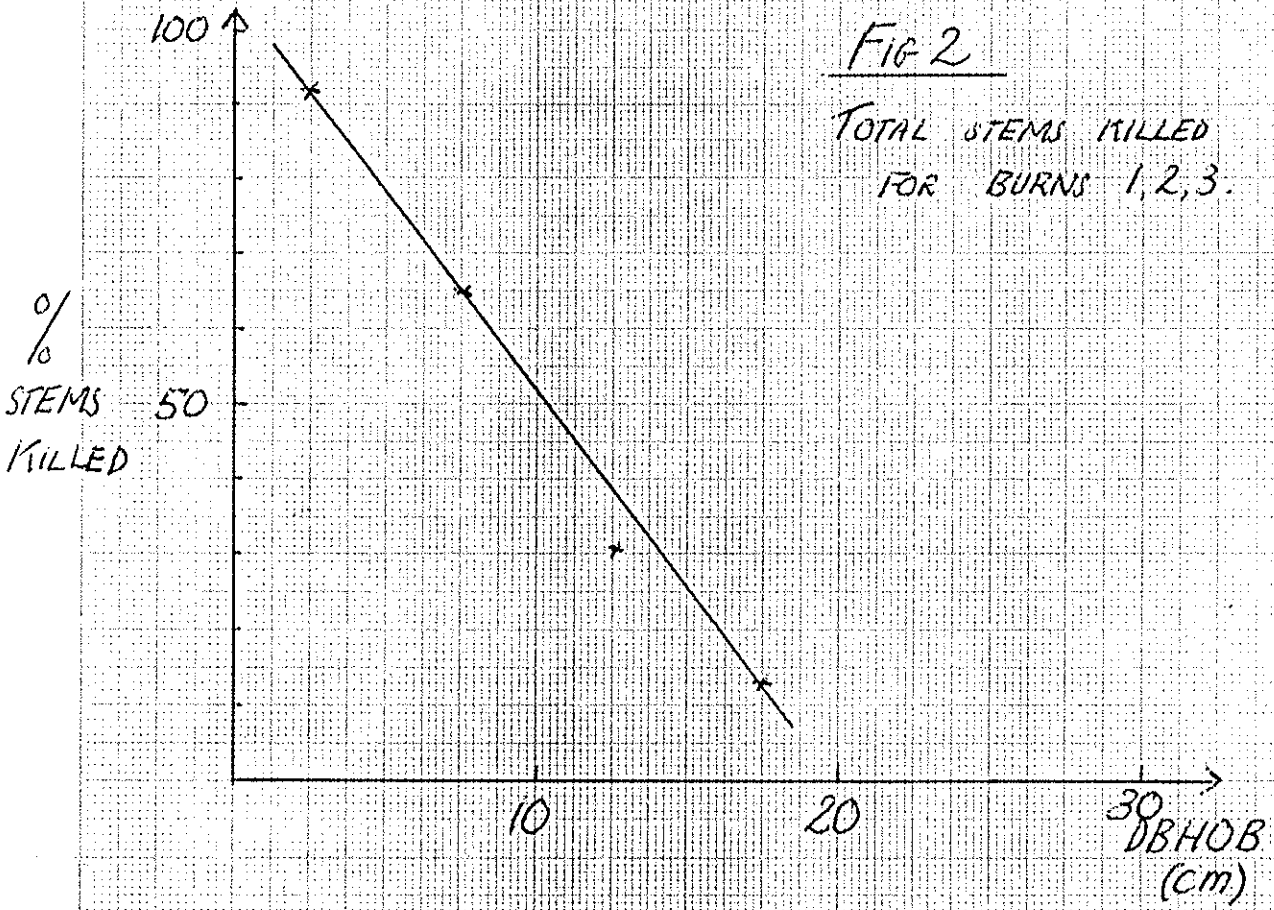
DWELLINGUP
: CAMERON
: 5733.0 ha
.L. :
CK : 5733.0 ha

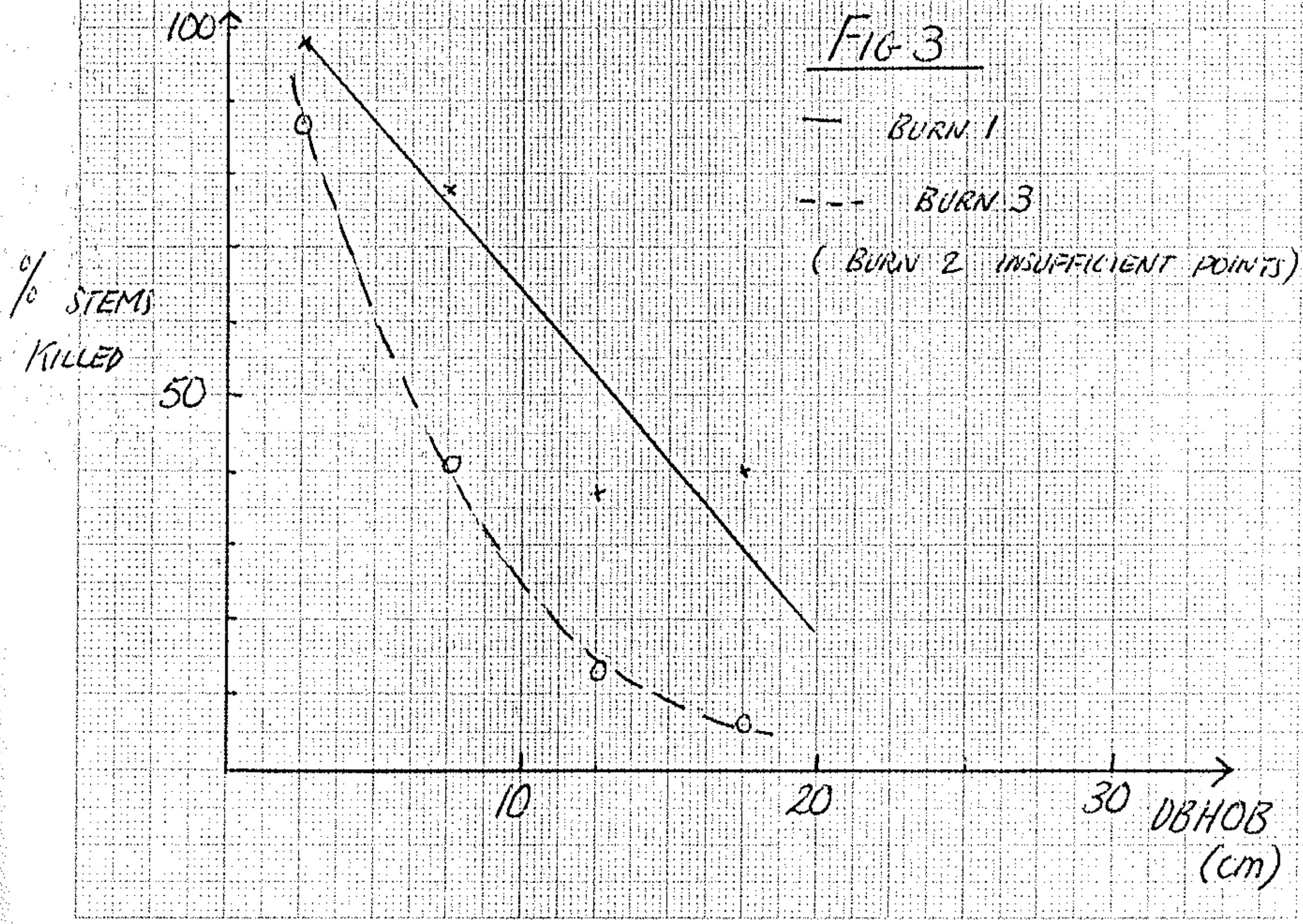
FIG 1. NE ROAD
FIRE ECOLOGY
LE. 311

---- BOUNDARY
BURN



LINES DRAWN BY EYE ONLY





GAF A4 1mm

TABLE 1 PRE BURN CONDITION

TOTAL OF STEMS FOR EX. BURNS 1, 2, 3

DBHOB (cm)	DEAD	DAMAGED	UN DAMAGED
0-4.9	31	5	158
5-9.9	45	56	251
10-14.9	17	59	87
15-19.9	3	23	24
20-24.9	1	35	12
25-29.9	-	25	7
30-34.9	-	10	4
35-39.9	-	8	3
40-44.9	1	6	2
45-49.9	-	5	2
50-54.9	-	4	1
55-59.9	-	-	2
60-64.9	-	3	-
65-69.9	-	1	3
70-74.9	-	1	-
75-79.9	-	1	1
80-84.9	-	-	-
85-89.9	-	1	-
90-94.9	-	1	-
105-109.9	-	1	-
110 114.9	-	1	-

TABLE 2 EXPERIMENTAL BURN 1

PRE BURN MORTALITY AND DAMAGE

DBHOB (cm)	DEAD	DRYSIDED Single[1]	Coppice[2]	Multi[3]	SCAR	DEAD TOP
0-4.9	16	1	-	-	-	
5-9.9	27	4	5	17	1	-
10-14.9	4	3	2	9	-	-
15-19.9	-	1	-	3		-
20-24.9	-	1	3	7	1	-
25-29.9	-	-	-	5	2	-
30-34.9	-	-	-	1	1	-
35-39.9	-	-	-	-	1	-
40-44.9	-	-	-	1	1	-
45-49.9	-	2	-	1	-	-
50-54.9	-	2	-	-	-	-
55-59.9	-	-	-	-	-	-
60-64.9	-	2	-	-	-	-
65-69.9	-	1	-	-	-	-
⋮						
85-89.9	-	-	-	-	-	-
90-94.9	-	1	-	-	-	-
⋮						
105-109.9	-	1	-	-	-	-

1. 2. 3. Indicates stem habit.

TABLE 3 EXPERIMENTAL BURN 2

PRE BURN MORTALITY AND DAMAGE

DBHOB (cm)	DEAD	DRYSIDED SINGLE	DRYSIDED COPPICE	DRYSIDED MULTI	SCAR	DEAD TOP
0-4.9	-	-	1	-	-	-
5-9.9	1	2	1	4	-	-
10-14.9	2	~~22~~	~~8~~ 1	9	-	1
15-19.9	-	1	3	-	-	-
20-24.9	-	1	2	2	-	-
25-29.9	-	3	1	-	-	-
30-34.9	-	1	2	-	-	-
35-39.9	-	-	-	2	-	-

TABLE 4 EXPERIMENTAL BURN 3

PRE BURN MORTALITY AND DAMAGE

DBHOB	DEAD	DRYSIDED SINGLE	DRYSIDED COPPICE	MULTI	SCAR	DEAD TOP
0-4.9	15	1	-	2	-	-
5-9.9	17	4	-	16	2	-
10-14.9	11	8	6	20	-	-
15-19.9	3	3	3	6	3	-
20-24.9	1	6	2	7	3	-
25-29.9	-	2	8	4	-	-
30-34.9	-	-	3	1	1	-
35-39.9	-	-	1	1	1	-
40-44.9	1	1	1	1	-	-
45-49.9	-	1	1	-	-	-
50-54.9	-	-	-	2	-	-
55-59.9	-	-	-	-	-	-
60-64.9	-	-	-	1	-	-
65-69.9	-	-	-	-	-	-
70-74.9	-	1	-	-	-	-
75-79.9	-	1	-	-	-	-
80-84.9	-	-	-	-	-	-
85-89.9	-	1	-	-	-	-
¦	-	-	-	-	-	-
110-114.9	-	1	-	-	-	-

TABLE 5 STAND STRUCTURE FOR STEMS UP TO 40cm DBH UNDAMAGED BEFORE EXPERIMENTAL BURNING.

DBHOB Size Class (cm)	E.B. 1			E.B. 2			E.B. 3			TOTAL
	SINGLE [1]	COPPICE [2]	MULTI STEM [3]	SINGLE	COPPICE	MULTI STEM	SINGLE	COPPICE	MULTI STEM	
0 - 4.9	15	-	34	10	-	22	40	-	37	158
5 - 9.9	26	8	96	3	4	29	33	2	50	251
10 - 14.9	5	1	32	-	-	10	14	2	23	87
15 - 19.9	1	-	4	1	1	1	6	2	8	24
20 - 24.9	3	-	2	1	-	-	5	-	1	12
25 - 29.9	2	-	-	1	-	-	4	-	-	7
30 - 34.9	1	-	-	1	-	-	2	-	-	4
35 - 39.9	-	-	-	-	-	1	1	-	1	3

1. 2. 3. Refers to stem habit.

Single - single dominant stem

Coppice - stems growing from stump of larger tree no longer in existence.

Multistem - several stems growing from a common lignotuber, usually but not necessarily of similar size class.

TABLE 6 POST BURN CONDITION OF PREVIOUSLY UNDAMAGED TREES

TOTAL DATA FOR BURNS 1, 2, 3

(A) ACTUAL NUMBER

DBHOB (cm)	PRE BURN	POST BURN UNDAMAGED	BARK RUPTURE	CAMBIAL DAMAGE EXPOSED	CAMBIAL DAMAGE HEALED	DEAD TOP	DEAD	TOTAL DEAD + DAMAGED
0-4.9	158	3	-	-	-	9	146	155
5-9.9	251	22	11	30	2	23	163	218
10-14.9	87	8	10	36	4	2	27	69
15-19.9	24	5	9	7	-	-	3	10
20-24.9	12	5	2	3	2	-	-	5
25-29.9	7	2	2	2	1	-	-	3

(B) EXPRESSED AS PERCENTAGE OF TOTAL WITHIN EACH SIZE CLASS

DBHOB (cm)	PRE BURN	POST BURN % UNDAMAGED	BARK RUPTURE	CAMBIAL DAMAGE EXPOSED	CAMBIAL DAMAGE HEALED	DEAD TOP	DEAD	TOTAL % DEAD + DAMAGED
0-4.9	100	2	-	-	-	6	92	98
5-9.9	100	9	4	12	1	9	65	87
10-14.9	100	9	11	41	5	2	31	79
15-19.9	100	21	38	29	-	-	13	42
20-24.9	100	42	17	25	17	-	-	42
25-29.9	100	29	29	29	14	-	-	43

Table 7 Comparison of Damage Between Burns 1, 2, 3
Damage to Previously Healthy Trees < 30 cm DBHOB

Ex Burn 1.

DBHOB (cm)	Pre Burn %	Post Burn: Undamaged	Bark Rupture	Cambial Damage: Exposed	Cambial Damage: Healed	% Dead Top	Dead	Total % Dead & Damaged
0-4.9	100 (49)	2 (1)	-	-	-	-	98 (48)	98
5-9.9	100 (130)	2 (2)	2 (2)	9 (12)	-	9 (12)	78 (102)	96
10-14.9	100 (38)	8 (3)	5 (2)	~~48~~ (17)	-	5 (2)	37 (14)	86
15-19.9	100 (5)	20 (1)	-	40 (2)	-	-	40 (2)	80
20-24.9	100 (5)	20 (1)	40 (2)	-	40 (2)	-	-	40
25-29.9	100 (2)	50 (1)	-	-	50 (1)	-	-	50

Ex. Burn 2

DBHOB (cm)	Pre Burn %	Post Burn: Undamaged	Bark Rupture	Cambial Damage: Exposed	Cambial Damage: Healed	% Dead Top	Dead	Total % Dead & Damaged
0-4.9	100 (32)	-	-	-	-	3 (1)	97 (31)	100
5-9.9	100 (36)	8 (3)	6 (2)	-	-	14 (5)	72 (26)	86
10-14.9	100 (10)	-	-	20 (2)	-	-	80 (8)	100
15-19.9	100 (3)	66 (2)	-	33 (1)	-	-	-	33
20-24.9	100 (1)	-	-	+ (1)	-	-	-	100

Ex. Burn 3

DBHOB (cm)	Pre Burn %	Post Burn: Undamaged	Bark Rupture	Cambial Damage: Exposed	Cambial Damage: Healed	% Dead Top	Dead	Total % Dead & Damaged
0-4.9	100 (77)	3 (2)	-	-	-	10 (8)	87 (67)	97
5-9.9	100 (85)	20 (17)	8 (7)	21 (18)	2 (2)	7 (6)	41 (35)	71
10-14.9	100 (39)	13 (5)	21 (8)	44 (17)	10 (4)	-	13 (5)	67
15-19.9	100 (16)	13 (2)	56 (9)	25 (4)	-	-	6 (1)	31
20-24.9	100 (6)	67 (4)	-	33 (2)	-	-	-	33
25-29.9	100 (4)	25 (1)	50 (2)	25 (1)	-	-	-	25

N.B. Figures in brackets are actual numbers of trees

TABLE 8 FACTORS CONTRIBUTING TO FIRE DAMAGE ON PREVIOUSLY UNDAMAGED TREES < 30 cm DBHOB

(A) E.B. 1 ACTUAL NUMBER OF TREES IN EACH DAMAGE CATEGORY.

DBHOB (cm)	UNDAMAGED	BARK RUPTURE			CAMBIAL DAMAGE							DEATH				DEAD TOP	TOTAL
					UNHEALED				HEALED								
		F*	C	M	F	D	C	M	F	C	M	F	D	C	M		
0-4.9	1											40	8				49
5-9.9	2	2			6	1	1	4				80	4	8	10	12	130
10-14.9	3			2	4	1		12				9	2	1	2	2	38
15-19.9	1	~~1~~			1	1								1	1		5
20-24.9	1	1	1						1	1							5
25-29.9	1								1								2

(B) E.B. 2

DBHOB (cm)	UNDAMAGED	BARK RUPTURE F	BARK RUPTURE C	BARK RUPTURE M	UNHEALED F	UNHEALED D	UNHEALED C	UNHEALED M	HEALED F	HEALED C	HEALED M	DEATH F	DEATH D	DEATH C	DEATH M	DEAD TOP	TOTAL
0-4.9												24	4		3	1	32
5-9.9	3			2								15	4	2	5	5	36
10-14.9								2				6	2				10
15-19.9	2						1										3
20-24.9					1												1
25-29.9					1												1

(C) E.B 3

DBHOB (cm)	UNDAMAGED	BARK RUPTURE F	BARK RUPTURE C	BARK RUPTURE M	UNHEALED F	UNHEALED D	UNHEALED C	UNHEALED M	HEALED F	HEALED C	HEALED M	DEATH F	DEATH D	DEATH C	DEATH M	DEAD TOP	TOTAL
0-4.9	2											55	4		8	8	77
5-9.9	17	2		5	4			14	1		1	23	2		10	6	85
10-14.9	5	3		5	3	2	2	10	3		1	3			2		39
15-19.9	2	3		6	2			2				1					16
20-24.9	4				1	1											6
25-29.9	1	2				1											4

*Explanation of symbols
F : damage attributed to fire intensity alone
D - " " debris (logs, stumps)
C - " " coppice stump
M - " " multiple stemmed habit.

Pre-fire Assessment - N.E. Road Fire Site

Method 2

Introduction

This assessment was carried out across the total area of burn on a grid pattern to establish the pre fire damage to each of four size classes of Jarrah trees.

Method

Each line with an uneven number was traversed. At each peg position, at 50 m. intervals along the line, a plot with 3 m. radius was established with the peg at the centre.

In each plot, Jarrah trees were assessed for fire damage which included:-

1. Butt scars
2. Bole scars
3. Fire induced bleeding
4. Death
5. Dog legs.

Jarrah trees were divided into four classes

1. Saplings
2. Poles
3. Piles
4. Veterans

Each specimen was assessed as healthy or damaged.

Healthy Trees		Defects recorded in brackets after species	
Sa	sapling	Sc	scar
Po	pole	D/S	Dry side
Pi	pile	D/L	Dog leg
V	veteran	D/T	Dead top
		D	Dead

Species		Height of saplings
M	Marri	6m = 6 metres
No symbol	Jarrah (remainder)	2m = 2 metres

Fire-killed poles & saplings were included as damaged.

Results

The 950 metres of line assessed represented 0.95 hectares.

Saplings	444 assessed	-	271 or 61%	damaged
Poles	200 assessed	-	122 or 61%	damaged
Piles	9 assessed	-	2 or 22%	damaged
Veterans	26 assessed	-	18 or 69%	damaged

Conclusions

These findings suggest that a considerable proportion of the forest crop is suffering from fire damaged following the previous fire regimes.

Some of this damage resulted from the Dwellingup fire and the "prickle disposal burns".

Saplings are the most fire sensitive. The majority of saplings recorded in the healthy group have resulted from growth since the last burn in Spring 1974.

Poles seem to gain fire resistance with age and size. The latter being a function of competition and site interaction.

The veterans include trees rejected by logging (culls) with many and varied defects.

Follow-up Work

Assessments of the same lines will be carried out in Autumn 1980 to ascertain what amount of damage was caused by the March 1979 fires.

Local Expt. 311

Pre-fire Assessment - N.E. Road Fire Site

Introduction

The application of prescribed fires to forest areas during Summer and Autumn inevitably results in some damage to Jarrah boles and crowns. This study was initiated to measure what damage existed before 3 separate fires were lit in early March 1979.

Method

A selection of lines was surveyed during February 1979. Jarrah and Marri stems occurring within 5 metres were classified as undamaged or damaged. In each category, the trees were grouped as saplings, poles, piles or veterans.

Saplings included those stems showing dynamic potential and ranged from 50 to 150mm D.O.B.B.H.

Poles ranged from 151mm to 300mm D.O.B.B.H.

Piles ranged from 301mm to 450mm D.O.B.B.H.

Veterans included trees in excess of 451mm D.O.B.B.H.

Only areas free of dieback were assessed and the lines chosen was typical of the better class of forest in the area.

Assessment strips varied in length but were all 10 metres wide.

Areas surveyed

Line No.	Distance from N.E. Rd. to Line	Length of line
5	Begins ~~on~~ 50m from N.E. Rd.	~~250m~~ 200m
7	Begins 150m from N.E. Rd.	100m
14	" 100m " " "	200m
16	" 50m " " "	100m
27	" 100m " " "	200m
29	" 100m " " "	100m

Booking Procedure

The following procedure was adopted.

Lines were represented on large strips of graph paper with a scale of 1cm = 1 metre in the field.

Healthy Trees		Defects recorded in Brackets after Species	
Sa	Sapling	Sc	Scar
Po	Pole	O/s	Dry side
Pi	Pi	D/l	Dog Leg
V	Veteran	D/t	Dea Top
		D	Dead

Species

M Marri

No symbol J (remainder)

Height of Saplings

6 m=6metres

2m = 2 metres

Fire killed poles and saplings were included as damaged.

Results

On the lines assessed there were 275 stations. These constituted a total area of 0.778.9 Ha.

Saplings	705 assessed	- 321	or 45.5%	damaged
Poles	249 "	- 178	or 71.5%	"
Piles	15 "	- 9	or 60.0%	"
Veterans	22 "	- 13	or 59.1%	"

Conclusions

As with method 1. a considerable proportion of the stand has been damaged by past fires.

Other comments noted in method 1 are applicable here.

Comparison Method 1 to Method 2

Method 1 had the failure of not covering the whole area and may lack representation from some sites.

Method 2 was a small sample, however time available before the burn precluded a larger plot size. Five metre radius was considered (78-575 m^2 compared with 28.29 m^2)

*

Follow Up Work

Re-assess in Autumn 1980

W.B. Edgecombe T/O
2/7/79

Method 2 indicated 45-5% of saplings were damaged whereas Method 1 indicated 61%; Pole damage was 61%.

EXP. 311 N.E. Rd JARRAH FIRE— AMAGE ASSESSMENT

PRE-FIRE													POST-FIRE									
					STEM TYPE			CAMBIAL DAMAGE		DAMAGE CAUSE				CAMBIAL DAMAGE			DAMAGE CAUSE					DATE
						MULTI																
LINE	PLOT	STEM	DEAD	DIA.	SINGLE	COPPICE	LIGNO	DRYSIDE	SCAR	DEBRIS	COPPICE STUMP	MULTI-STEMS	DEAD	DRYSIDE	DRYSIDE U.B.	BARK RUPTURE	DEBRIS	COPPICE STUMP	MULTI STEMS	EPICORMIC FORMATION	LIGNO. STEM FORMATION	COMMENTS

APPENDIX 3

Fire Damage and Log Defect in Jarrah.

Proposal for Pilot Study

(1) *Background*

Fire damage studies to date.

Peet and Williamson (1968) considered the damage caused by the 1961 Dwellingup wildfire in terms of

1) *volume of merchantable timber fire killed*
2) *degree of crown recovery in the remaining trees.*

The assessment was based on crown damage and did not consider losses associated with decay or insect attack through bole injuries.

Peet and Mc Cormick (1971) studied the effect of intense spring and autumn fires on Jarrah pole stands under experimental conditions. 30 trees were burnt in each treatment, being classified subsequently as undamaged, killed or drysided, with the extent of drysiding expressed as a percentage of the area of the 2.4m butt log.

Fire damage assessments in conjunction with experimental medium intensity fires at NE Rd., Cameron Block [1.] and Hakea Block [2.] have provided data on the relationship between cambial damage and size of tree.

More precise data relating fire intensity to tree size and area of cambium damaged is available from the Young Block small plot studied. (Forests Dept., internal report).

With existing data it is possible to make reasonable predictions as to the percentage of trees within a given size interval which will suffer cambial damage in a fire of given intensity, although the data base should be extended and refined wherever possible.

The major question arising from such studies is what is the significance of such injury to log quality and merchantable recovery in the longer term.

A study of log defect in E.delegatensis in NSW showed that actual volume loss due to fire was minimal, but that fire injuries were the major infection points for decay fungi and termities. (Greaves McInnes, Dowse, 1965).

1. *Local Experiment 311.*
2. *L.E. 345.*

Studies in North American hardwoods have also emphasized the importance of fire wounds in allowing entry of decay organisms. (Hepting 1935, Toole 1959).

However, little or no information is documented on the long term effects of fire injury on Jarrah .

Large areas of the Northern Jarrah have regenerated as densely stocked uniform pole stands following logging operations in the early years of this century. Many of these stands have been burnt by wildfires at one time, and some have been burnt repeatedly. These pole stands are of twofold significance:-

1. *they represent the crop trees of the not-too-distant future.*

and

2. *they act as a model for stands which should regenerate from current and future operations.*

Thus a knowledge of the relationship between fire injury and degrade in Jarrah pole stands has important implications for management.

These include:-

1. *improved forecasts of merchantable yield*
2. *better decision making in badly fire damaged stands*
3. *selection of desirable fire regimes for future management.*

(2) Proposal.

It is proposed to undertake a pilot study to examine the effect of fire injury on subsequent wood degrade. This study will attempt to define the extent of the problem and should act as a basis for determining the requirements for further work.

The major aims of the study are:-

2(1) a) To study the pattern of wood defect arising from fire injury, and to attempt to relate this to the age and physical characteristics of the wound.

b) To determine the loss of merchantable volume associated with this defect.

(3) Method

The study will involve the felling and dissection of a sample of trees from several stands with differing fire histories.

3 (1) a) Up to 10 trees will be sampled at each location. Several of these should be apparently undamaged to act as a control.

b) The remainder will be selected to examine a range of bole damage.

c) Where possible, felling of sample trees should conform with the thinning requirements of the stand.

3 (2) Pre-felling assessment

a) The following characteristics are to be noted for each tree:-

D B H O B
Length of clean bole
Crown vigour
Non fire wounds (broken branch stubs etc.)
Fire wounds.

b) Wounds will be described in terms of:-

Position on tree
Aspect
Width
Length
State of healing
Presence of visible decay or insect attack
Degree of charring
Estimated age (old or recent)

Wounds to be photographed in relation to scaled measuring stick.

3 (3) Post felling assessment

a) A disc is to be cut from the stump of each tree. This will be used for growth ring analysis in the lab to confirm the fire history of the stand.

b) The stem will be cut into 0.5m lengths and a 5cm disc cut from the upper end of each. These discs will be numbered and retained.

c) Each length will then be split longitudinally to permit the study of any defect present. Split sections will be photographed and where necessary complemented with scale sketches to record the pattern of defect.

All dissection and measurement is to be done on freshly felled material at the stump.

4. *Location*

- *see Appendix 1.*

5. *Staff Requirements*

All felling to be carried out by a qualified operator.

Other work to be undertaken by Fire Ecology personnel, with possibility of assistance from light-duties staff if required.

6. *Time Horizon*

Project to be commenced as soon as possible in November 1981.

Duration should be of the order of 4 - 6 weeks, depending on other commitments.

7. *References*

Greaves, T., R.S. McInnes, J.E. Dowse (1964). Timber losses caused by termites, decay and fire in an alpine forest in NSW, Aust. For. 29: 161-174.

Hepting G.H. (1935). Decay following fire in young Mississippi delta hardwood, USA Tech. Bull. 494.

Peet, G.B., J. McCormick (1971). Short Term responses from controlled burning and intense fires in the forest of WA, Bulletin 79 Forest Dept.

Peet, G.B. A.H. Williamson (1968). An assessment of forest damage from the Dwellingup fire in W.A., Paper to 5th Inst. For. Conf. , Perth.

Toole, E.R. (1959). Decay after fire injury to Southern Bottom-land hardwoods USDA Forest Service Tech. Bulletin, 1189.

L. McCAW
Fire Ecology Section
1/12/81