AFFORESTATION WITH PINES

IN THE

DONNYBROOK SUNKLANDS

STATEMENT OF INTENT

September, 1975.

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FORESTS DEPARTMENT OF WESTERN AUSTRALIA

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DONNYBROOK SUNKLAND

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AFFORESTATION WITH PINES IN THE DONNYBROOK SUNKLAND

STATEMENT OF INTENT

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SUMMARY

The project envisages the conversion of some 60,000 hectares of degraded dieback-infected native forest into pine plantations over a period of 30 years.

The additional softwood area is required to provide the resource base for current industrial developments and to ensure that the major proportion of the State's timber requirements will be met from local sources by 2000.

The area selected is scenically unattractive, has few special biological features or other major attractions and is the main additional area available for large scale planting. Broad swathes of native forest will be retained, separating the plantations which will occupy about 20 per cent of the total area. Planting will proceed in two or more localities simultaneously.

The effects of the project on major environmental factors are considered to be:

1. Hydrology

   Little effect on surface hydrology in view of the relatively free underlying sediments. Restoration of tree cover is likely to be beneficial in offsetting the present and anticipated destruction of native vegetation by dieback.

   Silvicultural techniques already developed at Wanneroo are directly applicable with management of underground water supplies.

2. Vegetation

   Based on extensive surveys, the native flora contains little of special significance, except in the Whicher Ranges where a substantial area will be excluded from the project. The vegetation types scheduled for conversion will continue to be represented in the hardwood buffer areas and two other areas are to be set aside for special management for flora protection.

3. Fauna

   Field surveys indicate a similar situation and similar proposals apply.

4. Recreation

   Except for the valley of the Blackwood River and perhaps the Whicher Ranges to a lesser extent, the area is of little recreational interest. Adequate areas are to be set aside in these localities to protect such recreational values as occur.

5. Scenic

Recreation is closely allied to scenery and similar comments apply. Variety will be added to an otherwise monotonous landscape by the proposed project and special treatment will be given to protection of scenic values in minor localities as the project develops.

The project is considered to have little adverse effect on environmental factors and its hydrological effects could in fact be advantageous.

Substantial social and economic benefits are foreseen as follows:

1. Initial stabilisation of the local forestry workforce followed by a substantial expansion within the next 5 years creating potential for seasonal employment in the local agricultural workforce.

2. Possible combination of stock agistment with plantation establishment to both silvicultural and agricultural advantage.

3. Consolidation of the resource base for existing and currently planned industry on a fully integrated and decentralised basis.

INTRODUCTION

The Forests Department is proposing to establish extensive pine plantations in selected portions of State Forest in the area known as the Donnybrook Sunkland. The following statement has been prepared to explain, in some detail, the proposed plantation development, the environmental implications of the project and the precautions being taken to prevent any deleterious effects.

The need to supplement the indigenous hardwood timber supplies with local plantation grown softwood in Western Australia has been outlined in a submission to a House of Representatives Standing Committee on Environment and Conservation, a summary of which is contained in Appendix V. Basically, the reason for a continued pine planting programme is to provide the resource base for current industrial development and provide for the timber requirements of future populations of this State. It is imperative that the demand for timber from the State's limited eucalypt forests be reduced and it is extremely unlikely that a sufficient, reliable supply of timber products will be available from external sources in the future.

The limited area of land, suitable for pine planting, available to the Forests Department, has been a major restriction on the pine planting programme. The Department's policy has been to use repurchased farmland as far as possible rather than convert high quality native forest to pines, but the possibilities of repurchasing any further significant areas of suitable farmland are remote. Few properties are being offered for sale and the prices asked have become unrealistically high. The situation is critical in that in order to maintain a Pinus radiata planting programme beyond 1980 the Forests Department must purchase such suitable farmland as is available and proceed with conversion of poor quality native forest.

The large area of poor quality forest between Nannup and Busselton, known as the Donnybrook Sunkland, has been shown, by trial and experiment, to be suitable for commercial pine production under appropriate nutritional regimes. This forest is badly degraded by jarrah dieback and a large proportion will inevitably be killed by this disease. Intensive research has shown that Pinus radiata can be grown successfully on selected sites here, even where the original forest has been killed by the root rot fungus Phytophthora.

There are no other large areas of proven, suitable soil with adequate rainfall available to the Department for planting Pinus radiata. The Forests Department has considered the environmental aspects of the conversion to pine plantation of some 60,000 ha out of the total Sunkland area of 283,000 ha and can see no valid reasons against the proposal on these grounds. The present state of the Department's knowledge and the reasoning on these aspects are set out and discussed in the ensuing chapters of this document.

The greater part of the area (approx. 80%) will be retained as natural forest and managed with multiple-use objectives. Planting will be in a number of cells containing much of the country worst affected by dieback and separated by broad swathes of native forest.

The vegetative types to be converted to plantations will continue to be adequately represented as it is not intended to convert the full extent of suitable soils into plantations. Areas of special interest, such as those of ecological, water supply or recreational import, will be demarcated and covered by special management priority plans to ensure the protection and preservation of those particular values.

From the social viewpoint, the project will stabilise the existing departmental work forces at Nannup, Margaret River and Ludlow until 1978, after which a substantial expansion can be anticipated, either in the form of direct employment or of employment on a seasonal contract basis, to which the predominantly agricultural local work force is ideally suited.

From the economic viewpoint, the project offers the advantages of cheaper establishment and maintenance than on repurchased land in the nearby Blackwood Valley, even if such land were available.

Favourable topography and geographic concentration will consolidate a highly economic large scale integrated processing industry in the locality, thus fostering the process of decentralisation.

It must be stressed this document is not an environmental impact statement. It is a land use proposal aimed at multiple use of the Sunkland area to produce the best compromise in land use in the long term.

In 1977 a decision must be taken whether the proposed pine planting programme in the Sunkland will go ahead. This Statement of Intent has been released to other State Government Departments and to the public for constructive comment and resolution of any possible conflicts or deficiencies in the land use plan before that time.

Up to mid-1975 some 85 ha of pine had been planted in a pilot plantation area near Jarrahwood. This pilot plantation will be extended in 1976 and 1977 to provide an area in which to carry out operational-scale site preparation trials and monitor the environmental impacts of these proposals.

1. GENERAL DESCRIPTION OF THE SUNKLAND

1.1 Location

The area generally referred to as "the Sunkland" is a tract of forest south of Busselton and west of Nannup, some 240 km south of Perth (see Locality Plan, Plan No.1). The nearest major town is Busselton (population 7,600) while a developing regional centre, Bunbury (pop. 20,000) is only about 48 km further to the north. Other smaller towns in the locality are Margaret River (800), Donnybrook (1000) and Nannup (200).

To the north the Sunkland is bounded by the intensively developed coastal plain, the scene of a large dairy and beef cattle grazing industry. To the west and south there is a large area of partly developed sheep and cattle grazing country around Cowaramup, Margaret River, Augusta and Scott River. On the east the Sunkland is bounded by well developed grazing country in the Upper Capel, Cundinup and Nannup districts, by existing Forests Department plantations around Nannup and by high quality State Forest east of the Vasse Highway.

The area is traversed in part by the Busselton-Nannup railway and by the Vasse and Brockman Highways.

1.2 Tenure

The Sunkland is a large compact block comprising mainly State Forest with some relatively small areas of Timber Reserve and vacant Crown Land (see Tenure Plan, Plan No.2). Narrow strips of private property have been developed for agriculture along the Blackwood River and St. John's Brook. Along the northern edge of the Sunkland several mineral claims are held by companies mining heavy minerals (ilmenite, zircon) near Capel.

1.3 Area

The total area of public land in the block referred to as the Sunkland is approximately 283,000 ha, composed of:-

State Forest	258,000 ha
Timber Reserve	12,500 ha
Crown Land	12,500 ha
Total	283,000 ha

2. ENVIRONMENTAL DATA

2.1 Climate

This part of Western Australia has a typically Mediterranean type of climate with hot, dry summers and cool, wet winters. The average annual rainfall in the Sunkland is about 1150 m.m falling on 120-150 days of the year. Rainfall isohyets on Plan No.1 (source; Weather and Climate in Western Australia by J. Gentilli) show a marked trend for increasing rainfall from the north to the south. The rainfall is very reliable and, being derived mainly from frontal activity, the rain is rarely of high intensity. Temperatures are moderate; the mean daily maximum at Bunbury ranging from 28 degrees C in February to 16 degrees C in July, with frosts a rarity except in some low-lying areas.

With a growing season of eight months this climate is ideally suited to the growth of Pinus radiata (Ref. Comm. Met. Bureau Climatic Survey. Region 16. South West Western Australia).

2.2 Geology and Land Forms

As its name implies the Sunkland lies between two north-south geological faults as shown on the locality plan - (See Plan No.1). These are the Darling Fault, coinciding with the Darling Scarp, and the Dunsborough Fault which runs from Dunsborough to Augusta. The Sunkland is a low undulating plateau 100 to 180 metres above sea level with a general slope from east to west and from north to south. It is composed mainly of mesozoic sediments up to 3,000 metres in thickness, lying between the Precambrian granites east of the Darling Fault and the granitic gneiss of the Leeuwin-Naturalist Ridge. The only surface occurrences of igneous rock in the Sunkland are occasional outcrops of Bunbury basalt. (Refer. Geological Surveys. Geology of the Southern Perth Basin by D.C. Lowry - Record No. 1965/17).

The area is dissected by the westward flowing Blackwood River and by three smaller rivers flowing north and west. The Ludlow and Sabina Rivers are ephemeral streams flowing only through the winter and spring. The Margaret River flows for a longer period.

In the south towards the coast the country is low lying and swampy. The swamps are thought to have formed through the blocking of drainage lines by coastal dunes.

2.3 Hydrology

The water resource in this region is considerable and will undoubtedly be utilised in the future.

At present the only major utilisation of water from the area is the water supply for Margaret River township from a dam on the Margaret River. All the streams

rising in the Sunkland are fresh including the tributaries of the Blackwood, Rosa Brook and St. John's Brook. The Blackwood River itself which rises in agricultural areas to the east is of high salinity.

Underground water is the major water resource in the Sunkland. The upper sections of the sedimentary strata contain very large quantities of potable water. The re-charge rate of these aquifers has been estimated by the W.A. Geological Survey to be 300,000 m3 per day. (Refer. D.B. Collett. Water Resources of the South West of W.A.)

2.4 Soils

The sediments of the Sunkland are capped by laterites and sand. The typical pattern is for the ridge tops to be composed of sandy lateritic gravels with a variable amount of massive ironstone. Broad depressions even in the higher country are generally filled with sand of varying depth over the laterite. Downslope the soils are sandy at the surface often becoming heavier in texture at depth. The lowest country is generally poorly drained and waterlogged for much of the year. The outstanding characteristic of the soils of the Sunkland is their extremely poor natural fertility.

More detailed descriptions and discussion of soil types is given in the section, 4.1, dealing with site mapping.

2.5 Vegetation

2.5.1 Forest types

The predominant forest type in the Sunkland is open jarrah (E. marginata) forest of poor quality. In general, marri (E. calophylla) is a minor component of the forest, although it does become more important on the more favoured sites in the valleys, especially along the Blackwood River. The few, small areas of high quality forest are confined to occasional outcrops of "Bunbury basalt". The largest such areas are in Canebreak and Milyeannup Blocks south of the Blackwood.

2.5.2 Survey and Mapping

The entire area is covered by Forests Department vegetation type maps compiled from air photos. Most of the area has been more recently mapped on a broader scale by F.G. Smith (W.A. Department of Agriculture: Vegetation Map Busselton, Augusta 1973).

Smith (Plan 11) has mapped the vegetation of a large section of the Sunkland on the basis of structural criteria of the tallest stratum such as life-form, height and density. He has classified the majority of the area as type B2, open forest with trees 10-30 m in height, with minor areas of B1 (closed forest 10-30m), F1 (closed sedgeland) D2 (open scrub over 2m in height, characterised by Kingia australis and a shrubby form of jarrah); C4 (low open woodland, trees less than 10m) and B3 (open woodland).

A detailed examination of the vegetation of the area is being undertaken in the site surveys currently in progress. A list of plant species known to occur in the Donnybrook Sunkland is appended as Appendix B2.

2.5.3 Impact of Phytophthora cinnamomi

In the early 1950's the dieback disease Phytophthora cinnamomi made its appearance. The particular combination of highly susceptible vegetation, gentle topography and moist soils predispose the Sunkland to very rapid spread of the disease. At the present time 16 percent of the total area is affected (See Plan No.3).

Because of the extreme susceptibility of the Sunkland forest, it is inevitable that, even without any new infections, some 60 percent of the forest in this area will be wiped out by the irrevocable extension of these existing infections. (See Dieback Risk Plan, Plan No.4).

2.6 Fauna

Two intensive fauna surveys have been carried out in the region, covering all habitat types. These studies have shown that the Sunkland contains a typical assemblage of animals for jarrah forest of this type. There appears to be no unusual or rare animals apart from Mueller's snake (Rhiniplocephalus bicolor).

A complete list of all fauna so far known to be present in the area and a summary of surveys is given in Appendix No.1.

3. LAND USE

3.1 Past Use

The Sunkland forest has been utilised since the early years of the century by the hardwood sawmilling industry, the generally small log size being offset by cheap extraction. Sawmills are still operating on the Sunkland forest, at Jarrahwood, Nannup, Witchcliffe and Busselton.

The Sunkland was unattractive to the early settlers who passed it by for more remote but more fertile land. Very little of it has been alienated for agriculture due no doubt to its obvious poor soil fertility. Almost the entire Sunkland area was traversed by land classification teams from the Lands Department in the period 1918-1930. However, alienation was not proceeded with, possibly because of the sad experiences at the time with the Group Settlement Scheme. Since 1950 the use of artificial fertilisers has made this type of land more attractive and there has been some pressure for alienation of public land in the region. However, there appears to be no real shortage of farming land in the region as evidenced by the fact that in the Margaret River-Augusta Shire 40% of the alienated land is still undeveloped. Current planning indicates that this undeveloped alienated land will be required for future farm development.

The area contains no special features of geological or historical interest and very little of scenic value apart from the Blackwood River. The river has been used for many years for fishing for perch and the freshwater crayfish (marron) and in recent years there has been an upsurge in its use for canoeing. As it is the largest river in the south west corner of the State this activity is expected to increase in the future.

3.2 Future Use

The Department's proposals for multiple use management of the Sunkland forest are illustrated on Plan No.7. Careful consideration is being given in the planning to avoid adverse environmental effects and in fact to conserve and improve the quality of the environment.

Out of a total area of some 283,000 ha, about 60,000 ha (21%) will eventually be converted to pine plantation over a period of thirty years. Some 33,000 ha are to be set aside as special management priority areas for the preservation or development of particular features, e.g. recreation, special ecological types etc. The remaining 190,000 ha will be managed as natural hardwood forest although the depredations of dieback will undoubtedly necessitate some rehabilitation treatment, - probably replanting with disease-resistant hardwoods.

4. POTENTIAL FOR PINE PLANTING

4.1 Site Mapping

An essential prerequisite to pine plantation development is a careful survey to delineate suitable soil types. Since early 1971 an officer has been engaged full time on site survey programme basically concerned with soil types, but with a considerable research content, to determine to what extent native vegetation can be used as a rapid predictor of suitability of a site for pine.

This programme has enabled the Department to accumulate an extensive fund of data on vegetation types and their occurrence in the Sunkland. (Unpublished Department report).

Soils have been mapped so far for about half the area north of the Blackwood and it is anticipated that the field work for the whole of that area will be completed by autumn 1975. At that time it will be possible to delineate accurately plantation cell boundaries and other special purpose areas.

The soils have been classified into seven distinct types as listed below:

Type 1 - Lateritic soils. Ironstone boulders or gravel in a sandy matrix. Sometimes with massive ironstone sheets.

Type 2 - Shallow sands over gravel or boulders. Less than 50 cm depth to gravel.

Type 3 - Deep sandy soils of yellowish-brown colour.

Type 4 - Deep grey sands.

Type 5 - Soils with sandy loam or heavier texture, depth and colour variable.

Type 6 - Soils of heavy texture over gravel in clay.

Type 7 - Soils of moderately heavy texture and strong red colour, associated with drainage lines.

A mapping technique has been developed which combines aerial photograph interpretation and ground traversing by foot or vehicle. The photo interpretation is quite reliable for types 1, 2 and 7, while types 5 and 6 are mapped with fair reliability. Types 3 and 4 cannot be separated with confidence on the photographs except that the extreme phases of dryness and wetness on the grey sands is obvious from vegetation density. Ground traversing is therefore used to separate 3 and 4 and to provide a constant check on boundaries of the other types.

The Laterite soils (Type 1) comprising heavy gravels and ironstone are not considered suitable for planting with pine.

The deeper sands and sandy loams, i.e. Types 3, 4 and 5, are the most suitable soils for P. radiata.

The shallow sands, (Type 2) are less attractive and will require more intensive site preparation such as deep ripping.

Type 6 is a difficult site for pines due to heavy soil texture but it is anticipated that future research could overcome these problems if required. This type is of restricted occurrence north of the Blackwood River.

Type 7 soils, located along drainage lines are too wet for P. radiata without considerable drainage work. These sites are prime fauna refuges so it is unlikely they will ever be utilised for planting to any extent.

The distribution of the soil types is extremely variable. This is illustrated by Attachment 5 which is a sample of the soil plans on which plantation planning is based. The same plan is shown in Attachment 6 with the soil types amalgamated into plantable and unplantable types. It can be seen that it is impossible to set out the plantations on a rectangular grid basis. Whatever plantation layout is adopted the boundaries will inevitably be sinuous and there will always be islands of native forest scattered throughout the pines and along the drainage lines.

4.2 Pine Trial Plots

Small areas of P. radiata and P. pinaster, mainly the latter species, were planted at Willcock plantation in 1952-1954, but this development was not proceeded with due to lack of soil survey information and inadequate

nutritional research. Sufficient well grown pine remains to justify the belief that given proper site selection, site preparation and fertiliser treatment, P. radiata can be grown very satisfactorily in the Sunkland. P. radiata is considered the more desirable species because of its faster growth rate and greater productivity.

A number of small trial plots of pines was established in the Sunkland between 1954 and 1969 but, almost without exception, they consisted of P. pinaster only.

The first really comprehensive trial plot of P. radiata was planted in 1969 in a multispecies trial for the rehabilitation of a dieback-affected site. This plot received good site preparation and phosphate fertiliser and growth was exceptional from the start. This success prompted the current phase of systematic nutrition and establishment research aimed at providing techniques for planting P. radiata on as wide a range of sites as possible in the Sunkland.

Plantings in 1970, 71 and 72 extended the plots to cover all major soil types in the Sunkland except Type 1. The total area of plots established now stands at some 120 ha. The new series of plots contains at least 100 ha of P. radiata, the remainder being P. pinaster P. taeda, P. elliottii var elliottii, P. muricata and P. caribea.

4.3 Results of Experimental Work

On all recent plots the early growth of P. radiata is extremely good. Initial survival is very high, never less than 95 per cent and there are very few problems from scrub competition. It is anticipated that large scale pine planting in this area will require very little, if any chemical weedicide for control of weed competition.

Recent research can be summarised as follows:-

(a) Thorough site preparation is essential and some drainage works will be required on most sites.

(b) In the early years (say up to age 5) phosphorus is the principal deficient major nutrient. A spot application of 100 gm superphosphate per tree is required at planting and it is likely that two more broadcast applications will be necessary during a rotation, probably about 200kg/ha at age 3 and the same amount again at age 8-10. Thereafter the normal nutrient recycling pattern is likely to provide sufficient phosphate for the requirements of the crop.

(c) Most soils in the Sunkland are critically deficient in zinc and marginal with respect to manganese and copper. Some areas of high organic content are also critically deficient in copper. At this stage no other minor element seems likely to influence pine growth.

(d) These minor element deficiencies are readily cured by a foliar application of the sulphate salts of all three elements in water.

All trial plots have been located on dieback diseased sites to evaluate any possible impact of the disease on the pine. It is known that P. radiata is susceptible to Phytophthora cinnamomi up to about age 3 and beyond age 30 in the open-grown situation. Observation in the last three years suggests that the disease may possibly kill a handful of pines in the first two years after planting but the incidence of deaths decreases with increasing age until at age four years none are lost. The place of dieback disease in relation to pine is kept under constant observation but it is most unlikely it will ever be a serious problem. The growth and development in the 1969-1972 trial plots shows that the early growth of P. radiata (7.5 metres in 5 years) is very satisfactory.

Under the favourable moisture regime in the Sunkland it is confidently expected that growth rates beyond this age will be equivalent to the overall average for P. radiata in Western Australia.

5. DEVELOPMENT PLANS

5.1 Preliminary Broadscale Planning

Broadscale planning envisages approximately one fifth of the Sunkland being planted to pines. The remainder will be left as natural forest, i.e. some 60,000 ha of pine plantation are proposed in a total area of 283,000 ha. Extension of planting south of the Blackwood River during the period under review is considered to be most unlikely.

Pines will be established in a number of discrete "cells" ranging in size from 1,000 to 10,000 ha and separated from each other by belts of natural forest about 2 km wide. Plan No.7 illustrates the distribution and extent of the plantation cell proposals. Within each of the plantation cells only about 75 per cent of the forest would be converted to pine.

5.2 Area retained as Natural Forest

The large and continuous areas of natural forest left unplanted will include the full range of ecological types in the Sunkland. This will receive similar management to jarrah forest elsewhere, with regular prescribed burning for fire protection. Some rehabilitation work will be required on dieback affected areas.

A number of Management Priority Areas have been defined. These are areas of special environmental significance and appropriate management prescriptions will be included in the Department's General Working Plan to ensure that they will receive the special attention required for the preservation or development of the features concerned e.g.:-

(a) Recreation

The Blackwood River in its course across the Sunkland provides a most valuable recreation area. Because of its high salt content the river is unlikely to be dammed for water supply purposes and its use for recreation (i.e. canoeing, fishing etc.) will undoubtedly increase. A broad strip of land on either side of the river is to be set aside for recreational purposes (see also Plan No.7).

Part of the Margaret River near the junction of the north and south branches of the river is a popular fishing and picnic area. Recreational values in this area will be preserved by reservation of a strip of hardwood forest on both sides of the river.

(b) Biological Reserve

The whole of Milyeannup Block (about 5,700 ha) is to be given special status to ensure that it remains an undisturbed "benchmark" area. It is one of the least disturbed parts of State Forest anywhere in W.A., having no interior roads at all. The only entry by vehicles to the interior was along a seismic survey line some years ago. This exploration activity is thought to be responsible for the only occurrences of dieback disease in the block. Most of it is believed to be protectable from the disease. There have been some small gravel pits opened along the Brockman Highway but these have been closed and a small pine plot along the southern boundary will not be extended.

Milyeannup is particularly well suited for preservation as a biological reserve as it contains a wide diversity of vegetation types from high quality jarrah forest to sedgeland.

The whole of Layman Block is also proposed for a biological reserve, although it has received more disturbance than Milyeannup and contains more dieback disease.

(c) Forest Reserves

At least two forest reserves are planned. One, in the Whicher Range, had been selected to preserve a major occurrence of Eucalyptus haematoxylon. Recently the Conservation Through Reserves Committee (appointed by the Environmental Protection Authority) has recommened the setting aside of a tract of country in the same area for conservation of flora and fauna. There is no intention that this interesting piece of forest should be converted to pines. In fact special care will be taken to ensure the protection of the natural vegetation here.

Another proposed forest reserve is a one-kilometre strip on either side of St. John Brook downstream from the private property. This area carries some of the best quality natural forest in the Sunkland, is a popular recreation area (e.g. Barrabup Pool) and contains valuable fauna habitats.

The approximate areas under each future land use category are as follows:-

		Hectares
Recreational Reserve:	Blackwood River	20,000
	Margaret River	1,200
Forest Reserve:	Whicher-Bovell	6,000
	St. John Brook	2,500
	Karri outlier	300
Biological Reserve:	Milyeannup	5,700
	Layman	6,700
Pine Plantation		60,000
Hardwood Forest		180,600
	Total	283,000 ha

5.3 Plantation Cells

The plantation cells have been selected following soil and site survey. They consist mainly of plantable land, i.e. the deep sandy soils but there will be pockets of varying size of unplantable land within the cells. Similarly large areas of plantable types exist within the hardwood forest not planned for conversion to plantations. Attachments 5 and 6 are examples of the soil maps produced in the site survey. They show the very variable and complicated pattern of soil type distribution.

The development of each plantation cell will be carefully planned in advance. Using the soil plan as a basis, a sub-division plan is prepared showing proposals for the plantation layout as regards:-

(a) Area to be planted - by species
- by year of planting

(b) Road system

(c) Fire control proposals

An example of a subdivision plan is included as Plan 10.

Some aspects of planning, shown on this plan are:-

(a) Areas of unsuitable soil left unplanted.

(b) Location of drainage lines to be left uncleared.

(c) Roading system to provide access for management purposes.

(d) Gross and net areas of each compartment.

(e) Any features requiring special treatment, such as trial plots and road reserves.

5.4 Planting Programme

As explained in the preamble, the Sunkland planting project is intended to make up the deficiency in this State's projected softwood requirements when repurchased private property in the Blackwood Valley is fully planted in about 1978. (The exact date is subject to minor change as small areas of private property are currently being obtained through exchange for isolated pockets of State Forest elsewhere.) In a project of this nature it is not possible to begin a large planting programme overnight. It is necessary to phase in the programme gradually. In the present case some further large scale establishment trials to be undertaken aim at simplifying procedures and developing the most efficient establishment techniques.

For these reasons, and to provide suitable facilities for monitoring the environmental impacts of pine planting in this area, a pilot plantation is being established in the western part of the forest shown in Plan 10.

The tentative planting programme is as follows:-

1975	-	80 ha
1976	-	120 ha
1977	-	200 ha
1978	-	500 ha
1979	-	1000 ha
1980/2000	-	2000 ha per year

Once the full level of planting has been achieved it is intended development will proceed in several cells at the one time, rather than being concentrated in one cell.

5.5 Economics of Pine Planting in the Sunkland

The light open forest of the Sunkland (often already degraded by Phytophthora) can be cleared and prepared for planting at a relatively low cost. The easy topography also helps in both establishment and management by allowing efficient use of machinery.

Current establishment costs on large scale trials in 1974 in the Sunkland are as follows:-

	$
Windrow and rootrake	70 per ha
Final clearing	45
Site preparation (double ploughing plus mound ploughing)	37
Planting	30
Initial fertiliser	15
Total	$197 per ha

This compares well with $240/ha for establishment in steeper country with heavier vegetation in areas to the east of the Darling Fault. Current research indicates the above costs can be reduced appreciably.

Because of the very thorough site preparation which is achieved by double ploughing, scrub regrowth is not expected to be a problem inxthe Sunkland and early pine growth is rapid. On the other hand the pines will need a continuing fertiliser regime: at least in the early years. Apart from fertiliser costs other maintenance costs are expected to be lower than elsewhere because of the easy terrain and economies of scale.

The rates of growth achieved in trial plots up to five years of age suggest that the productivity of the Sunkland plantations will be at least as high as that achieved with P. radiata in other major plantation centres.

Without considering inflation (which would be expected to increase the money value of future returns,) benefit cost analysis shows that, on present day costs and returns, an average quality P. radiata plantation should return better than 7% compound interest on the investment. The economics of these proposed plantations are therefore considered to be very favourable.

It is not considered that the economics of converting the degraded Sunkland forest to pines needs to be compared to an alternative use for agriculture. Abundant, well located land alienated for agriculture is available to the west of the Sunkland forest for development in what promises to be the major State dairying venture. In certain of the pine cells it is planned to consider cattle grazing under leasehold, combined with pine growth. This would increase interim returns but requires further large scale research.

6. ENVIRONMENTAL IMPACT OF PINE PLANTING

6.1 Impact on Hydrology

The conversion of part of the Sunkland to pine plantation is unlikely to have any serious effect on the hydrology of the area. The current and future degrading effect of dieback in the region will decrease evapotranspiration and greatly alter water yield.

In the short term, clearing for pine planting is likely to produce an increase in runoff compared with that under healthy hardwood forest. As this pine crop grows its water useage will increase to the point where it matches or even exceeds that under native forest. Studies by the Forests Department in the Wanneroo area north of Perth have indicated it is possible to manipulate water yield by varying the silvicultural system within limits which still achieve the timber production goals set. For water management it may be desirable to manipulate stand density to maximise evapotranspiration on certain dieback intensive areas.

A more serious effect of changed catchment characteristics elsewhere in Western Australia is increased salinity following clearing or even a marked change in the forest cover. To test for this possibility, extensive monitoring of the salinity levels of most major streams in the Sunkland has been going on for over 12 months. A considerable amount of data has been collected which indicates that the impact of dieback or conversion of native forest to pines in this area is unlikely to result in increased water salinity.

All the catchments sampled have been outlined in Plan No.8. Each sample point has been shown with its number and the crude mean total soluble salts (TSS) content for the whole period since sampling began. The length of sample period varies from eight to twelve months.

These means are considered to be adequate for comparative purposes, although the hydrological information would be greatly improved by more complete flow data, which so far are only available from the P.W.D. flow meters on the Margaret and Ludlow Rivers.

In general, the data show that where a stream has its catchment entirely within the zone of sedimentary parent material, i.e. the Sunkland proper, TSS values are very low, of the order of 150-200 mg/litre. As soon as a catchment extends onto the Precambrian shield to the east the TSS values rise appreciably to about 500 mg/litre. The latter areas, are partly developed for farming and subject to permanent clearing. They show an increase in water salinity following the removal of forest cover similar to that found in certain sections of the northern catchment areas.

This is a good illustration of the importance of the soil parent material in determining whether there will be a salinity problem. On the Precambrian granite shield the dominant soil type is the classical lateritic profile of gravel and ironstone overlying a deep zone of Kaolin clay. It is the "pallie zone" clay which contains the salt and any increase in throughflow of water due to agricultural clearing brings about removal of salt into the groundwater. The sedimentary Sunkland area does not have this deep zone of clay formed in situ. Observation suggests also that the forest in the Sunkland does not play the same role in regulating runoff as it does on the main plateau. The water table is generally very much closer to the surface so that the trees have very much shallower root systems.

Rehabilitation of dieback areas with pines will minimise any likely deleterious effect on water quality associated with rises in water table due to destruction of native vegetation by dieback.

Data from sample point 2, located in a small catchment which is 80 percent cleared and converted to pines indicates there has been no increase in salinity compared with the adjacent uncleared catchment (see Appendix No.4). In view of the low salt levels in the underlying sediments it is expected this evaluation will also apply in the case of larger areas being con-

verted to pine. Further confirmation of this has been obtained from water samples collected from farmland cleared for about 10 years on Sunkland sites in the Rosa Brook area. Salinity levels in streams in that area are not significantly higher than current levels in the Margaret River.

Much of the Margaret River catchment is severely affected by dieback disease and has been heavily cut over to salvage millable timber. This has not adversely affected water quality. Salinity levels now are on a par with other streams in the Sunkland which have had only slight disturbance. Plan No.9 shows the catchment area in relation to disease-affected forest and the position of the sampling points. The results of the weekly water samplings for the last 12 months are given in Appendix No.3 for each of the six sample points in the catchment. Base flow figures are generally in the range 200-250 mc/litre which is quite satisfactory.

Underground water is the major water resource in the area. It is probable that exploitation of these underground supplies will provide the cheapest and greatest yield of water in the future. Current research and limited experience with bores tapping aquifers in the Wanneroo area suggest the pine planting project is compatible with this activity.

Planting of pine is also unlikely to cause changes in pH of the runoff. Evidence for this comes from a 40 year old plantation at Grimwade, where the pH of the water from a pine catchment is currently the same as that of the adjacent hardwood catchment.

6.2 Impact on Vegetation

In Section 5.2 (c) it is shown that vegetative disturbance for pine planting will be restricted to approximately 20 percent of the Sunkland area and largely comprises the area most susceptible to dieback.

In the plantation cells, the overstorey will be removed and many of the understorey species will either be removed or much reduced in extent. However, a change almost as great as this is inevitable due to the activity of *Phytophthora cinnamomi* which is a dominant factor of the environment in the area.

Certain sites such as the lateritic ridges, and the wet flats and the riparian segments will be more or less untouched by the planting project. Apart from the buffer areas between the cells, other areas such as the more dissected country in the northern part of the Sunkland will be avoided because the proportion of plantable soils is too low to justify plantation development and they could have useful amenity value.

Part of the plantation area is likely to be managed on a pines with pasture regime with livestock grazing on an agistment basis.

6.3 Impact on Fauna

Changes to vegetation within the 20 percent to be gradually converted to pines will undoubtedly affect some fauna. The larger macropods are likely to be favoured by the pine planting project. Some smaller marsupials such as the quokka are likely to be little affected since their prime habitat will not be changed. Others, such as the honey possum might also be affected. These are not rare species and will be adequately catered for in the very large undeveloped areas and in the forest areas south of the Blackwood.

It is difficult to estimate what effect the project might have on the bird population. Some birds, such as ducks will no doubt be favoured by the water storages which will be developed for firefighting purposes; others such as honeyeaters will lose part of their food source. Some species will be favoured by the extensive forest edge situation which the plantation will create. Possibly the richest bird population is found in the dry Kingiajarrah shrubby flats (Smith's type D4 high open shrubland), which appear unsuitable for pine planting.

6.4 Impact on Recreation

Recreation in the area is focussed on the main water courses and is generally seasonal in character. In winter and spring the Blackwood River is much used by canoeists. Due to the paucity of large rivers in the south west this activity will probably increase in the future. A broad strip of land on both sides of the river where it runs through State Forest has been set aside for recreational purposes.

In summer, pools on the main watercourses are used for fishing for the freshwater crayfish (Cherax tenuimanus - marron). The increased roading associated with pine planting might mean the marron population would be more intensively fished. No other direct detrimental effect is foreseen. Swimming in permanent pools such as Barrabup Pool will continue and provision would be made for protection of recreation values along the Margaret River in the Rapids area.

The only other recreation, apart from some illegal kangaroo shooting, is some wildflower viewing along main roads in spring. Since the plantation cells intrude on main through roads only in a very minor way this activity will not be reduced to any significant extent.

Apart from along the watercourses, the jarrah forest of the Sunkland is rather monotonous and unattractive aesthetically. Any person viewing the depradations of dieback within this situation must agree that the variety added by well-sited and well-managed pine plantations can only improve the future aesthetic appeal of the area.

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APPENDIX I

FAUNA SURVEY DATA

(i) February 1974

(ii) October 1974

(iii) Fauna List

A PRELIMINARY STUDY OF FAUNA

IN THE PROPOSED PINE PLANTING AREAS

OF THE SUNKLANDS

by

P. SKINNER

April 1974

Research Branch
Forests Department
WESTERN AUSTRALIA

SUMMARY

A preliminary survey of areas to be planted with pine in the Sunklands region near Jarrahwood, carried out in February 1974, has indicated the presence of at least 8 indigenous and 6 introduced mammals and 50 species of birds. Eleven species of lizards, 2 of snakes, 3 of frogs and 4 of fish were also found.

Two areas were studied in some detail. One, recently burnt, was typical of lateritic soils containing good quality jarrah. The second, unburnt for some time, contained poorer quality jarrah interspersed with sandy flats. No previous fauna work had been carried out in either area by the Forests Department.

The indications from this short survey were that the diversity and density of mammal, bird and reptile species were apparently fairly normal for jarrah forest. However these indications will need to be checked out by a further survey, both in the 2 areas covered and in the 3 areas not touched in this survey.

INTRODUCTION

The survey dealt with in this report was undertaken at the request of the Pine Research Branch, during early February 1974, to provide preliminary information on fauna before more intensive studies are commenced. These studies are likely to be the subject of another survey before the start of pine planting, followed by monitoring surveys during and after the conversion of the area to pine.

The survey should be studied in conjunction with one carried out in Nannup pine plantations 2 weeks later. The comparison of species encountered in the two surveys has some relevance, although it should be emphasised that the Nannup pines were mainly planted on older cleared farmland. Thus a change in species present because of the conversion to farmland before the pines were planted, had already probably occurred.

The unpublished Research Branch Report, No.22, Forests Commission, Victoria, and subsequent secondary statements, are extremely relevant to any study of flora and fauna in pine plantations.

THE STUDY AREAS

Within the proposed planting area 5 sections are to be planted, priorities 1, 2, 3, 4 and 5 respectively. The sections come within the B2 Open Forest area of the Vegetation Map (Busselton and Augusta region) of W.A., published by the W.A. Department of Agriculture. Priority 1 was chosen as an area typical of the lateritic, good quality jarrah, with an open understorey of Banksia grandis and Persoonia longifolia. Priority 4 was chosen as an area of poorer quality jarrah, or jarrah/marri mixture containing sandy flats, blackboy swamps and patches of Banksia

verticulata woodland. Ground cover in priority 4 was relatively heavy, with Dasypogon and monocote predominant.

Priority 1, recently burnt, was to the north of Vasse Highway, and bounded by No.6, No.8 and Quilergup road. Priority 4, a larger unburnt area, was bounded by Gt. North Road in the west, Sabina and Hill Roads in the north, Lilly and Jalbarragup roads to the east, and Mowen Road in the south.

The Margaret River and creeks in the south, and Sabina River and creeks in the north, provided the numerous sandy flats and swamps in Priority 4.

The entire region has been lightly cut over in the past 15 to 20 years.

METHODS

(i) Trapping

Three types of traps were used, seventy-seven 33cm x 10 cm x 10 cm Elliott folding aluminium traps, eighty 15 cm x 10 cm breakback rat traps, and fifteen 56 cm x 20 cm x 20 cm wire cage traps. All were baited with universal bait - a mixture of peanut butter, bacon, rains, oatmeal and wheatgerm, and in each trapping line the traps were alternated, e.g. alternate Elliott and breakback, with each eleventh being a wire cage trap. There was thus more chance of catching a variety of species.

Five trap lines were set, the number and type of trap and period set being determined by the type of terrain in each line. This method better achieved the object of finding out the variety and abundance of species present overall rather than a comparison of species within the different terrains.

(ii) Observations

a) Daylight Observations

Fauna sighted whilst moving through the area on foot or in vehicles were recorded, though no attempt was made to count the relatively numerous Grey Kangaroo (Macropus fuliginosus) or Brush Wallaby (Macropus irma). Any evidence of fauna activity, such as scats, diggings or prints were recorded. Swamps and flats were examined for signs of reptiles and small creeks and water holes fished with a small net.

b) Night Observations

Observations were made from a vehicle with two spotlights, 4 spotlighting runs being made between the hours of dusk and 10 p.m. The runs were planned to cover a variety of terrain.

RESULTS

(1) Trapping

Trapping results are given in Tables 1 and 2. Mammals captured were the Southern Bush Rat (Rattus fuscipes), Common Rat (Rattus rattus), Common House Mouse (Mus musculus), Mardo (Antechinus flavipes), and Native Cat (Dasyurus geoffroii). Smith Skink (Egernia carinata) and Mourning skink (Egernia luctuosa) were also caught.

As expected, the South Bush Rat and Mourning Skinks were caught in the denser areas near swamps or creeks. The Mardos were caught in areas of reasonably thick ground cover, all near old logs and felling slash. The Smiths Skinks were caught in most types of terrain.

No.8 road traps produced only 2 mammal species, a Common Rat, and a Native Cat. The recent burning here is a probable cause of the low result of mammals. There was however, an abundance of Smiths Skinks.

In all areas trouble was experienced with ants eating the bait.

(ii) Observations

(a) Daylight. All lizards, frogs, snakes and fish, apart from the two species of lizard trapped and the minnow netted at night, were found in daylight. Lizards were found under rocks or logs or in blackboy stumps and caught by hand. Frogs and snakes were observed while walking or travelling in the vehicle. The fish were caught in creeks or water holes by a small hand net.

Some animals were identified by prints, scats or runnels. Table 4 lists all mammal species identified and the evidence of their presence.

(b) Night. Spotlighting results are presented in Table 3. Number of observations are about average for jarrah bush. The Ridge and Whicher Road run gave a higher average figure per hour and per mile than the other three runs, which was expected as the terrain here is more broken by creeks and gullies with patches of thick undergrowth. The two unidentified sightings were small, hopping type animals, not seen clearly because of the very thick undergrowth.

Numerous bats were seen on all the spotlighting runs, comprising at least two species. One bat was shot and has been identified by the W.A. Museum as a Chalinolobus gouldii. Attempts to catch bats in mist nets were unsuccessful, though the nets were erected in several different localities and left for several hours each night.

SYSTEMATIC ACCOUNT OF MAMMALS

1. ORDER MARSUPIALA

A. Family Macropodidae

1. Western Grey Kangaroo, Macropus fuliginosus No attempt was made to count this species, which was seen frequently by day and night throughout the entire survey area. The population appears to be about normal for this type of bush.

2. Brush Wallaby, Macropus irma

This species also was frequently seen throughout the survey area, by day and night. There appears to be a relatively high population in most localities.

3. Tammar, Macropus eugenii

None was seen, though suitable habitats occur throughout the area. There is a report of a small wallaby in the St. John's Brook locality, only a few miles from the proposed pine planting areas. A cursory examination of St. John's locality indicated the presence of a small wallaby, which could be a Tammar.

4. Quokka, Setonix brachyurus

None were seen or trapped as this is a particularly retiring and trap-shy species, and time did not allow the erection of large pen-type traps. There were very definite signs of quokka habitation in several of the swamps and creeks with thick ground vegetation where many runnels were seen. Quokkas have also been trapped recently in Sabina Road by Mr. Shugg.

B. Family Phalangeridae

5. Common or brush-tailed possum, Trichosurus vulpecula

Three individuals were seen, all by spotlight at the western and north-eastern ends of priority 4 area. None were trapped, though this species can be caught in wire traps. Though no definite signs of common possum were seen elsewhere it is likely that the species is scattered throughout the survey area, as the habitat is similar. The population appears to be very low.

C. Family Petauridae

6. Ringtail possum, Pseudocheirus peregrinus

None were seen, and no evidence of their presence. The nearest recorded sighting is from Nannup, where one was recorded in the pine plantations in February 1974.

D. Family Burramyidae

8. Honey possum, Tarsipes spencerae

No evidence for this species was found, but there is a museum record from near Mowen Road.

F. Family Peramelidae

9. Short-nosed bandicoot, Isoodon obesulus

There is a museum record of this species in the vicinity, and it is quite common in the Margaret River/Cowaramup region to the west.

Chances of its occurrence in the survey area are high. The unidentified animals sighted on the Ridge/Whicher road spotlight run could well have been bandicoots.

G. Family Dasyuridae

10. Native Cat or Chuditch, Dasyurus geoffroii

Only one specimen was caught, by a wire cage trap, in the recently burnt area. The habitat throughout the survey area was suitable and this species probably occurs throughout.

11. Native squirrel or wambenger, Phascogale tapoatafa

There are museum records from the vicinity. Records of this species come mainly from traffic casualties. It is seldom seen or trapped in the bush, and could well be present in the survey area.

12. Mardo, yellow-footed pouch mouse, Antechinus flavipes

Three individuals were caught, all in breakback traps in the Margaret and George Road trapping lines. All 2 were in relatively heavy undergrowth and either in or near old logging slash - a habitat favoured by this species. None were caught in the recently burnt area - studies being carried out at Dwellingup indicate that this species apparently disappears from a locality for 15 months or so after a burn.

13. Dunnart, Sminthopsis murina

There are museum records from the vicinity, but none were seen. The habitat is suitable for the species, and it is almost certain that they occur here. There is a definite recording from near Dido Road, either in or very near the priority 5 planting area.

2. ORDER RODENTIA

Family Muridae

14. Southern bush-rat, Rattus fuscipes

Five individuals were caught on 3 separate trap lines. Four of these were on creeks or swamp and the fifth in thick undergrowth on a sandy flat. There are numerous suitable areas for this species in which it undoubtedly occurs throughout the area.

15. Water rat, Hydromys chrysogaster

None were seen, but it is quite possible they occur along the Margaret and Sabina rivers and tributaries.

16. Common rat, Rattus rattus

Three specimens were caught, and each in a different locality. Two of these were in thick undergrowth on George and Margaret roads, and the third within the recently burnt area of No.8 road. This latter however was captured in a patch of unburnt scrub near a creek.

17. House mouse, Mus musculus

Two specimens caught, both on Margaret road in medium scrub. Mus musculus is caught fairly easily in both Elliott and breakback traps, so if the population is high it is likely that greater number would have been caught.

3. ORDER CHIROPTERA

18. Bats. At least 2 different species were seen in flight. There are probably several more within the area. Attempts to capture specimens by mist netting or shooting yielded only one, which has been identified by the W.A. Museum as a Chalinolobus gouldii. Sightings were numerous throughout each spotlighting run.

4. ORDER LAGOMORPHA

19. Rabbit, Oryctolagus cuniculus

Rabbits were evident, though not abundant, in some localities. Scats and scratchings were seen, but very few specimens. The area does not appear to have a high population.

5. ORDER CARNIVORA

20. Dingo, Canis familians

None were seen in the area. A few miles to the south, near Canebreak road, a torn up grey kangaroo and canine prints were discovered. The evidence suggests dingoes rather than foxes.

21. Fox, Vulpes vulpes

Identified from prints. Very few scats were seen. It probably occurs throughout the area, though it is not abundant. One of the common food sources of the foxes, i.e. rabbits, are not plentiful, which may account for its apparent low density.

22. Feral cat, Felis cattus

Prints were seen but no specimens sighted. Probably occurs throughout the area in small numbers. None was caught in wire-cage traps as would be expected if population was high.

6. ORDER MONTREMATA

23. Echidna or spiny anteater, Tachyglossus aculeatus. No evidence seen. The habitat is suitable for this species and they could be present.

7. ORDER EQUIDAE

24. Horse, Equus caballus

Last reported sightings in the locality date back 15 years. Several scats were seen in different localities so there are apparently a few still in the area.

DISCUSSION

1. Limitations of the Study

This survey was not intended to be exhaustive, only a preliminary study. There are several reasons why the results must be interpreted with caution.

(a) Study areas.

The proposed pine planting area is large and divided into 5 sections in order of planting priority. While 2 of these sections are mainly good quality jarrah in lateritic soils, and the other 3 mainly poorer quality jarrah or jarrah/marri containing sandy flats and swampland, each section has some diversity of soil, topography and vegetation within it. To cover each type of terrain within each section thoroughly would be impossible without months of work, and is outside the scope of ecology section.

By choosing 2 representative areas and working across a variety of terrain, as much as possible has been achieved in the limited time available.

(b) Trapping

Trapping has been confined to limited areas, and to 3 types of traps only. Since small mammals usually occur in low densities and uneven distribution, it is unlikely that all types of small mammals present were caught. Season of trapping is also important, it is quite possible that a bigger catch might have been made at a different time of year.

Some animals are trap-shy and almost impossible to detect. Others however, might be caught in different types of trap. Pen-traps, pit-traps, snares, bottle traps etc. are all necessary for a complete survey, and time and personnel available did not allow for all these.

(c) Spotlighting

Four runs were carried out in diverse localities, but time spent was still limited. Particularly as time had to be found for trying to capture some of the numerous bats by shooting or mist-netting.

Only one team, using two spotlights from a moving vehicle, was possible each night. Several of the larger types of mammal, such as brush wallaby and common possum, were sighted, but the heavy undergrowth and dense foliage made sightings of possible smaller ground-dwelling or arboreal mammals difficult. Some spotlighting excursions on foot could well be profitable in some areas.

More intensive spotlighting in selected areas is also necessary. On the final run, in the vicinity of Ridge and Whicher roads, unidentified animals were glimpsed. These could well have been native cats or bandicoots, but the possibility of their being something more uncommon, such as Bettongia penicillata, could amply repay a more sustained effort in this vicinity.

(d) Scat analysis, prints and runs.

Interpretation of these is a very important part of any survey. Of the 14 mammal species listed, 4 were identified by prints and runnels. The quokka for instance, is seldom seen and hard to trap, but scats and runnels in a suitable habitat is a good indication of its presence. In flats and sandy areas prints are a most useful source of identification. Time is needed to search for such signs, and undoubtedly more would have been found had the survey been extended.

Very few scats were found and these yielded no new information.

DISCUSSION OF RESULTS

The result of the survey, considering the above limitations, appears satisfactory. A total of 8 indigenous and 6 introduced species of malla, 50 birds, and 20 of other vertebrate fauna identified in 5 days is about what might be expected in the type of country covered.

The survey has given only a rough estimation of the abundance of the larger mammals, no reliable estimate of population or densities of smaller mammals, and has almost certainly failed to find some species of mammals, birds and reptiles that are there. An interesting record in the bird list is that of the emu wren, which to our knowledge has not previously been reported from this area.

It provides a useful source of information to assist in any planning of operations in the area however, and gives a base for any future, more intensive, fauna work, which were the main objects of the survey.

The survey failed to find positive evidence of some mammals that could be expected there - bandicoots (Isoodon obesulus) and dunnart (Sminthopsis murina) for example, though museum reports and other indications make their presence likely. There are outside reports of a variety of other animals there, some dating back a long time, but others more recent. It is possible that Woilie (Bettongia penicillata) could still exist in the area, there is an old museum record for the Whicher ranges. Other reports seem extremely unlikely, e.g. hopping mouse, rabbit-eared bandicoot. It was believed that the brumby (feral horse) was no longer there, the last report being a brief sighting in the mid 1950's. The scat evidence suggests that there are still a few around however.

The 2 sightings of small unidentified animals in the Ridge Road/Whicher Road area are tantalising. These could well be quite common species, but until this is proved, the possibility of something rarer should not be discounted.

The past history of logging and burning in the area was not investigated too closely, as this was not really relevant to the object of the study. There appears to be nothing unusual in the pattern, periodic burning and felling has taken place and the effect on the native fauna has been similar to elsewhere. The proportion of introduced to indigenous fauna is about the same as elsewhere.

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TABLE I

TRAPPING RESULTS

Area	No. of trap nights (all types)	Mammals	No. of Individuals	Reptiles	No. of Individuals	Trap success percentage		
						Mammals	Reptiles	Combined
Margaret Road	263	Rattus rattus Antechinus flavipes Mus musculus	1 2 2	Egernia carinata Egernia luctuosa	14 1	1.9	5.7	7.6
No. 8 Road	165	Rattus rattus Dasyurus geoffroii	1 1	Egernia carinata	9	1.2	5.5	6.7
River Swamp	16	Rattus fuscipes	2	Egernia luctuosa	3	12.5	18.7	31.2
George Road	130	Rattus rattus Antechinus flavipes Rattus fuscipes	1 1 2	Egernia carinata Egernia luctuosa	6 4	3.1	7.7	10.8
Ridge/Whicher Rd.	64	Rattus fuscipes	1	Egernia carinata	1	1.6	1.6	3.1

TABLE 2

BREAKDOWN OF SPECIES CAUGHT IN DIFFERENT TRAP TYPES

Trap Type	SPECIES CAUGHT						
	Rattus rattus	Rattus fuscipes	Mus musculus	Antechinus flavipes	Dasyurus geoffroii	Egernia Carinata	Egernia luctuosa
Elliott	-	2	1	-	-	16	4
Break back	3	2	1	3	-	14	4
Wire Cage	-	1	-	-	1	-	-

TABLE 3

MAMMAL SPOTLIGHTING RESULTS

Area	Hours	Miles travelled during spotlighting	Specimens detected	Specimens per hour	Specimens per mile	Remarks
Cave Break Margaret, Gt. North and Crossing roads	1.3	6.3	2 brush-tailed possum	1.5	0.3	
Molloy and Margaret Roads	1.1	4.8	2 grey Kangaroo	1.8	0.4	2 Tawny frogmouth also seen
Gt. North road and George road and Blunsdon road	1.2	6.4	2 Grey Kangaroo	1.7	0.3	
Ridge and Whicher roads	2.0	10.1	2 brush wallaby 1 Grey Kangaroo 1 brush-tailed possum 2 unidentified	3.0	0.6	6 Tawny frogmouth also seen Unidentified animals were small hopping animals.

TABLE 4

MAMMAL SPECIES IDENTIFIED

Species	Trapped	Observed	Shot	Identified from prints, scats or runnels	Spotlight
Antechnius flavipes	*				
Dasyurus geoffroii	*				
Trichosurus vulpecula					*
Macropus fuliginosus		*		*	*
Macropus irma		*		*	
Setonix brachyurus				*	
Mus musculus	*				
Rattus rattus	*				
Rattus fuscipes	*				
Oryctolagus cuniculus		*		*	
Equus caballus				*	
Vulpes vulpes				*	
Felis catus				*	
Chalinolobus gouldii			*		*

NB. These species were identified by the survey team within the proposed pine planting area. Other species recorded by the W.A. Museum and other sources, in or near the area, are mentioned in the "Systematic account of mammals".

BIRDS IDENTIFIED

Emu	Dromaius novaehollandiae
Little Grebe	Podiceps novaehollandiae
Little Black Cormorant	Phalacrocorax sulcirostris
Little Pied Cormorant	Phalacrocorax melanoleucos
Darter	Anhinga rufa
White-faced Heron	Ardea novaehollandiae
Brown Bittern	Botaurus poiciloptilus
Mountain Duck	Tadorna tadornoides
Black Duck	Anas superciliosa
Maned Goose	Chenonetta jubata
Whistling Eagle	Haliastur sphenurus
Brown Hawk	Falco berigora
Brush Bronzewing	Phaps elegans
White-tailed Black Cockatoo	Calyptorhynchus baudini
Western Rosella	Platycercus icterotis
Red-capped Parrot	Purpureicephalus spurius
Parrot	Barnardius zonarius
Frogmouth	Podargus strigoides
Owlet-Nightjar	Aegotheles cristatus
Kookaburra	Dacelo gigas
Sacred Kingfisher	Halcyon sancta
Bee-eater	Merops ornatus
Tree Martin	Petrochelidon nigricans
Pipits	Anthus novaeseelandiae
Black-faced Cuckoo-shrike	Coracina novaehollandiae
Red-winged Wren	Malurus elegans
Emu Wren	Stipiturus malachurus
Western Warbler	Gerygone fusca
Broad-tailed Thornbill	Acanthiza apicalis
Western Thornbill	Acanthiza inornata
Woebill	Smicrornis brevirostris
Scarlet Robin	Petroica multicolor
Western Yellow Robin	Eopsaltria griseogularis
White-breasted Robin	Eopsaltria georgiana
Grey Fantail	Rhipidura fuliginosa
Willy Wagtail	Rhipidura leucophrys
Golden Whistler	Pachycephala pectoralis
Black-capped Sitella	Neositta pileata
Rufous Tree-creeper	Climacteris rufa
Spotted Pardalate	Pardalotus punctatus
Silvereye	Zosterops gouldi
Spinebill	Acanthorhynchus superciliosus
Tawny-crowned Honeyeater	Gliciphila melanops
New Holland Honeyeater	Phylidonyris novaehollandiae
Little Wattle Bird	Anthochaera chrysoptera
Red-eared Firetail	Zonaeginthus oculatus
Dusky Wood Swallow	Artamus cyanopterus
Squeaker	Strepera versicolor
Western Magpie	Gymnorhina dorsalis
Raven	Corvus coronoides

LIST OF REPTILES, AMPHIBIANS AND FISHES IDENTIFIED

Lizards	Phyllodactylus marmoratus	(C)
	Varanus gouldii	(O)
	Tiliqua rugosa	(O)
	Egernia luctuosa	(T)
	Egernia carinata	(TO)
	Lygosoma billardieri	(C)
	Lygosoma initiale	(C)
*	Hemiergis peronii	(C)
*	Ctenotus impar	(C)
*	Cryptoblepharus plagiocephalus	(C)
	Legless lizard (unidentified)	(C)
Snakes	Demansia nuchalis affinis	(O)
	Notechis soutatus occidentalis	(O)
Frogs	Hyla	(C)
	Limnodynastos dorsalis	(C)
	Helioporus eyrei	(C)
Fishes	Galaxias occidentalis	(N)
	Brachygalaxias nigrostriatus	(N)
	Edelia vittata	(N)
	Nannatherina balstoni	(N)

C - caught by hand

O - observed

T - trapped

N - netted

N.B. Three lizards marked by * identified by W.A. Museum. Remainder follow the identifications in "A Handbook of the lizards of Western Australia" by L. Glauert.

FAUNA SURVEY

DONNYBROOK SUNKLANDS

15th - 28th OCTOBER 1974

P.C. KIMBER, K.I. PENTONY, P.R. SKINNER

FAUNA SURVEY. - DONNYBROOK SUNKLANDS

INTRODUCTION

The geomorphological zone known as the Donnybrook Sunklands lies between the Nannup fault scarp in the east and the Naturaliste-Leeuwin ridge on the west coast. It is bounded in the north by coastal sands and in the south by large dune systems. Surveys of the fauna in State forests within this zone were made in February and October 1974. This report describes the results of the latter survey in detail, but also incorporates additional species located in the February survey. A separate report exists for the February survey.

The purpose of the survey was to forecast the impact of a projected pine plantation scheme on fauna populations, and to locate any animal species or animal/vegetation/soil association which may be of exceptional scientific interest and therefore require particular attention in planning the pine project. A team of five completed the present study period 15th - 28th October 1974. Intermittent visits to the area and trapping was also carried out for three weeks prior to the main study period.

Geomorphology, Soils and Vegetation

The geomorphology and soils have been dealt with in detail by Smith (1951). The study areas encompass two main geomorphic types; the deeply incised valley of St. John's Brook, and the gentle to moderate undulating surface of Smith's low plateau. A generalised catenary series of the low plateau commences with dry lateritic ridges and upper slopes with pisolite gravels and a sandy matrix, through sandy lower slopes to silty, moist valley bottoms. Jarrah forest dominates the series with the exception of very moist valley bottoms where dense scrub is dominant, typical of the north-western jarrah forest swamps.

St. John's Brook carries recent moist soils of above average fertility, the undergrowth is denser than in the plateau country and blackbutt (Eucalyptus patens) contributes significantly to the tree canopy.

An aberrant soil/plant association occurs in patches throughout the sunklands but is apparently independent of any geomorphological characteristic. It is called the Kingia suite by Smith (1951), and is typified by moderate to sparse waist high scrub with stunted trees of jarrah and marri up to 6 metres high. The vegetation is reminiscent of heath types and is probably maintained by fire and edaphic conditions. Evidence exists of impeded drainage in elevated topographical situations and the soils (not examined in detail) appear to have a high clay fraction. Kingia australis is frequent.

West Australian Museum Records

The West Australian museum have records of 9 mammal species within the area of State Forest in the sunklands. An additional 11 mammal species are recorded within 20 km of State Forest.

The Study Areas.

1. St. John's Brook and Cambray. A steeply incised valley with fresh, moist soils and a jarrah/marri/blackbutt forest association. The area contains a large perennial watercourse with extensive pools. Burnt under prescription in spring 1973.

2. Great West, and Macatee Roads. Typical undulating plateau country with extensive sandy lower slopes and flats. Last burnt in 1969-1970.

3. Whicher Block. Plateau country dominated by laterite ridges and relatively steep sided valleys with little development of sandy lower slopes and flats.

4. Lawson Road. An example of the Kingia suite. Last burns in 1969-1970.

METHODS

Trapping, shooting, netting, spotlighting and searching were the basic methods in all study areas except Lawson Road where observation and searching were the only methods employed.

1. Trapping. The bulk of the trapping effort was with backbreak rat traps, and possum traps which catch alive animals up to the size of a quokka. Elliot traps were used in Whicher and Cambray for a few days but contributed little to the overall trapping effort. Small fish traps were placed in tributaries of St. John's Brook, and the main river was netted with a 2½ inch mesh gill net for 1 night.

   Wire pen traps with a falling door mechanism were erected in the St. John's Brook and Whicher areas. These are effective for quokka and short-nosed bandicoot.

   Mist nets were used at Macatee Road, Whicher and Cambray to take small species of birds which are not readily observed.

2. Spotlighting. Spotlighting runs were made along St. John's Brook and at Cambray and Whicher. Each run was started shortly after dusk, continued for 1½ to 2 hours and covered 10-14 km. Two spotlights were operated from one vehicle on each run.

3. Shooting. Approximately three hours were spent shooting bats at Cambray. Five birds were shot at various localities for laboratory specimens.

4. Observation and Searching. Nearly all bird records were direct observations aided by an Audubon bird-call.

   Searching resulted in the location of many reptiles some amphibians, and the spoor and scats of the larger mammals.

RESULTS

The results of the survey are presented in a way which permits the association of fauna concentrations with habitat type and locality. Where comprehensive lists are given these include species located in the February 1974 survey but which were not found in the survey on which this report is based.

The relative success of the various study methods are shown in Appendix 1 and species check lists in Appendix 2 and 3.

Species Representation.

The total number of species identified from both surveys was as follows:

Mammals	-	18 (of which 6 were introduced species)
Birds	-	74
Lizards	-	19
Snakes	-	5
Tortoises	-	1
Frogs	-	9
Fish	-	6
Crustaceans	-	1

Animal Distribution by Plant/Soil Associations.

All records of captures on the various soil/plant associations are shown in Table 1 which gives an indication of favoured habitats.

TABLE 1

Animal Captures by Plant/Soil Associations

Association	Animal Numbers							
	Mammals		Lizards		Frogs		Totals	
	Nos.	Spp.	Nos.	Spp.	Nos.	Spp.	Nos.	Spp.
Laterite ridges and upper slopes	2	2	14	7	1	1	17	10
Sandy valleys and Lower Slopes	10	6	31	10	18	5	59	21
Swamps	16	3	0	0	Not Studied		16	3
Steep valleys, Fresh soils	9	2	3	2	14	4	26	8

The most populous association in terms of both individuals and species was the sandy lower slope and valley situation. Laterite ridges and upper slopes had the low mammal populations typical of these habitats in the northern jarrah forest (Schmidt and Mason, 1973). However, they were surprisingly rich in lizards.

Swamp areas, although yielding only moderate captures, are an important habitat for the quokka (Setonix brachyurus),

short-nosed bandicoot (Isoodon obesulus), and mardo (Antechinus flavipes). Captures of these species were confined to swamps. Sixty percent of southern bush-rat (Rattus fuscipes) captures were also in swamp.

The steep, fresh valley habitats had been burnt one year prior to the survey. This factor undoubtedly reduced small mammal populations which have not yet recovered to their pre-fire levels. Capture data was consequently not indicative of the potential of the area. Larger mammals were frequent and this was the only association where the brush-tailed possum (Trichosurus vulpeculus) was recorded.

Animal Distribution and Locality.

Table 2 lists the numbers of species identified by capture and observation, in the various localities examined.

TABLE 2

Species Representation by Localities

Locality	Number of Species			
	Mammals	Lizards	Frogs	Total
Whicher Block and Sabina Rd (adjacent to Whicher).	8	11	6	25
St. John's Brook and Cambray	6	4	3	13
Macatee Road and Great West Road	3	5	0	8

The data is Table is unlikely to represent the entire species representation in any one area, but it gives a useful comparison of relative numbers. Whicher Block yielded the greatest variety of animals, and this location remains outstanding even if the mammal species located outside the block but in close proximity to it on Sabina Road are excluded. These species were Setonix brachyurus and Isoodon obesulus.

Species numbers were relatively low in St. John's Brook and Cambray due to prescribed burning in 1973.

Birds.

The 74 species of birds identified in this survey comprised 12 aquatics, 7 species associated with clearings and forest glades, 3 species normally associated with heath or sandplain scrub, and 52 true forest species.

Heath sandplain species were confined to the Kingia suite of soils. The three species were crested bellbird (Oreoica gutturalis), tawny crowned honeyeater (Gliciphila melanops), and white-browed babbler (Pomatostomus superciliosus). Both the tawny crowned honeyeater and the white-browed babbler occur adjacent to or within forest in separate localities

near the south coast. Their occurrence together and in the same locality as the crested bellbird is unique within the jarrah forest zone.

Snakes.

Five species of snake were located. The western tiger snake (Notechis scutatus) and dugite (Demansia nuchalis) were identified in the February 1974 survey. One little whip snake (Denisonia gouldii) was collected on a laterite ridge.

One blind snake (Typhlina australis) and three Muellers snakes (Rhinhoplocephalus bicolor) were collected on the Kingia suite soils. This is the northernmost recorded occurrence of the Muellers snake, which is a species of coastal sand/heath associations.

Fish, Crustaceans and Aquatic Reptiles.

Permanently flowing water courses on the area were Margaret River (covered by the February survey) and St. John's Brook. Species collected from these two rivers are listed in Table 3.

TABLE 3

Fish, Crustaceans and Aquatic Reptiles

Species	Locality	
	St. John's Brook	Margaret River
Fish		
Bostockia porosa	X	
Brachygalaxias nigrostriatus		X
Edelia nittata	X	X
Galaxias occidentalis	X	X
Nantherina balstoni		X
Tandanus bostocki	X	
Crustacean		
Cherax preissii	X	
Reptile		
Chelodina oblonga	X	

DISCUSSION

If museum records and our survey records are combined, a total of 21 mammal species have been recorded within the study area. An additional 5 species have been recorded within 20 km of the boundaries of State Forest. One of

the museum records, the flying fox (Pteropus scapulatus) is a rare vagrant. Another, the woylie (Bettongia penicillata) was not located in either of our surveys. This suggests that the species no longer exists in the area, or is of extremely limited distribution.

The range of mammal species represented in the sunklands is almost identical to that found elsewhere in the jarrah forest.

The range of bird species islikewise typical of jarrah forest associations with the exception of the southern emu wren which is, however, widespread in forest areas to the south and south east of the sunklands, and the 3 heath-scrub species found in association on the Kingia suite of soils.

Lizards species were particularly numerous throughout the area and especially in Whicher Block. A number of the lizard records provided an extension of the previously known range of two species, (Ctenotus catenifer) and Morethia obscura).

Soil/plant associations of the Kingia suite are found at various localities throughout the sunklands. They are generally sizeable units reaching 100 to 200 ha or more in area. One such association was studied on Lawson Road by observation and searching. No trapping was done. The presence of the tawny-crowned honeyeater, crested bellbird, white-browed babbler, and the Muellers snake show this area to be of exceptional scientific interest.

RECOMMENDATIONS

The entire area proposed for pine plantations should be checked by trapping and spotlight survey to determine the status of the Woylie (Bettongia penicillata).

At least one block of forest should be retained in its present state to provide a permanent example of the soil/plant associations represented. This is particularly important for the sandy lower slopes and valleys which are rich in fauna and flora.

Examples of the Kingia soil suite should be retained, each with a peripheral buffer of indigenous forest.

ACKNOWLEDGEMENTS

We are indebted to the West Australian Museum for the identification of 88 specimens, and to West Australian Government Railways for the use of their house at Cambray.

REFERENCES

Schmidt, W. and Mason, M. (1973). The effect of prescribed burning on the fauna of the jarrah forest. Res. Pap. No. 11.

Smith, R. (1951). Soils of Margaret and Lower Blackwood Rivers, W.A. Bulletin No. 262. C.S.I.R.O. Melbourne.

Success of Various Methods of Capture

Method	Captures							
	Mammals		Lizards		Snakes		Frogs	
	No.	%	No.	%	No.	%	No.	%
Pit traps	1	3	16	35			26	81
Break-back traps	7	19	21	46				
Elliot traps	6	17						
Possum traps	9	25	4	8				
Pen traps	10	28						
Hand caught			5	11	3	100	6	19
Shot	3	8						
Totals	36	100	46	100	3	100	32	100

Percent = percentage of total captures within the animal group.

Check Lists

Mammals, Lizards, Snakes, Tortoises, Frogs

I = non-native species C = captured

O = observed M = museum record

Mb = Museum record within 20 km of study area.

Species	Source	Notes on location etc
MAMMALS		
Macropus fuliginosus	O	All localities
M. irma	O	All localities
Setonix brachyurus	C	Swamp, Sabina Road
Bettongia penicillata	M	No recent record
Trichosurus vulpecula	C	St. John's Brook
Cercartetus concinnus	M	
Tarsipes spencerae	C	Whicher
Isoodon obesulus	C	Swamp, Sabina Road
Dasyurus geoffroii	C	February survey
Phascogale tapoatafa	M	
Antechinus flavipes	C	February survey
Sminthopsis murina	C	Whicher
Rattus fuscipes	C	Whicher, Sabina Rd.
R. rattus	I.C	February survey
Hydromys chrysogaster	Mb	
Mus musculus	I.C	All localities
Nyctophilus geoffroyi	Mb	
Chalinolobus gouldii	C	Cambray
C. morio	Mb	
Eptisicus pumilis	Mb	
Pipistrellus tasmaniensis	C	Cambray
Pteropus scapulatus	Mb	Rare vagrant
Canis familiaris	Mb	
Vulpes vulpes	I.O	All localities
Oryctolagus cuniculus	I.O	Sparse all localities
Equus caballus	I.O	February survey
Felis cattus	I.C	Whicher
LIZARDS AND GECKOES		
Cryptoblepharus plagiocephalus	C	February survey
Ctenotus catenifer	C	Whicher
C. impar	C	Whicher

Species	Source	Notes on location etc.
Lizards and Geckoes cont.		
Cryptoblepharus labillardieri	C	Whicher
Egernia carinata	C	Whicher
E. kingii	C	St. John's Brook
E. nitida	C	All localities
E. pulchra	C	Macatee Road
E. pulchra subspecies	C	Macatee Road
Hemiergis peroni	C	Whicher, Sabina Rd
Lerista distinguenda	C	Whicher
Leiolepisma trilineatum	C	Moist gullies
Lygosoma initiale	C	February survey
Morethia obscura	C	Whicher, Sabins Rd. Macatee Rd.
Phyllodactylus marmoratus	C	Whicher
Menetia greyii	C	Macatee Rd
Tiliqua luctuosa	C	Whicher, Sabins Rd Macatee Rd
Tiliqua rugosus	C	All localities
Varanus gouldii	O	St. John's Brook
SNAKES		
Demansia nuchalis	O	February survey
Notechis scutatus	O	February survey
Denisonia gouldii	C	Whicher
Typhlina australis	C	Lawson Rd
Rhinhoplocephalus bicolor	C	Lawson Rd
TORTOISES		
Chelodina oblonga	O	St. John's Brook
FROGS		
Crinia georgiana	C	Whicher, St. John's Brook
C. glauerti	C	Farmland
Heleioporus eyrei	C	Whicher
H. inornatus	C	St. John's Brook
Helioporus sp.	C	Whicher
Limnodynastes dorsalis	C	St. John's Brook
Litoria moorei	C	St. John's Brook
Metacrinia nichollsii	C	Whicher
Pseudophryne guentheri	C	Whicher, Sabina Rd

Western Warbler (Gerygone fusca)
Broad-tailed thornbill (Acanthiza apicalis)
Western thornbill (A. inornata)
Yellow-tailed thornbill (A. chrysorrhoa)
Spotted scrub wren (Sericornis maculatus)
Weebill (Smicornis brevirostris)
Scarlet robin (Petroica multicolor)
Western yellow robin (Eopsaltria griseogularis)
White-breasted robin (E. georgiana)
Grey fantail (Rhipidura fuliginosa)
Willy Wagtail (R. leucophrys)
Golden whistler (Pachycephala pectoralis)
Grey thrush (Colluricincla rufiventris)
Crested bellbird (Oreoica gutturalis)
Black-capped sitella (Neositta pileata)
Rufous tree creeper (Climacteris rufa)
Spotted pardalote (Pardalotus punctatus)
Striated pardalote (P. substriatus)
Silvereye (Zosterops gouldii)
White-naped honeyeater (Melithreptus lunatus)
Spinebill (Acanthorhyncus superciliosus)
Tawny-crowned honeyeater (Gliciphila melanops)
White-eyed honeyeater (Phylidonyris novaehollandiae)
Red wattle bird (Anthochaera carunculata)
Little Wattle bird (A. chrysoptera)
Red-eared firetail (Zonaeginthus oculatus)
Magpie lark (Grallina cyanoleuca)
Dusky woodswallow (Artamus cyanopterus)
Grey currawong (Strepera versicolor)
Western magpie (Gymnorhina dorsalis)
Raven (Corvus coronoides)

Emu (Dromaius novaehollandiae)
Little grebe (Podiceps novaehollandiae)
Little black cormorant (Phalacrocorax sulcirostris)
Little pied cormorant (P. melanoleucos)
Darter (Anhinga rufa)
White egret (Egretta alba)
White-faced heron (Ardea novaehollandiae)
Brown bittern (Boraurus poiciloptilus)
Mountain duck (Tadorna tadornoides)
Black duck (Anas superciliosa)
Maned goose (Chenonetta jubata)
Musk duck (Biziura lobata)
Whistling eagle (Haliastur sphenurus)
Australian goshawk (Accipiter fasciatus)
Little eagle (Hieraoetus morphnoides)
Wedge-tailed eagle (Aquila audax)
Brown hawk (Falco berigora)
Crake spotless (Porzana tabuensis)
Bronzewing pigeon (Phaps chalcoptera)
Brush bronzewing (P. elegans)
White-tailed black cockatoo (Calyptorhyncus baudini)
Red-tailed black cockatoo (C. banksi)
Western rosella (Platycercus icterotis)
Red-capped parrot (Purpureicephalus spurius)
Twentyeight parrot (Barnardius zonarius)
Elegant parrot (Neophema elegans)
Pallid cuckoo (Cuculus pallidus)
Fan-tailed cuckoo (Cacomantis pyrrophanus)
Golden bronze cuckoo (Chrysococcyx lucidus)
Boobook owl (Ninox novaehollandiae)
Tawny frogmouth (Podargus strigoides)
Owlet nightjar (Aegotheles cristatus)
Kookaburra (Dacelo gigas)
Sacred Kingfisher (Halcyon sancta)
Bee-eater (Merops ornatus)
Welcome swallow (Hirundo neoxena)
Tree martin (Petrochelidon nigricans)
Pipit (Anthus novaeseelandiae)
Black-faced cuckoo shrike (Coracina novaehollandiae)
White-browed babbler (Pomatostomus superciliosus)
Splendid wren (Malurus splendens)
Red-winged wren (M. elegans)
Southern emu wren (Stipiturus malachurus)

(iii) FAUNA LIST - SUNKLAND AREA

1. BIRDS

Common Name	Scientific Name
Emu	Dromaius noveahollandiae
Little Grebe	Podiceps noveahollandiae
White-faced Heron	Ardea noveahollandiae
Black Duck	Chenonetta jubata
Musk Duck	Biziura lobata
Whistling Eagle	Haliastur sphenurus
Brown Goshawk	Accipiter fasciatus
Wedge-tailed Eagle	Aquila audax
Crake	Poryara tabuensis
White-tailed Black Cockatoo	Calyptorhynchus baudini
Red-tailed Black Cockatoo	Calyptorhynchus banksi
Western Rosella	Platycercus icterotis
Red-capped Parrot	Purpureicephalus spurius
Twentyeight Parrot	Barnardius zonarius
Elegant Parrot	Neophema elegans
Fan tailed Cuckoo	Cacomantis pyrrophanus
Crested Bellbird	Oreoica gutturalis
Golden Bronze Cuckoo	Chrysococcyx licidus
Boobook Owl	Ninox noveaseelandiae
Tawny Frogmouth	Podargus strigoides
Owlet Nightjar	Aegotheles cristatus
Kookaburra	Dacelo gigas
Sacred Kingfisher	Halcyon sancta
Bee-eater	Merops ornatus
Welcome Swallow	Hirundo neoxena
Tree Martin	Petrochelidon nigricans
Black-faced Cuckoo Shrike	Coracina noveahollandiae
Splenddid Wren	Malurus splendens
Red-winged Wren	Malurus elegans
Southern Emu Wren	Stipiturus malachurus
Western Warbler	Gerygone fusca
Broad-tailed Thornbill	Acanthiza apicalis
Western Thornbill	Acanthiza inornata
Yellow-tailed Thornbill	Acanthiza chrysorrhoa
Spotted scrub Wren	Sericornis maculatus
Weebill	Smicrocornis brevirostris
Scarlet Robin	Petroica multicolor
Yellow Robin	Eopsaltria griseogularis
White Breates Robin	Eopsaltria georgiana
Grey Fantail	Rhipidura fuliginosa
Willy Wagtail	Rhipidura leucophrys
Golden Whistler	Pachycephala pectoralis
Western Shrike Thrush	Colluric incla rifiventris
Black capped Sitella	Neositta pileata
Spotted pardalote	Pardalotus substriatus
Silvereye	Zosterops gouldi
White Naped Honeyeater	Melthreptus lunatus
Spinebill	Acanthorhynchus superciliosus
Tawny Crowned Honeyeater	Gliciphila melanops
White Eyed Honeyeater	Phylidonyris noveahollandiae
Red Wattle Bird	Anthochaera carunculata
Little Wattle Bird	Anthochaera chrysoptera
Magpie Lark	Grallina cyanoleuca
Squeaker	Strepera versicolor
Western Magpie	Gymnorhina dorsalis
Raven	Corvus coronoides
Dusky Wood Swallow	Artamus cyanopterus
Mountain Duck	Tadorna tadornoides
Pipit	Anthus noveaseelandiae

BIRDS cont...

Common Name	Scientific Name
Rufous Tree Creeper	Climacteris rufa
White Egret	Egretta alba
Pallid Cuckoo	Cuculus pallidus
White Browed Babbler	Pomatostomus superciliosus
Bronze Wing Pigeon	Phaps chalcoptera
Little Eagle	Hieraoetus morphnoides
Little Pied Cormorant	Phalacrocorax melanoleucos
Little Black Cormorant	Phalacrocorax sulcirostris
Darter	Anhinga rufa
Brown Bittern	Botaurus poiciloptilus
Brown Hawk	Falco berigora
Brush Bronze Wing Pigeon	Phaps elegans
New Holland Honey Eater	Phylidonyris novaehollandiae
Red-eared Firetail Finch	Zonaeginthus oculatus

2. MAMMALS

Grey Kangaroo	Macropus fuliginosus
Black Gloved Wallaby	Macropus irma
Quokka	Setonix brachyurus
Brush-tailed Possum	Trichosurus vulpecula
Ring-tailed Possum	Pseudocheirus peregrinus
Bush Rat	Rattus fuscipes
Honey Possum	Tarsipes spencerae
Mouse Dunnart	Sminthopsis murina
Mardo	Antechinus flavipes
Brush-tailed Phascogale	Phascogale tapoatafa
Western Native Cat	Dasyurus geoffroyii
Short nosed Bandicoot	Isoodon obesulus
Common Rat	Rattus rattus
House mouse	Mus musculus
Cat	Felis cattus
Fox	Vulpes vulpes
Water Rat	Hydromys chrysogaster
Rabbit	Oryctolagus cuniculus
Bat	Chalinolobus gouldii

3. REPTILES

King Skink	Egernia kingii
Smiths Skink	Egernia carinata
Morning Skink	Egernia luctuosa
	Egernia nitidia
Frys Skink	Egernia pulchra
	Leiolepisma trilineatum
Red Legged Skink	Ctenotus labillardieri
	Hemiergis peronii
	Lerista distinguenda
	Ctenotus impar
Greys Skink	Menetia greyii
Bobtail	Tiliqua rugosa
Racehorse Goanna	Varanus gouldii
Carpet Python	Python spilotes
Dugite	Demansia nuchalis affinis
Tiger Snake	Notechis scutatus occidentalis
Muellers Snake	Rhinoplocephalus bicolor
	Phyllodactylus marmoratus
Burrowing Skink	Lygosoma initiale
	Cryptoblepharus plagiocephalus

4.AMPHIBIANS

Common Name	Scientific Name
Green & Gold Tree Frog	Hyla moorei
Banjo Frog	Limnodynastes dorsalis
	Crinia georgiana
	Pseudophryne guentheri
	Heleioporus sp.
	Metacrinia nichollsi
	Heleioporus eyrei
	Crinia glauerti
	Heleioporus inornatus

5. FISH

	Galaxias occidentalis
	Brachygalaxias nigrostriatus
	Edena vittata
	Nannatherina balstoni

Whicher

Margaret River Rd

Crossing Rd

Great West Rd

Lawson Rd

McAtee Rd

OCTOBER 1974

FEBRUARY 1974

TRAPPING LINES

SPOTLIGHT LINES

SUSSEX LAND DISTRICT

KEY TO SYMBOLS

Sealed Road
1st Class Road
2nd Class Road
3rd Class Road
Powerline
Block Boundary
Private Property

Forests Dept. Headquarters
Sawmill
Lookout Tower
Survey Reference Tree Theodolite
Survey Reference Tree Compass
Loading Ramp
Permanent Water Supply
Permanent Water Supply Developed

1 : 126720

Kilometres

Miles

INDEX TO ADJOINING SHEETS

	COLLIE	MUJA
BUSSELTON	KIRUP	GRIMWADE
AUGUSTA	MANJIMUP	PERUP

FAUNA SURVEY APPENDIX I

Whicher

Great West Rd

Lawson Rd

McAtee Rd

St Johns Brook

Cambray

SUSSEX LAND DISTRICT

1 : 126720

Kilometres

Miles

INDEX TO ADJOINING SHEETS

	COLLIE	MUJA
BUSSELTON	KIRUP	GRIMWADE
AUGUSTA	MANJIMUP	PERUP

B. J. BEGGS
CONSERVATOR OF FORESTS
APRIL 1974

SUNKLANDS FAUNA SURVEY

APPENDIX II

(i) List of plant species

(ii) Procedure for site mapping

APPENDIX II

(i) List of plant species known from the Donnybrook Sunkland (G.S.M., 1974)

Where a botanical authority is quoted the identification has been verified by the Western Australian State Herbarium, except for very common species not collected.

X Indicates species used as site Indicators

GENUS	SPECIES AND COLLECTION NUMBER	
AMARANTACEAE		
Ptilotus	manglesii	544
AMARYLLIDACEAE		
Anigozanthus	flavida	214
Conostylis	several species	-
CAESALPINIACEAE		
Labichea	punctata Benth	355
CASUARINACEAE		
Casuarina	drummondiana	424
	fraseriana Miq.	-
COMPOSITAE		
Helichrysum	bracteatum	112
Lagenophora	stipitata Labill	49
CYCADACEAE		
Macrozamia	reidlii C.A. Gardn	-
CYPERACEAE		
Gahnia	preissii Nees.	190
Juncellus	laevigatus	502
Lepidosperma	angustatum	36
Mesomelaena	tetragona X	
Tetrariopsis	octandra	304

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GENUS	SPECIES AND COLLECTION NUMBER	
DILLENIACEAE		
Hibbertia	aurea Steud.	330
	Huegelii X	319
	Montana Steud. X	162
	montana (var. minor) X	
	perfoliata Endl.	189
	quadricolor (Domin.) X	256
	racemosa	453
	rhadinopoda F. Muell.	259
	stellaris	503
	sp. nov.	371
	vaginata (Benth) F.Muell.	257
	hypericoides Benth.	453
EPACRIDACEAE		
Andersonia	caerulea	342
	longifolia	497
Astroloma	epacris	449
Conostephium	pendulum	454
Leucopogon	australia R.Br. X	367
	capitellatus D.C. X	2
	corifolius	495
	gilbertii Stchegl.	369
	glabellus R.Br. X	237
	parviflorus	
	pendulus	448
	polymorphus	483
	racemulosus D.C.	
	STRIATUS	479
	verticillatus R.Br. X	
Lysinema	ciliatum R.Br.	261
Sphenotoma	capitatum (R.Br.) Lindl.	404
Styphelia	tenuiflora Lendl. X	262

GENUS	SPECIES AND COLLECTION NUMBER	
EUPHORBIACEAE		
Ricinocarpus	cyanescens	532
	glaucus Endl	328
	tuberculatus Muell.	417
GENTIANACEAE		
Villarsia	albiflora	546
GOODENIACEAE		
Dampiera	linearis	39
	sacculata	322
Goodenia	sp.	48
Leschenaultia	biloba	-
Scaevola	microphylia Benth.	130
	striata R. Br.	1
Velleia	trinervis Labill	320
HALORRHAGACEAE		
Loudonia	aurea	528
IRIDACEAE		
Patersonia	occidentalis R. Br.	
	umbrosa Endl.	323
	xanthina F. Muell.	
LABIATEAE		
Hemiandra	pungens R. Br.	401
Hemigenia	incana	508
	rigida	549

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GENUS	SPECIES AND COLLECTION NUMBER	
LAURACEAE		
Cassytha	racemosa	172
LILIACEAE		
Caesia	parviflora	93
Dasypogon	bromeliaefolius R.Br. X	-
	hookerii Drummond X	-
Johnsonia	lupulina R. Br.	300
Kingia	australia R. Br. X	-
Lomandra	sp.	277
Thysanotus	multiflorus R. Br.	-
Xanthorrhea	gracilis Endl. X	-
	preissii Endl. X	-
LOBELIACEAE		
Isotoma	hypocrateriformis	543
LOGANIACEAE		
Logania	vaginalis	8
LORANTHACEAE		
Nuytsia	floribunda Labill	-

GENUS	SPECIES AND COLLECTION NUMBER	
MIMOSACEAE		
Acacia	alata	17
	browniana X	348
	divergens	327
	diptera Lindl. X	344
	drummondii Lindl.	427
	gilbertii Meissn.	422
	mooreana W.V.Fitzg. X	249
	myrtifolia	18
	nervosa	34
	oborata Benth. X	250
	preissiana	347
	stenoptera Benth.	241
MYRTACEAE		
Agonis	flexuosa Schan.	-
	linearifolia Schan. X	273
	parviceps Schan. X	-
Astartea	fascicularis Labill DC	242
Beaufortia	sparsa R. Br. X	272
	squarrosa	-
Callistemon	speciosus	542
Calothamuus	sanguineus Labill.	-
Calytrix	brachyphylla Turcz.	400
	variabilis Lindl.	373
Eremaea	pauciflora	547
Eucalyptus	calophylla R. Br.	
	haematoxylon Maiden	
	marginata SM	
	megacarpa Muell X	428
	patens Benth. X	
	rudis Endl.	

GENUS	SPECIES AND COLLECTION NUMBER	
MYRTACEAE		
Hypocalymma	angustifolium X	399
	cordifolium (Lehm) Schan.	270
	robustum Endl.	396
	strictum Schau.	243
Kunzea	recurva Schau.	236
Leptospermum	crassipes Lehm X	238
	ellipticum Endl. X	332
	firmum	452
Melaleuca	densa	506
	polygaloides	513
	preissiana Schau. X	255
	scabra, var. tuberculata	540
	thymoides Labill. X	254
Verticordia	densiflora Lendl.	374
ORCHIDACEAE		
Orchidaceae	species rarely collected	-
PAPILIONACEAE		
Aotus	villosa	518
Bossiaea	linophylla R. Br.	535
	ornata Meissn. X	227
	pulchella Meissn.	372
Burtonia	conferta DC.	246
	scabra R. Br.	407
Chorizema	glycinifolium Druce.	433
Daviesia	alternifolia Endl.	388
	incrassata Sm. X	268
	pectinata Lindl.	-
	quadrilatera	498

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GENUS	SPECIES AND COLLECTION NUMBER	
PAPILIONACEAE		
Dillwynia	cinerascens	482
	uncinata Turcz.	434
Euchilopsis	linearis	-
Gastrolobium	spinosum	-
Gompholobium	aristatum	529
	burtonioides Meisn.	339
	ovatum	499
	polymorphum R. Br.	101
	venustum R. Br.	334
Hovea	chorizemifolia sweet X	29
	elliptica D.C.	-
	trisperma Benth.	210
Jacksonia	horrida DC.	248
Kennedya	coccinea Vent.	69
	stirlingii	510
Mirbelia	dilatata R. Br.	4
Oxylobium	sp.	418
Pultenaea	andrewsii	514
	drummondii X	316
	reticulata Benth. X	360
	skinneri	516
	strobilifera Meissn	365
Sphaerolobium	macranthum Meissn	345
	scabriusculum Meissn	336
Viminaria	juncea	234
PITTOSPORACEAE		
Billardiera	sp. unknown	164

GENUS	SPECIES AND COLLECTION NUMBER	
PODOCARPACEAE		
Podocarpus	drouyniana Muell	-
POLYGALACEAE		
Comesperma	virgatum	545
PROTEACEAE		
Adenanthos	barnigera Lindl. X	-
	meissneri Lehm. X	264
	obovatus Lebill. X	-
Banksia	attenuata R. Br. X	-
	grandis Willd.	-
	illicifolia R. Br. X	466
	quercifolia Meissn.	393
	sphaerocarpa R. Br.	-
Conospermum	acerosum Lindl.	403
	caeruleum	492
	capitatum R. Br.	269
	flexuosum	310
	teretifolium	541
Dryandra	bipinnatifida R. Br.	244
	nivea R. Br.	-
Franklandia	triaristata Benth.	358
Grevillea	brachystylis	329
	brevicuspis Meisn X	353
	manglesioides Meissn.	351
	occidentalis	477
	ornithopoda Meissn.	271
	pulchella X	333
	quercifolia R. Br.	194
	umbellulata	391

GENUS	SPECIES AND COLLECTION NUMBER	
PROTEACEAE		
Hakea	ambigua	311
	bipinnatifida X	119
	ceratophylla (Sm.)R.Br. X	251
	cyclocarpa Lindl.	315
	lasiantha	222
	marginata	481
	ruscifolia Labill	247
	varia R. Br.	380
Isopogon	attenuatus R. Br.	375
	axillaris R. Br.	252
	formosus R. Br.	318
	sphaerocephalus Lindl. X	-
Lambertia	multiflora Lindl.	484
	rariflora Meissn.	420
Petrophile	diversifolia R.Br. X	245
	linearis R. Br. X	338
	serruriae R. Br.	326
	squamata R. Br.	312
Persoonia	elliptica R. Br.	-
	longifolia R. Br. X	-
	saccata R. Br.	415
Stirlingia	latifolia Steud X	-
Strangea	stenocarpoides (F.Muell ex Benth).	253
Synaphaea	favosa R. Br.	309
	preissii	
Xylomelum	occidentale R. Br.	-
RESTIONACEAE		
Anarthria	prolifera R. Br.	324
	scabra	196

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GENUS	SPECIES AND COLLECTION NUMBER	
RESTIONACEAE		
Hypolaena	exsulca R. Br.	37
Leptocarpus	scariosus R. Br.	376
	tenax R. Br.	240
Loxocarya	flexuosa Benth.	325
Lyginia	tenax Labill.	239
Restio	ustulatus Muell.	378
RHAMNACEAE		
Cryptandra	arbutiflora	494
Trymalium	ledifolium	366
RUTACEAE		
Boronia	crenulata	314
	elatior	538
	fastigiata Bartl.	413
	gracilipes	298
	heterophylla	-
	juncea	313
	megastigma F. Muell	-
Crowea	augustifolia Turcz.	406
Eriostemon	nodiflorus Lindl.	390
	spicatus	321
Urocarpus	pallidus	507
SANTALACEAE		
Leptomeria	sp.	

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GENUS	SPECIES AND COLLECTION NUMBER	
STACKHOUSIACEAE		
Stackhousia	huegeli	90
STERCULIACEAE		
Thomasia	grandiflora Lindl. X	331
STYLIDIACEAE		
Stylidium	scandens R. Br.	266
THYMELAECEAE		
Pimelea	rosea	509
	spectabilis (Fisch. & Mey.) Lindl. X	263
	suaveolens	486
TREMANDRACEAE		
Tetratheca	setigera X	185
	viminea	-
VERBENACEAE		
Pityrodia	bartlingii Benth.	
VIOLACEAE		
Hybanthus	floribundus	35
UMBELLIFERAE		
Platysace	compressa (Labill.) Norman	267
Xanthosia	candida	288
	sylvatica	197

(ii) SITE MAPPING

The method adopted has been to gain knowledge of soils and vegetation by moderately intensive ground surveys on two areas having differences in site conditions, with the addition of scattered traverses over a wide area.

Soil types recognized are mapped on aerial photographs, using as a guide soil types and boundaries known from traversing of tracks and widely spaced survey lines. Spacing has varied from about 30 chains to about 80 chains between traverses of one sort or the other. Knowledge of topography/soils and vegetation/soils relationships gained on the more intensive surveys is then used to inter-polate boundaries over the area to be mapped.

Vegetation/Soils Relationship

From the ground surveys, quantitative data on both has been subjected to statistical analysis (Principal Components). As a result of the first such analysis it has been possible to arrange vegetation species into seven groups which can be related to three recognizable site characteristics and a further one not identified. These groups are displayed in Attachment III.

However, vegetation "type" can as yet only be used as a guide to soil type, though time can frequently be saved in the field by avoiding or reducing profile inspection.

Results of another analysis on data from the second survey are still being worked on to try to define better the site characteristics influencing species distribution, and also to produce closer definition of vegetation types. Achievement of this would facilitate classification of site in the field, for both mapping and demarcation purposes.

An assessment of the agreement between soil type and vegetation type on 137 recorded sites has given figures of 60% for an earlier system of assessing vegetation type, and 65% for the current one applied to 25 sites. The approach used was to record whether soil type was "as expected" or "not as expected" on the basis of vegetation type. The more stringent test of predicting soil type and calculating a success rate would produce a lower figure.

Lower storey vegetation of two types can be recognized on photographs, and crown density and height are of aid in interpretation of a further two soil types.

Soil Profile Inspection

Necessary as a supplement to, or alternative to, vegetation classification on field traverses, this has been made less troublesome and time-consuming by adoption of a small diameter core sampler in conjunction with a depth probe. This equipment, however, becomes difficult to use when soil has dried out.

Soil Types

The original classification comprised six types, with a

seventh fore-shadowed, which has since been described. These are briefly defined as follows:-

(1) Lateritic soils - boulders and gravel at surface.

(2) Shallow sandy soils - less than 50 cms. depth over laterite.

(3) Deep (more than 50 cms.) sandy soils of yellowish-brown colour.

(4) Deep sandy soils of greyish colour.

(5) Soils with texture sandy loam or heavier; depth and colour variable.

(6) Soils with very heavy texture, often from surface; gravel-in-clay basement.

(7) Soils of moderately heavy texture and strong colour associated with drainage lines.

Note that the characterizing texture for these types is that found at 60 cms. depth. This was adopted when the statistical analysis showed a better correlation (with vegetation distribution response) than for texture at a lesser depth. This procedure contrasts with that usually adopted where near-surface texture characterizes the soil profile, and could have more relevance to tree site requirements.

More recently the above types have been subdivided in an attempt to obtain more constant agreement between vegetation types and soil types. Two of these new phases for one soil type are recognizable on aerial photographs. This sub-division is defined in Attachment I, "Key to Soil Types".

Reliability of Interpretation on Photographs

Reasonably reliable interpretation, depending mainly on topographic differences, can be done for three soil types out of the seven recognized. These are the laterite and shallow sand over laterite, and the olluvial soils flanking drainage lines. It is known that gravel may occur in the field and be undetected on photograph because of lack of topographic differentiation and unusually poor quality of forest cover. The error of mapping gravel where it does not exist is not thought to occur often; where it does the soil will probably prove to be the shallow sand types, so that the error will not be of great significance.

Soil types of heavy texture are believed to be mapped with fair reliability, but are not separable into the two types recognized.

The remaining two deep sand types can not be separated with any confidence, except that extreme phases of dryness and wetness in grey sands are obvious (this by means of vegetation, as before mentioned). Difference in tone between the two types, probably due to more dense ground vegetation beneath more open canopy on the grey sands, has been observed, but is not known to be consistent.

When aspect and degree of slope were included in a computer analysis of site characteristics, no effect of these upon the ordination of the sites was evident. However, a recent tabular analysis of aspect for Types 3 and 4 only, does suggest a difference in distribution between the yellowish-brown and the grey sands. This has not been tested either on photo-interpretation or in the field.

Because most of the track traversing was done by another officer using a simpler system of classification and slightly different depth criteria, and the information was mostly recorded only by colour code on plans, its value was reduced. Depth limit differences mean that the area of shallow sand shown on plan will have been over-estimated slightly. This may help to counteract under-estimation of laterite areas.

An objective test of reliability has been planned but field checking will not be carried out until the first requirement for soil maps has been met.

Plan Compilation

Boundaries delineated on photographs are transferred to base plans of the "20-chain" topographic series by Drafting Branch personnel using the "Wild" stereoplotter.

Where ground surveys have previously been done the existing plans have been correlated with presently-used soil types and their boundaries used on current plans.

Such plans so used have been:-

(1) 1955 survey; Willcock Group (Hill and van Noort)

(2) 1967 land use survey; Whicher, Molloy, Vasse Groups (McCutcheon)

(3) 1935-37 surveys; Jarrahwood, Cundinup Groups (Helms et.al.)

With the latter survey, such difficulty has been encountered in correlating soil types, for several reasons, that the map produced retains the original soil types and phases. Banded colour to indicate approximate equivalence to current types (in conjunction with an additional key) is used on the plans concerned, but area assessment is on the basis of suitability classes only, for the portions surveyed in 1935-37. Appendix II displays the variations in correlations, and suitability estimates based on profile descriptions recorded in 1937.

Suitability Ratings

These have been assessed, not by consideration of individual areas, but by assuming that all occurrences of a particular soil type will have similar suitability, and assessing this by consideration of the typical profile.

Thus all of Type 1 is classified as unsuitable despite the fact that some limited occurrences of deep gravels with a loamy matrix may well prove suitable. All of Type 2 is classified as doubtful on the grounds of likely moisture stress problems.

Type 7 is classified as suitable; it will frequently be unsuitable for Pinus radiata but suitable for Pinus elliottii. However in practice it will often not be planted because of conservation considerations and because clearing could be a difficulty.

Type 6 has been set up mainly because it is expected to be an extremely difficult site for pines, probably unsuitable without an uneconomic degree of amelioration by mechanical and perhaps chemical means. However in the region so far mapped it is not important.

No difficulties is anticipated with most areas of Type 5; some may need draining, but is classified as suitable at this stage as only ground examination will determine such need.

Type 3 is classified as uniformly suitable, and may prove to be the best site type available.

Type 4 is classified as suitable though the Type 4A may require heavier thinning and more frequent fertilization and Type 4D will require draining.

Areas Plantable - Plan *No's. 159, 156, 155, 154, 176, 173.

Out of a total of 6571 ha of State Forest mapped, the following assessment has been arrived at:-

Suitable	54.0%
Doubtful	5.0%
Unsuitable	41.0%

It should be noted that extensive areas of mainly lateritic soils occur on the strongly dissected portions of river catchments, viz. Ludlow and Sabina Rivers to the north-west, and the St. John Brook and tributaries to the east. These areas contribute to a lower figure for proportion of suitable soil than is to be anticipated for the region south and west of that mapped so far. However, nearer the Blackwood River dissection again reduces the proportion of suitable soils.

The break-down of the area by soil types and by suitability classes is shown in Table I, following.

T A B L E I

Soil Type	Suitable	Doubtful	Unsuitable	Total
1			23041	23041
2		2462		2462
3	7526			7526
4	12853			12853
5	4696			4696
7	2470			2470
Sub Total	27546	2462	23041	53050
1937 Survey	8153	815	3700	12668
TOTAL	35698	3277	26741	65716

Usability of the land suitable for planting has been assessed by exclusion of all portions which are:-

(1) Isolated from other suitable land and less than 40 ha in area by ocular comparison with a sample square or rectangle, or

(2) Connected to other suitable land but forming a strip less than roughly 200 metres in width.

* Identified as "Sunkland Reconnaissance, Pine Site Assessment" File 313/67.

On this basis the percentages of non-usable plantable land on the various plans are 154 - 7.4; 155 - 3.3; 156 - 2.2; 159 - 1.3; 173 - 2.5; 176 - 8.2; overall 4.5 per cent.

Soil Type Evaluation

To assist in evaluation of pine performance on various sites intensive s oil surveys are being carried out on the larger plots in the region. Soil plans are part completed for 9 of the northern plots averaging 6.5 ha each, and one plot has yet to be studied.

Correlation of pine sites with adjoining native vegetation types is to be carried out around plots of all sizes, but as yet only 5 such "ecological" plots have been recorded.

ATTACHMENT I

KEY TO SUNKLANDS SOIL TYPES (FORESTS DEPARTMENT 1974)

			SOIL TYPE NO.
A.		Gravel percentage within 50 cms of surface more than 20%	
	B.	Texture "sand" or "loamy sand"	
		C. Gravel more than 20% within 20 cms of surface	
D.		Gravel within 20 cms of surface more than 60%; massive laterite present -	1b
D.		Gravel within 20 cms of surface; less than 60%; nor massive laterite -	1g
		C. Gravel more than 20% deeper than 20 cms from surface	
D.		Colour range grey or greyish-brown	
	E.	Basement is moderate to heavy gravel	2 Gg
	E.	Basement is massive laterite	2 Gb
D.		Colour range yellowish-brown or brownish-yellow	
	E.	Basement is moderate to heavy gravel	2 Yg
	E.	Basement is massive laterite	2 Yb
	B.	Texture "sandy loam" or heavier	
		C. Gravel more than 20% within 20 cms of surface	1 F
		C. Gravel more than 20% deeper than 20 cms from surface	
D.		Colour range grey, greyish brown, yellowish brown	
	E.	Basement is moderate to heavy gravel	
		F. Texture between gravel not heavier than "clay loam"	5g (shallow phase)
		F. Texture between gravel "sandy clay" and maybe "clay" at surface: colour pale and mottling a feature	6 (shallow phase)
	E.	Basement is massive laterite	
D.		Colour range brownish yellow, strong brown, reddish; usually associated with drainage lines	7 (shallow phase)

			SOIL TYPE NO.
A.		Gravel percentage within 50 cms of surface less than 20%	
	B.	Texture "sand" or "loamy sand"	
		C. Colour range light yellowish brown to brownish yellow	3
		C. Colour range light grey to dark greyish brown	
D.		Profile dry; texture "sand"; colour very light grey	4A
D.		Profile moist but well drained; texture "loamy" sand	4
D.		Profile moist to wet; texture "loamy sand"; organic "coffee-rock" present	4C
D.		Profile poorly drained, or water-gaining site	4D
		C. Colour strong brown or reddish <u>and</u> associated with drainage line	7
	B.	Texture "sandy loam" or heavier	
		C. Colour range, greys, greyish brown, yellowish brown	
D.		Profile shows change of two texture classes between A_2 and B horizons	5D
D.		Texture change down profile is gradual	
	E.	Gravel forms base to profile, with matrix of "sandy clay", which texture may occur at surface; profile colour pale and mottling a feature	6
	E.	If gravel base, matrix texture not heavier than "clay loam"	5G
		C. Colour strong brown or reddish; usually associated with a drainage line	7

NOTE:- Characterizing texture (level B in the key) is normally determined at 60 cms depth, unless it is obvious from the profile description that a lesser depth applies. In this case the depth of description will be that immediately above some limiting feature.
Moisture status of greyish sands may be partly inferred from colour (amount and depth of black humus incorporation) and from texture.

ATTACHMENT I I

1937 CORRELATION			BRIEF DESCRIPTION FROM PROFILE DESCRIPTION WHERE AVAILABLE	CORRELATES WITH 1974 TYPE	1974 SUITABILITY ASSESSMENT (Suitable = S, Doubtful = D, Unsuitable = U)	
JARRAHWOOD SOIL GROUPS BASED ON SURFACE INDICATIONS	SURVEY LOCALITY *	TYPE DESCRIPTION				
3A		1	Sand, loamy gravel and scattered lateritic boulders	1b	U	
	Cu	A1	Sand and heavy gravel with boulders and shallow massive laterite	1b	U	
	Ca	3A	-	-	-	U
		3A1	Yellowish-brown sand with heavy gravel, boulders and massive pan.	1b	U	
		3B1	As above but laterite more broken, with pockets of clay-loam.	1b	U	
3B	Cu	A2	Grey- grey-yellow sand with some gravel and scattered boulders.	2Gb	D	D
	Ca	3B	-	-		
3C	J	1A	Sand, light gravel, occasional lateritic boulders, deeper than type 1	1g	U	U
	Ca	3C	-	-	-	
2A	J	3B	G. sandy loam with light gravel becomes yellowish-brown; sandy clay with heavy gravel	5G	S	

2A1	J	3A1	T-G sand becoming CL by 100 cms and gravelly; pan at 125 cms.	5	S	
	Cu	A3	Y-B sandy loam grading to clay over laterite at 75 cms	5G	D	S
		B1	Y sand becoming Y-G sandy clay loam over laterite at 250 cms	3	S	
2B	J	2B	Dark grey, becoming yellowish grey, sand; lat. hardpan at 100 cms	4	S	
	Cu	C4	Y sand over laterite at 103 cms.	3	S	
	Ca	2B	Shallow (37 cms) G to Y-G sand over heavy gravel in loamy matrix.	2Gg	D	S
		2F	Y-G sand increasing to mottled light clay with heavy gravel: 150 cms	4D	S; wet	
	also 2D, 2E1, 2G			-	-	
2B1	Cu	B4	Y-G sand grading to sandy clay by 112cms	3	S	S
2C	J	3C	G to Y-G sand, becoming CL over lat. pan at 130 cms.	4	S	
	Cu	A4	Y to G-Y sand over heavy gravel then laterite at 90 cms.	3	S	
		B2	Y-B sandy loam, texture and gravel increasing to laterite at 90 cms.	5G	D	S

ATTACHMENT II (Cont'd)

2C (cont.)	Ca	2C	-	-	-	S
		2E	-	-	-	
4A	J	3A	Y-B to G-B sandy loam becoming clay loam; pan at 125 cms.	5G	S	
	Cu	B3	R-B sandy loam becoming gravelly by 112 cms.	7	S	
		D1	B-Y to R-B sandy loam grading to sandy clay at 112 cms.	7	S	S
		D2	As above but with laterite at 75 cms	5G	D	
	Ca	4A1 4A2	Types 4 generally are very leached s oils with coffee-rock	4C	S	
4A1	-	-	-	-	-	-
4B	J	4A	G to white sand with org. stain over lat. pan at 190 cms	4C	S; wet	
		4B	GS with B stain at 82 cms, then white; laterite at 200 cms.	4C	S	
	Cu	C2	G sand with org. stains becoming rusty mottled at 240 cms; wet.	4C	S	S
		C5	G to Y-G sand, wet; texture increases at depth; laterite at 200 cms.	4D	S	
	Ca	4B	GS with org. stain at pan at 105 cms.	4C	S	

* J = Jarrahwood Cu = Cundinup Ca = cambray

4C	J	2A	Deep (150 cms) grey sand over lat. hard pan	4	S; wet	S
	Cu	C1	G sand grading to light sandy clay, with gravel; laterite at 90 cms.	4	D	
		C5	See above	4D	S	
	Ca	4C	G sand over Fe/org. pan at 60 cms.	4D	S	

* J = Jarrahwood Cu = Cundinup Ca = Cambray

ATTACHMENT III - SOIL - VEGETATION ASSOCIATION.

	G	F	E	D	C	A
LEUCOPOGON GLABECCUS	×	×	×	×	o	o
BANKSIA ATTENUATA	×	×	×	×	×	/
PETROPHILA LINEARIFOLIA	×	×	×	×	×	/
ADENANTHOS MEISSNERI.	×	×	×	×	o	
DASYPOGON BROMELIAEFOLIUS	×	×	×	×		
HIBBERTIA PACHYRRHIZA	×	×	×	×	o	
MELALEUCA THYMOIDES	×	×	×	o		
HIBBERTIA VAGINATA	×	×	×	×		
AGONIS PARVICEPS	×	o			/	
ADENANTHOS OBOVATA	×	×	×		/	o
STIRLINGIA LATIFOLIA	×	×	×	o	/	o
DAVIESIA INCRASSATA	×	×	×	o	/	×
MESOMELENA TETRAGONA	×	o	×	o	/	×
PUCTANAEA RETICULATA	×	×	×	o		×
BANKSIA LITTORALIS	×	×	×	/	o	×
HAKEA CERATOPHYLLA	×	×	×	/	o	×
MELALEUCA PREISSII	×	×	×	/	o	×
HYPOCALYMMA ANGUSTIFOLIUM	o		×	/	o	×
DASYPOGON HOOKERII	×	o	o		o	×
LEPTOSPERMUM CRASSIPES	×	×	×		o	×
LEPTOSPERMUM ELLIPTICUM	×	×	o		o	×
XANTHORRHOEA PREISSII	o				o	o
AGONIS LINEARIFOLIA	×	×	/	o	×	×
EUC. MARGINATA	×	×	/	×	×	×
EUC. PATENS	×	×	/	×	×	×
ACACIA BROWNIANA				×	×	×
PULTANAEA DRUMMONDII	o			o	×	×
LEUCOPOGON AUSTRALIS		/		o	×	×
PIMELIA SPECTABILIS	o	/		o	×	×
HAKEA LISSOCARPA	o	/	o	×	×	×
XANTHORRHOEA GRACILIS		/	o	o	×	×
KINGIA AUSTRALIS	×		×	o	o	×
BORONIA CRENULATA						
ANDERSONIA CAERULEA						
BEAUFORTIA SPARSA						
GREVILLEA PULCHELLA						
ACACIA OBOVATA						
ACACIA DIPTERA						
GREVILLEA BREVICUSPIS						
PETROPHILA DIVERSIFOLIA						
THOMASIA GRANDIFLORA						
HIBBERTIA QUADRICOLOR			×	o	×	×
DAVIESIA PREISSII			×	×	×	×
DAVIESIA PECTINATA		o	×	×	×	×
ACACIA EXTENSA		×	o	×	×	o
TETRATHECA SETIGERA		×	o	×	×	×
LEUCOPOGON VERTICILLATUS		o	×	×	×	×
ADENANTHOS BARBIGERA		o	×	.	.	×
HIBBERTIA MONTANA		×	o	.	.	×
ISOPOGON SPHAEROCEPHALUS	/	o	×	.	.	×
BOSSIAEA ORNATA	/	×	×	×	×	×
HOVEA CHORIZEMIFOLIA	/	×	×	×	×	×
PERSOONIA LONGIFOLIA		×	×	×	×	×
LEUCOPOGON CAPITELLATUS		×	×	×	×	×
STYPHELIA TENUIFLORA.		×	×	×	×	×

LEGEND

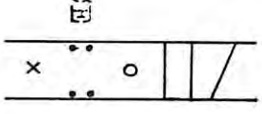
OBLIGATORY

PROBABLE

POSSIBLE

SLIGHT CHANCE

BARRED



APPENDIX III

Water Sampling Data - Margaret River Catchment

Total dissolved solids mg/litre (Note: Solute nearly all NaCl)

Date:	SAMPLING POINT NUMBER					
	1	12	5	27	13	6
09.11.73	170	139	120		174	170
16.11	182	149	125		175	161
23.11	195	155	124		190	176
30.11	195	152	130		180	169
07.12	189	156	130		184	173
14.12	211	159	131		195	206
21.12	209	170	134		202	186
28.12	223	172	149		202	196
04.01.74	223	192	148		262	198
11.01	246	197	156		Dry	202
18.01	Dry	206	163			206
25.01		Dry	149			202
01.02			149			216
08.02			217			306
15.02			Dry			222
22.02						216
01.03						192
08.03						192
15.03						195
						Dry
10.05.74		227	163		227	
17.05	317	263			263	218
24.05	217	214	148	174	214	196
30.05	176	173	152	192	173	187
07.06	188	162	139	172	162	184
14.06	197	171	139	183	171	189
21.06	197	175	139	187	175	188
28.06	154	130	114	141	130	158
05.07	141	123	108	124	141	142
12.07	123	110	92	90	116	126
19.07.74	92	131	83	80	92	107
26.07	83	79	87	99	108	109
02.08	54	58	64	65	68	65
09.08	89	82	66	81	92	87
16.08	110	97	86	92	105	104
23.08	87	83	67	87	90	83
30.08	109	94	70	99	116	96
07.09	119	92	77	89	107	104
13.09	117	94	75	117	112	106
20.09	133	104	90	116	123	117
27.09	133	112	90	121	133	121
04.10	146	131	87	137	156	132
11.10	163	132	109	139	153	146
18.10	162	134	108	132	161	149
25.10	164	138	121	146	157	159
31.10	168	137	116	149	158	158
08.11	158	136	116	146	158	150

APPENDIX IV

Comparison of Water Quality Data

For Hardwood and Plantation Catchments

Total dissolved solids mg/litre

Date	Uncleared hardwood forest	Pine plantation age 1 & 5 years.
09.11.73	128	91
16.11	134	94
23.11	138	92
30.11	138	90
07.12	142	97
14.12	148	96
21.12	151	Dry
28.12	161	
04.01.74	166	
11.01	Dry	
30.05.74	163	114
07.06	156	111
14.06	154	106
21.06	156	104
28.06	138	95
05.07	126	85
12.07	121	77
19.07	85	67
26.07	90	70
02.08	64	52
09.08	63	50
16.08	70	56
23.08	70	51
30.08	77	50
07.09	77	53
13.09	79	51
20.09	94	62
27.09	97	63
04.10	112	77
11.10	118	83
18.10	117	84
25.10	127	92
31.10	129	91
08.11	126	90

APPENDIX V

1. Reasons for a Pine Planting Programme in Western Australia

1.1 Inadequacy of the Existing Forest Resource

1.1.1 The original forested area of the State was about 6.5 million hectares concentrated in the high rainfall zone of the South West. This has now been reduced by progressive agricultural development to about 1.8 million hectares under secure tenure for forestry purposes. (This represents 0.8 percent of the total land surface of the State compared with the Australian average of 2.4 percent).

1.1.2 The limited residual area of forests under secure tenure is being managed according to multiple use principles in order to meet an ever-increasing range of public use. The forests of the South West have particular significance in regard to water supply and contain the major catchments for the Metropolitan and inland water supply schemes. No alternative water sources exist, yet the present area of State Forest is being continuously eroded by pressures for single-use management such as open cut mining, public facilities, (including transmission lines and damsites) and requests for large scale reservations for National Parks.

1.1.3 The forest disease identified in 1965 and known as Jarrah Dieback is the largest single factor affecting the native vegetation and productivity of the forests. This disease attacks and eventually kills the standing indigenous trees and much of their associated ground flora. So far some 180,000 hectares have been affected to varying degrees and current estimates indicate that this area is increasing by about 9 percent annually.

1.1.4 The present yield of hardwood sawlogs from State Forest (0.96 millionm^3) cannot be sustained in the long term because of slow growth rates and the impact of dieback disease. Depending on the ultimate effects of dieback, yield will have to be reduced to the order of 0.5 million m^3 per year to ensure any degree of continuity in hardwood log supplies. This reduction should be accomplished by 2010, or preferably earlier, and it should be achieved by the progressive phasing-in of pine sawlog supplies to avoid a major disruption of the rural economy in the South West.

1.1.5 Supplementary hardwood supplies from freehold land have fallen from 25 percent to 9 percent of total production in the last decade and are becoming increasingly scarce. It is expected that they will be completely exhausted within the next decade. Compensatory supplies are not available from State Forest which is already heavily overcommitted.

1.1.6 Very conservative estimates of future demands indicate that the State's total sawlog requirements will increase to 1.4 million m^3 per year by 2010. (Fig.1) Using the highest estimate of hardwood availability, i.e., 0.50 million m^3 per year by that time, the State's future pine sawlog requirement is 0.86 million m^3 per year. The present limited planting programme will be capable of supplying only 0.50 million m^3 per year depending on standards of log acceptability at the time. To meet the full requirement a total plantation area of about 140,000 ha will be required by 2000 A.D. (Fig.2).

1.1.7 The overall supply demand situation is shown in more detail in Figures 1 and 2. It must be stressed that because the minimum plantation rotation is 30 years (considerably shorter than proposed rotations in the Eastern States) action to remedy the anticipated shortage by 2010 must be taken now. It must also be stressed that any apparent short term surpluses are regarded purely as a contingency margin against the accelerated loss of hardwood production due to dieback. It should be noted these projections make no allowance for possible fire losses. It would be desirable to have a 10 percent margin to allow for this contingency.

1.2 Environmental Considerations

1.2.1 Jarrah dieback is known to have adverse effects on water salinity in parts of the northern jarrah forest which contains the major catchments supplying the inland and Metropolitan water schemes. Should current measures to control the long term spread of disease fail, it will be necessary to close these forests to all other uses in view of the overall and already acknowledged paramountcy of management for water production in these areas. In this event an expanded plantation programme in less sensitive localities will be the only alternative means of preventing the State from reaching a condition of virtual destitution in timber supplies.

1.2.2 Similarly it is becoming increasingly apparent that it will be necessary to curtail production demands in certain areas of the indigenous forests in order to meet public pressures for multiple purpose use such as fauna and flora conservation and recreation. These pressures are acknowledged as justifiable subject to appropriate zoning and would be more readily accommodated in the national interest if adequate timber supplies were guaranteed from areas of lesser environmental sensitivity and biological significance.

1.2.3 The opportunity to reduce these excessive pressures on prime native forest by creating highly productive plantations in poor quality degraded forest is a necessary adjustment to current land use practice. In fact, one hectare converted to pine will have a productive capacity equivalent to 30 hectares of better quality jarrah forest.

1.3 Economic and Social Considerations

1.3.1 Relative self-sufficiency in timber for Western Australia is considered imperative because of geographic isolation and the adverse effects of high and rapidly-increasing transport charges on the costs of a bulky commodity basic to lowpriced housing and public utility.

1.3.2 Maintenance of a reasonable level of hardwood exports in specialty timbers (heavy and long length constructional members and veneers) is considered desirable to counter imports for other specialty manufactures and to offset adverse trade balances with the Eastern States currently running at a deficit of approximately 1:5. At present 12.6 percent of total production is exported overseas and 15 percent interstate.

1.3.3 Assured local supplies, commensurate with the minimum level of predicted future demands, are essential to the stability of local manufacturing industries. Availability of imports from overseas is subject to gross uncertainty and to savage short term price fluctuations, due to worldwide economic conditions.

1.3.4 Continued timber production is basic to the stability of the rural economy in the South West where some 3507 employees are directly engaged in sawmilling and forestry. Excluding the multiplier effects of employment in service and support activities and in remanufacture of timber products outside the region, this represents 43 percent of the workforce in primary production or 17 percent of the total workforce in the region. Over the past decade the primary workforce has remained relatively static. It would undoubtedly have decreased following the decline in agriculture were it not for the fact that employment in the forestry and timber industries has enabled a considerable number of farmers to continue in their agricultural pursuits.

1.3.5 Given that decentralisation is a socially desirable end, it is unlikely there is any more effective way of achieving it than the proposed southern region pine plantation programme.

1.3.6 Pine plantations and grazing are compatible at certain stages in the rotation. It is anticipated that in the future, considerable areas of plantation will be available for grazing under leasehold to local farmers. This will provide the advantage of greatly reduced fire hazard and will make available useful areas for the continuation of existing pastoral pursuits.

1.3.7 Continuation of the present inadequate planting programme is desirable to offset the otherwise inevitable reduction in workforce which will accompany the reduction in hardwood yield. An expanded plantation programme (subject to the environ-

mental and other conditions mentioned below) is essential to meet minimum future demands. This will provide the main area for decentralised industrial development within the region requiring an additional workforce of about 3000 skilled and semi-skilled employees. A seasonal component probably drawn from the farming community will also be involved in plantation establishment. The expanded plantation programme will provide a supplementary factor in the resource base for the timber manufacturing, agriculture, and greatly expanded support services.

1.3.8 If the deficit in local sawlog production is to be made up from local sources, softwood plantations are the only feasible way of doing it. Replanting diseased sites with tolerant eucalypts such as E. resinifera and E. globulus is not an alternative as sawlog rotations of the order of 70 to 80 years would be necessary, compared with 30 years for P. radiata. Short rotation eucalypt crops are suited for pulp production only.

1.3.9 For many purposes softwoods are technologically better. The future softwood resource will enable our hardwoods to be used to take best advantage of their unique properties.

2. The Present Plantation Situation in W.A.

2.1 The Present Plantation Area

The total area of plantation established by the Forests Department to date is 37,000 hectares made up of 16,000 hectares of Pinus radiata and 21,000 hectares of Pinus pinaster. The geographical spread of the plantations is illustrated on the map of the South of W.A. included as Figure 3. The present annual planting programme is 2,400 ha. This is totally inadequate to meet the desired target of 140,000 ha by 2000.

Prior to 1969, 6,700 hectares (or 0.4 percent of the total area of dedicated State Forest) of high quality hardwood forest was converted to plantations of the faster-growing P. radiata. This practice was then terminated to conserve remaining areas of jarrah-blackbutt forest growing on the relatively fertile red loams. Since 1955 the Department has actively pursued the policy of repurchasing cleared farmlands for replanting to the limits of its financial ability. To date 14,000 hectares have been acquired in this way. Further availability of such land is now extremely limited.

2.1.1 Private plantations, mainly Pinus radiata, amount to 7,000 hectares, most of which was established during the last decade on sites of varying suitability. This useful supplement to the Departmental programme cannot be expected to continue, largely because of increasing scarcity of suitable land located within economic hauling distances of existing and potential processing sites.

2.1.2 Because of the scattered distribution of soils hitherto regarded as suitable for Pinus radiata, fragmentation both of Departmental and private plantations has been inevitable. Though having some environmental advantages, this has the economic disadvantages of excessive hauling distances and inability to support the intake required for viable, capital-intensive processing facilities from the one locality. On present indications about 25,000 hectares of closely grouped plantations are required to support a viable sawmilling enterprise and to gain the economic advantages of scale and integrated manufacture using a common resource base.

2.1.3 Quality sawlog production is the prime objective of the Departmental softwood programme and cultural practices have been modified accordingly because of the more favourable economics and plantation hygiene. It has also been demonstrated that the amount of chipwood produced in the process will meet the foreseeable demands for local particle board manufacture.

2.1.4 Guidelines have been established and are followed to ensure that the environmental aspects of the programme are carefully considered and protected. Some of the earlier work may, on present standards, have overlooked wildlife and aesthetic values to some extent. These omissions have been remedied by greater attention to plantation layout and landscaping, preservation of selected buildings of local significance and reservation of substantial areas of the vegetation types undergoing conversion.

2.2 Climate and Species Suitability

2.2.1 The planting programme is made up of approximately 50:50 Pinus pinaster and P. radiata which are the only two species found to be suitable for commercial planting under Western Australian conditions. In the Mediterranean climate of the South West, both species require an annual rainfall of at least 750 mm so the choice of location of plantation areas is restricted (Fig.3). Although both species are used, P. radiata is preferred because of its greater productivity and management flexibility.

2.2.2 Pinus pinaster is more drought resistant and grows well on the very infertile sands of the Swan coastal plain with the addition of comparatively small amounts of superphosphate. Its use is almost entirely confined to a large area of Banksia woodland just north of Perth. The relatively slow growth of the species is compensated for in this case by inexpensive establishment and maintenance and the ideal location close to markets. This Banksia woodland has restricted agricultural potential and has no other proven commercial use

apart from some honey production. It does, however, form part of a large underground water catchment area. Close liaison with the W.A. Metropolitan Water Supply Department has established that production forestry and catchment management requirements are compatatible. A large area of State Forest in this vicinity has been set aside for the purposes of flora and fauna protection and a further larger area is in the process of being reserved for the same purpose and vested in the W.A. Wildlife Authority. The region contains several representative National Parks.

2.2.3 Pinus radiata is much more demanding in its site requirements. Until recently its use was virtually confined to the moderately fertile red loam soils which are found over basic igneous rock in discontinuous areas in the lower South West of the State. Most such land has long since been alienated for agriculture so the amount of land available and naturally suited for this species is extremely limited. Recent research indicates that the range of P. radiata in high rainfall areas can be extended by the use of appropriate fertilisers onto the less fertile sandy soils of low grade hardwood stands degraded by dieback disease.

2.3 Land Availability

2.3.1 After 1975 the Department will have a further 27,000 ha on the coastal plain suitable for P. pinaster. For P. radiata there are only approximately 6,500 ha of proven suitable soil available. Most of this is in the Blackwood Valley and the remainder is better class sand on the coastal plain south of Perth.

To maintain the current P. radiata programme after 1980, the Forests Department must purchase such farm land as is available and proceed with the conversion of poor quality native forest.

2.3.2 The prospects for repurchasing any significant areas of naturally suitable farmlands are becoming increasingly restricted. Fewer properties are now offering. The prices asked have become unrealistically high and the funds available from Departmental sources are becoming increasingly scarce due to the pressures of current wages escalation. Repurchase of all alienated land in the Blackwood Valley for pine planting is considered undesirable on the grounds that a balanced mix of forestry and agriculture in that area will provide the optimum economic and social benefit to the State as a whole.

2.3.3 For very similar reasons and because of presently unfavourable taxation provisions private plantations are not expected to make a major contribution within the overall programme.

FIG. 1

TOTAL SAWLOG VOLUME WESTERN AUSTRALIA
ESTIMATED SUPPLY AND DEMAND

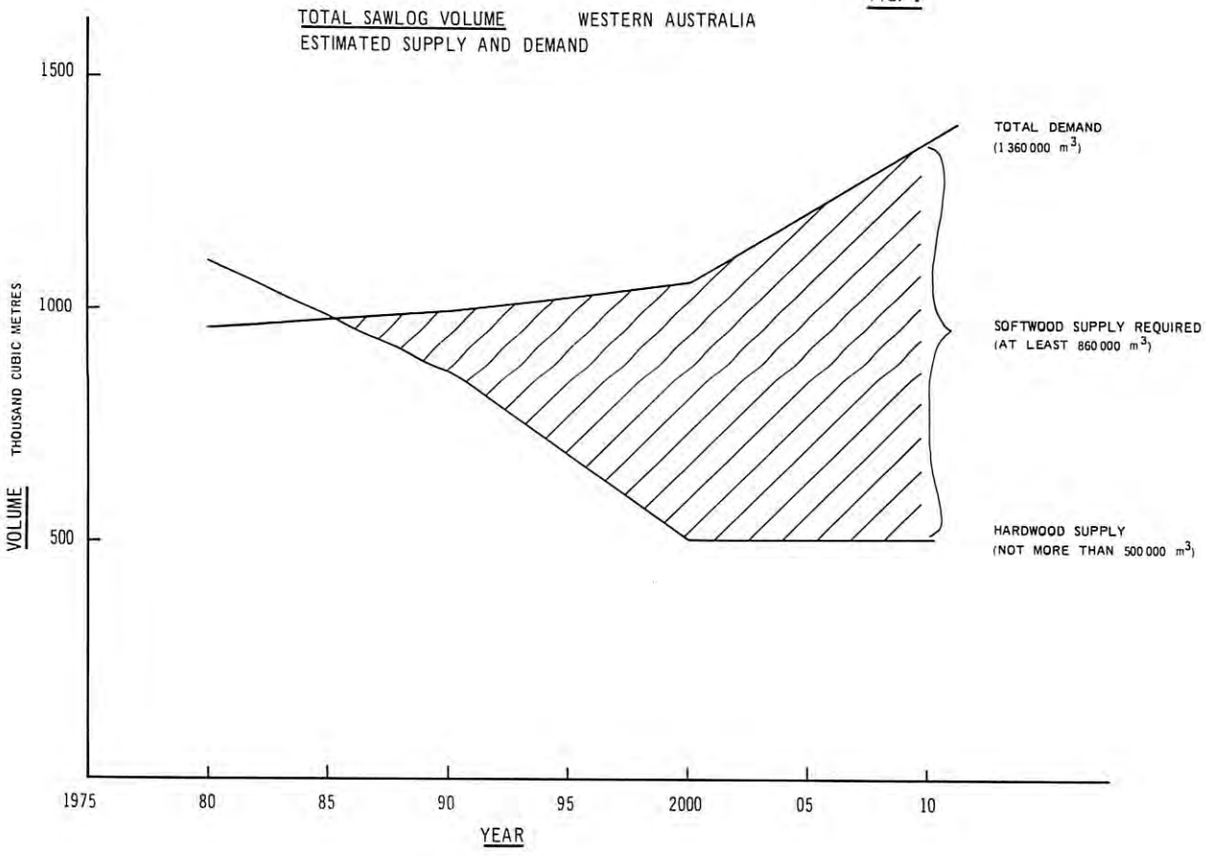
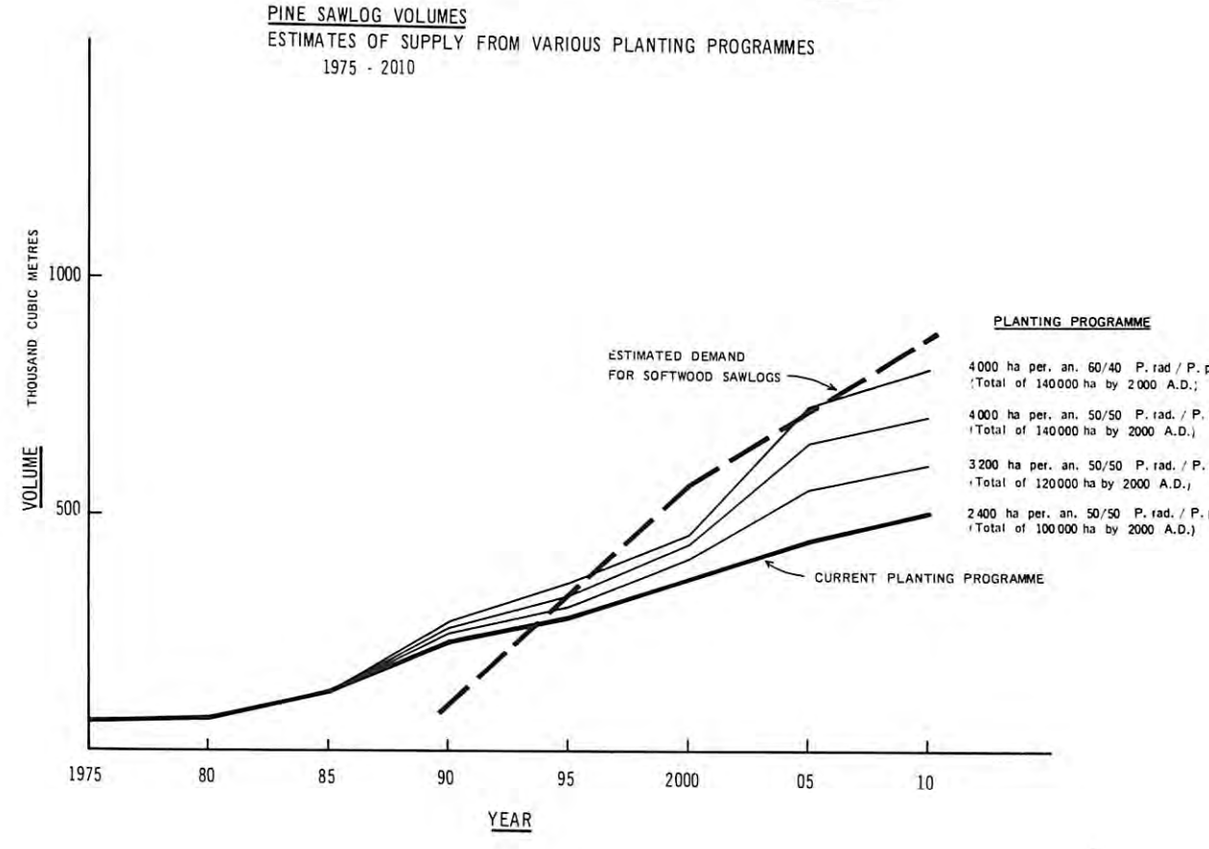


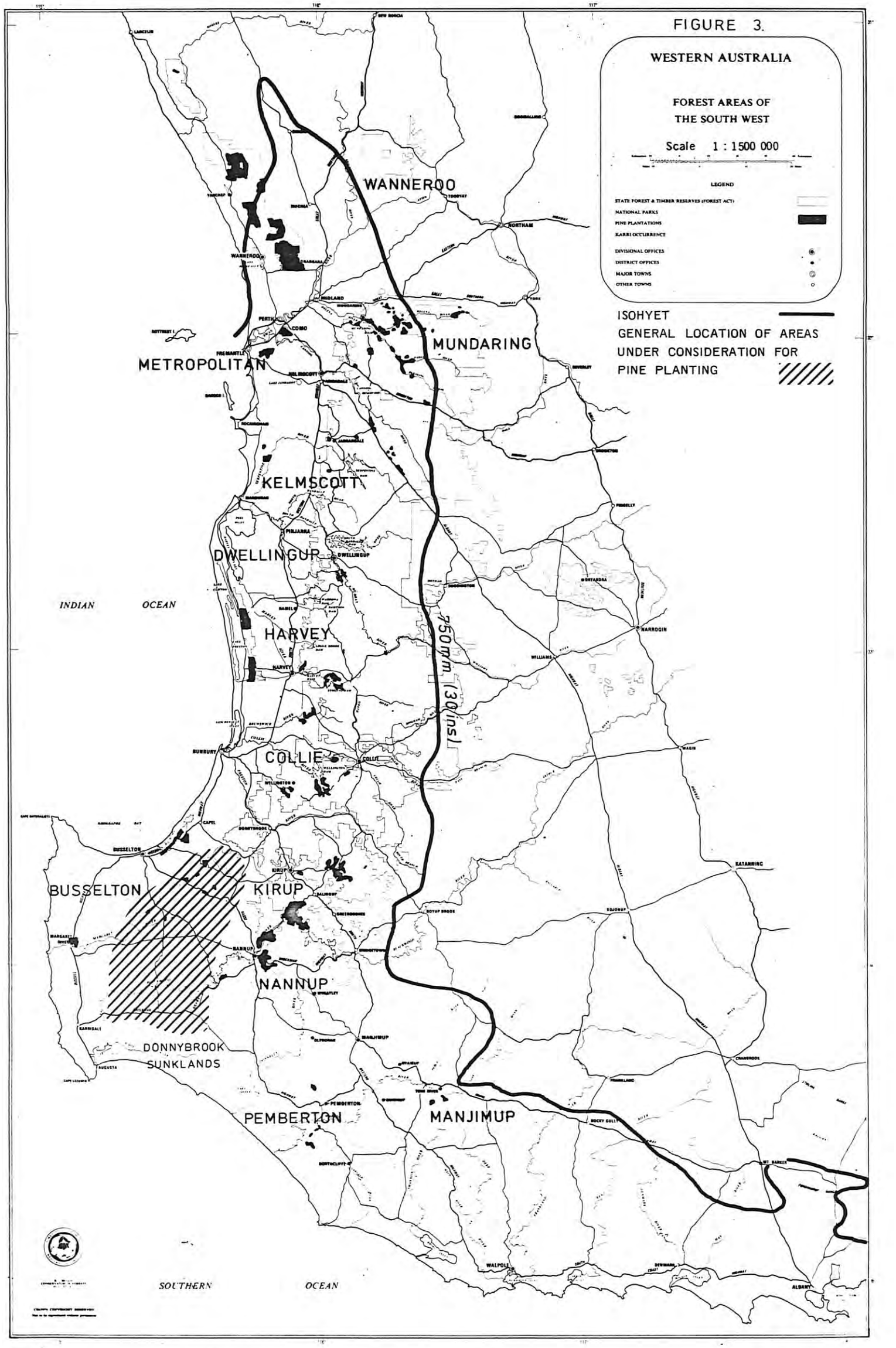
FIG. 2

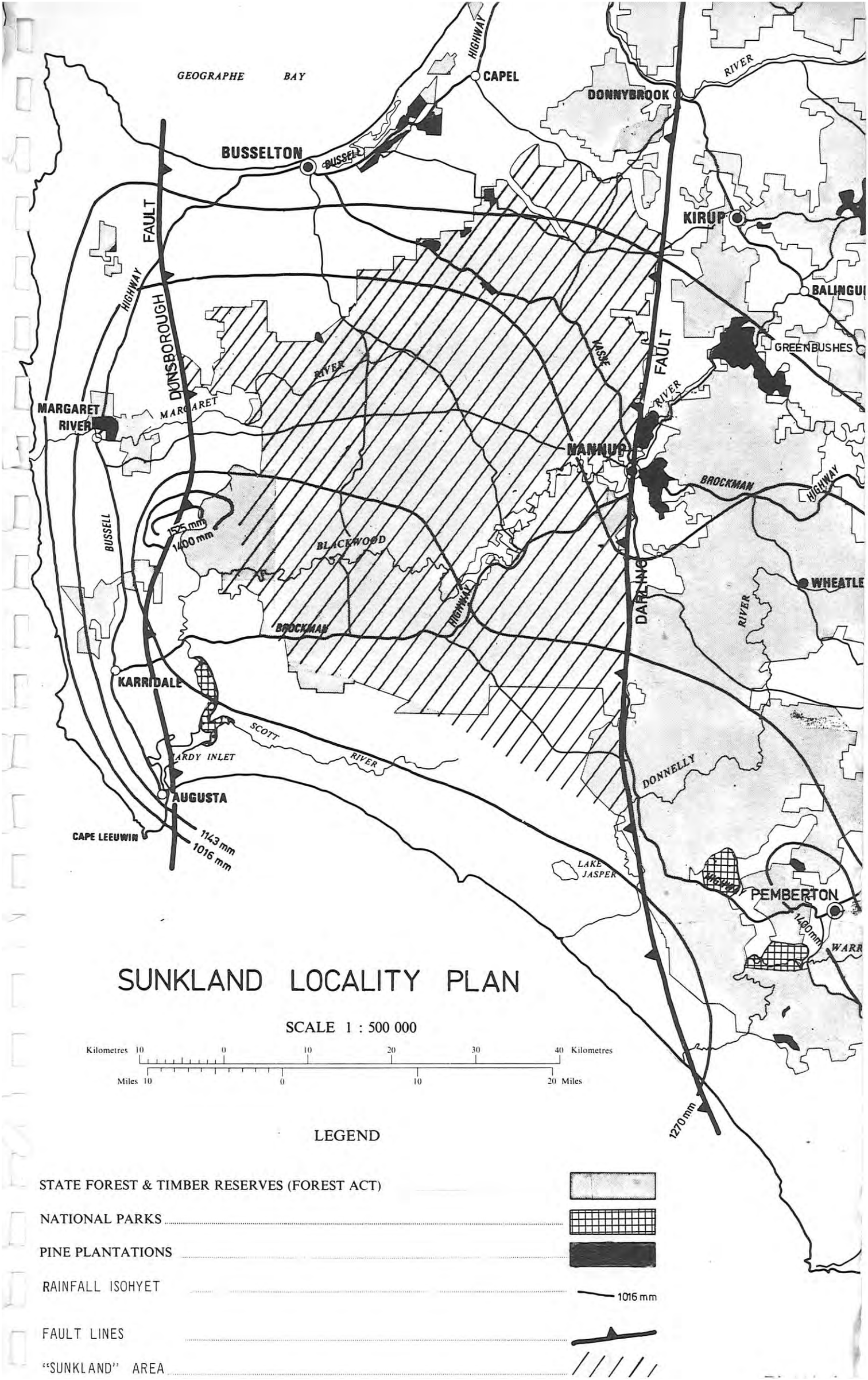
PINE SAWLOG VOLUMES
ESTIMATES OF SUPPLY FROM VARIOUS PLANTING PROGRAMMES
1975 - 2010



100477/2/76–150–1598

FIGURE 3.


WESTERN AUSTRALIA
FOREST AREAS OF
THE SOUTH WEST
Scale 1 : 1500 000
LEGEND
STATE FOREST & TIMBER RESERVES (FOREST ACT)
NATIONAL PARKS
PINE PLANTATIONS
KARRI OCCURRENCE
DIVISIONAL OFFICES
DISTRICT OFFICES
MAJOR TOWNS
OTHER TOWNS
ISOHYET
GENERAL LOCATION OF AREAS
UNDER CONSIDERATION FOR
PINE PLANTING
WANNEROO
MUNDARING
METROPOLITAN
KELMSCOTT
DWELLINGUP
HARVEY
COLLIE
BUSSELTON
KIRUP
NANNUP
DONNYBROOK
SUNKLANDS
PEMBERTON
MANJIMUP
INDIAN OCEAN
SOUTHERN OCEAN
750mm (30ins)



SUNKLAND LOCALITY PLAN

SCALE 1 : 500 000

Kilometres 10 0 10 20 30 40 Kilometres

Miles 10 0 10 20 Miles

LEGEND

STATE FOREST & TIMBER RESERVES (FOREST ACT)

NATIONAL PARKS

PINE PLANTATIONS

RAINFALL ISOHYET — 1016 mm

FAULT LINES

"SUNKLAND" AREA

MINING CLAIMS

MINING CLAIM

1966

1966

1967

1970

1974

1971

1972

1968

1951,61,72

1970

1970

1971

1971

1971

1972

1971

1971

1974

1971

TENURE PLAN 2

MINING CLAIMS

MINING CLAIMS

1966

1966

1968

1972

1974

1971

1967

1970

1971

1951,61,72

1970

1971

1971

1972

1974

1971

1974

1969

1969, 70

1969, 70

1970

1967

1971

1972

1969, 70

1969, 70

1974

1969

1969, 70

1969, 70

1970

1967

1971

1972

1969, 70

1969, 70

1969, 70

1971

1967

1971

1972

1969,70

1969,70

1969,70

PLOT No. 4

SOUTHERN OCEAN

SCOTT RIVER

LEDGE POINT

WHITE POINT

NELSON

KEY TO SYMBOLS

Sealed Road	Forests Dept. Headquarters
1st Class Road	Sawmill
2nd Class Road	Lookout Tower
3rd Class Road	Survey Reference Tree Theodolite
Railway W.A.G.R.	Survey Reference Tree Compass
Telephone Line	P.O. Office
Powerline	Loading Ramp
Block Boundary	Permanent Water Supply
Land District Boundary	Permanent Water Supply Developed

1:126 720

Kilometres

Miles

STATE FOREST TIMBER
& FREEHOLD LAND IN

TIMBER RESERVES (LA

CROWN LAND REQUEST
STATE FOREST OR TI

1967

1971

1972

1969,70

1969,70

1969,70

1971

1969,70

TENURE PLAN

LEGEND

STATE FOREST TIMBER ↑ (FOREST ACT)
& FREEHOLD LAND IN NAME OF CONSERVATOR

TIMBER RESERVES (LAND ACT)

CROWN LAND REQUESTED FOR
STATE FOREST OR TIMBER ↑

RESERVES

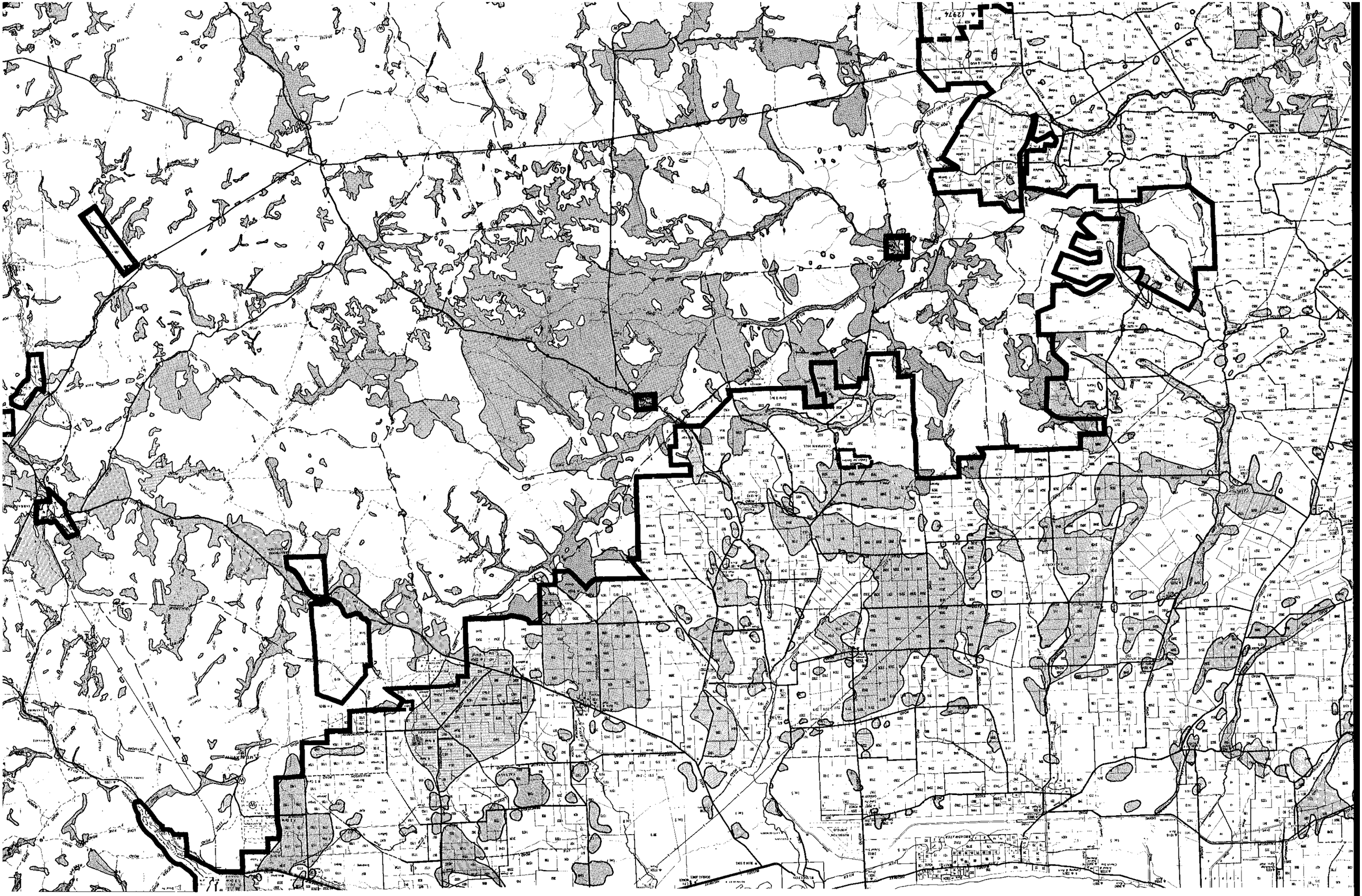
PRIVATE PROPERTY

EXPERIMENTAL PLOTS

1:126 720

Kilometres

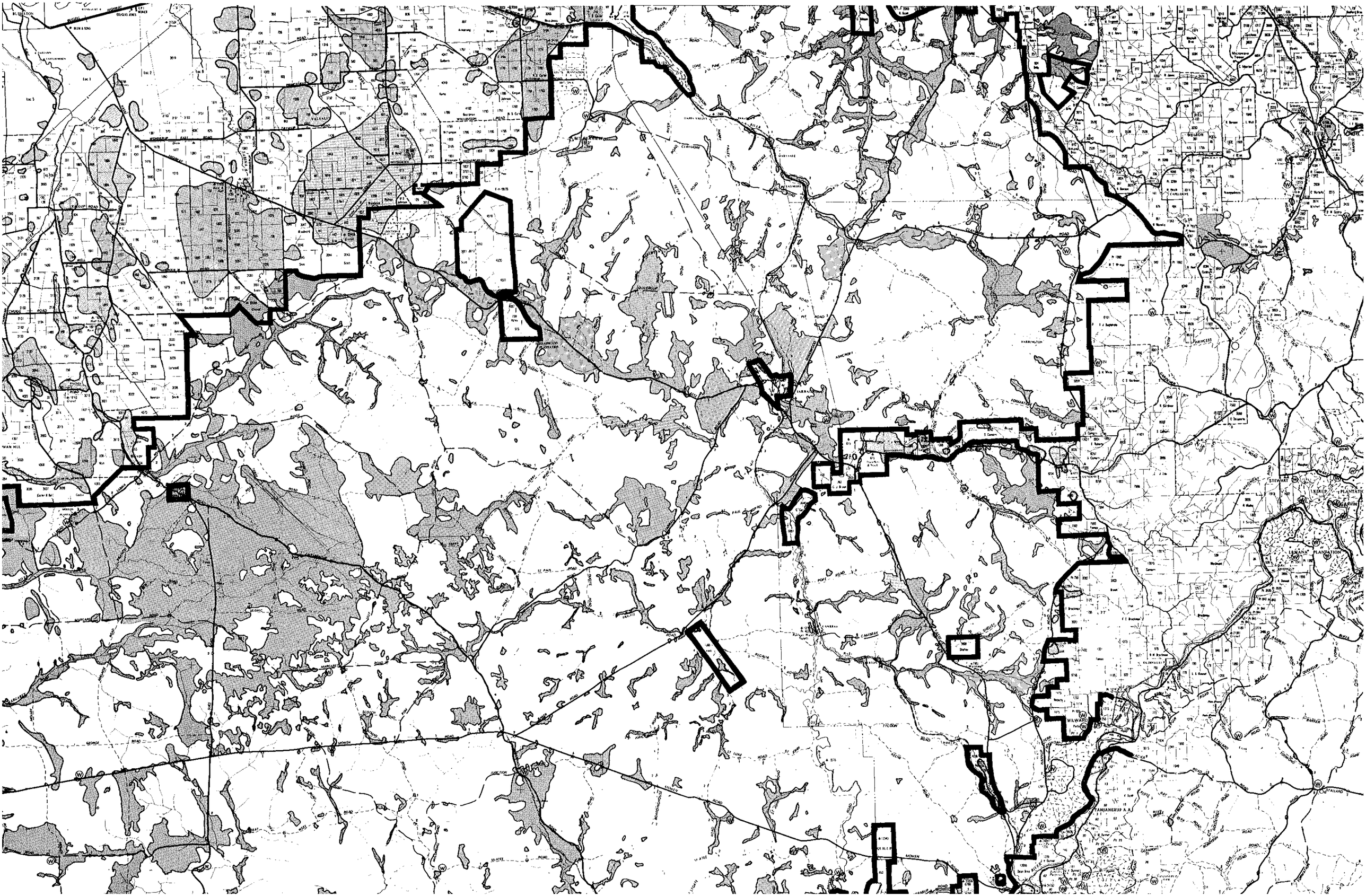
Miles

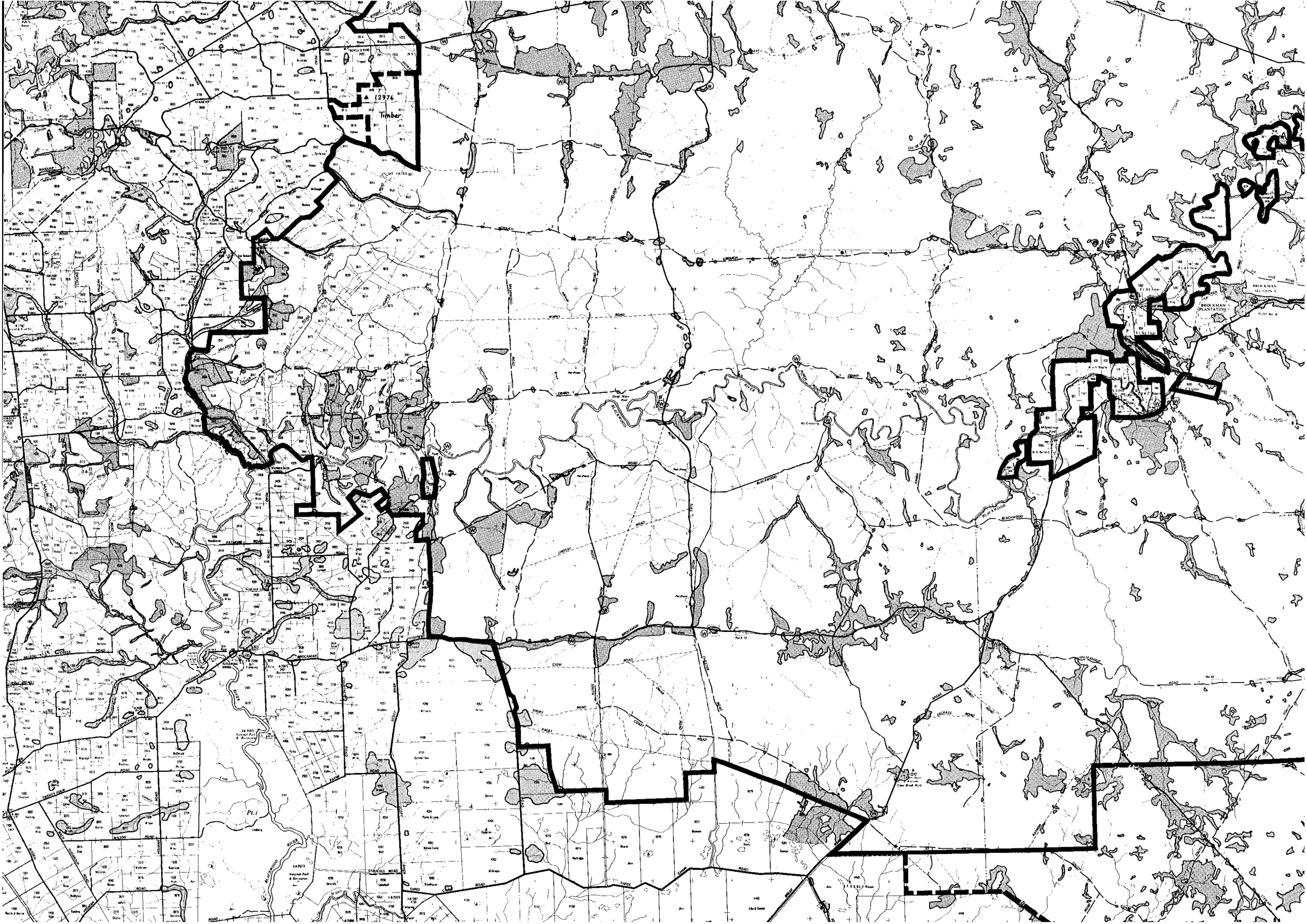


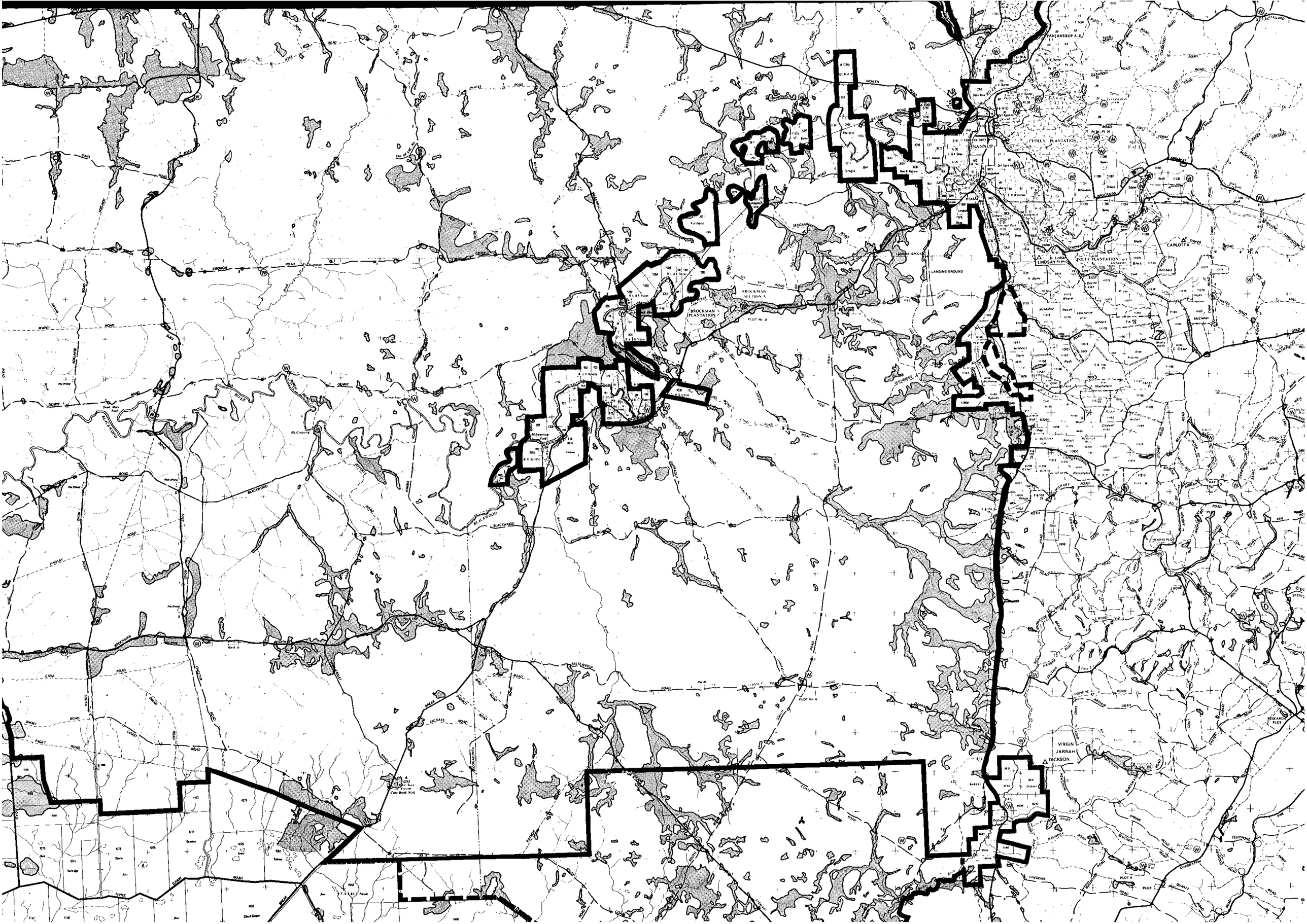
NI

INCIDENCE OF DIEBACK DISEASE

PLAN 3




▲ 1297ft
Timber
BROCKMAN PLANTATION
Pt. 1


BROCKMAN PLANTATION
FOLLY PLANTATION
LANDING GROUND
CARLOTTA
VIRGIN JARRAH
DICKSON
BLACKWOOD ROAD
CROUCH ROAD
WARD ROAD
DERBY ROAD
CHEM ROAD
SHORT FACET ROAD
THREE CHAIN ROAD
TIGHE ROAD
TAYLOR ROAD
GREAT TAYLOR ROAD
SLOCUM ROAD
HECKMAN SETTLEMENT
PLOT No 8
PLOT No 4
RESEARCH PLOT
TELEPHONE

1 : 126720

KEY TO SYMBOLS

Sealed Road
1st Class Road
2nd Class Road
3rd Class Road
Railway W.A.G.R.
Telephone Line
Powerline
Min.A Boundary
Land District Boundary
Private Property
Forests Dept. Headquarters
Sawmill
Lookout Tower
Survey Reference Tree Theodolite
Survey Reference Tree Compass
Post Office
Loading Ramp
Permanent Water Supply
Permanent Water Supply Developed

PROVEN AND SUSPECT DIEBACK INFECTIONS 1973

STATE FOREST, TIMBER ∧ (FORESTS ACT)
& FREEHOLD LAND IN THE NAME OF CONSERVATOR

TIMBER RESERVES (LAND ACT) & CROWN LAND
REQUESTED FOR STATE FOREST OR TIMBER ∧

INC

OCEAN

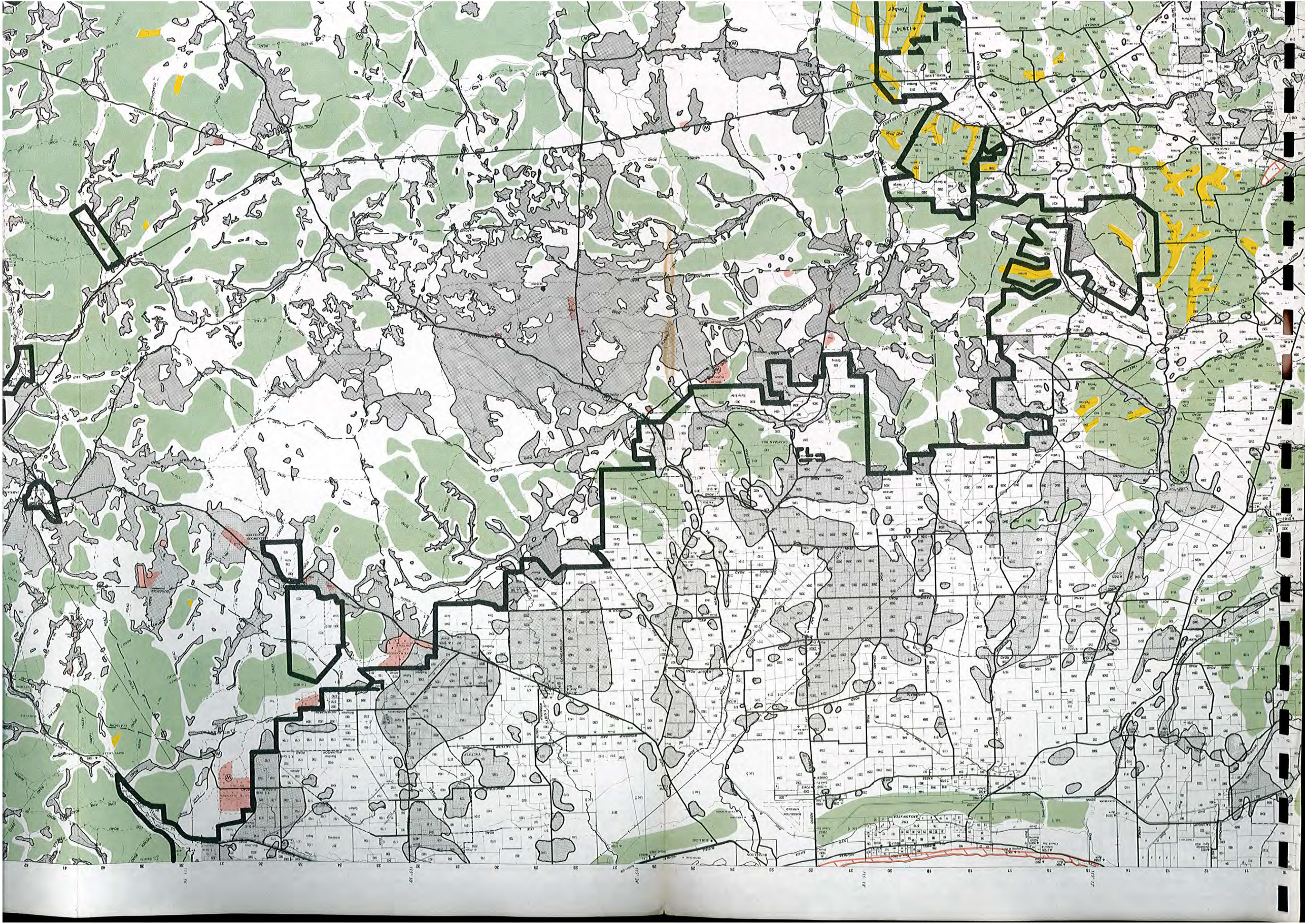
INCIDENCE OF DIEBACK DISEASE

PLAN 3

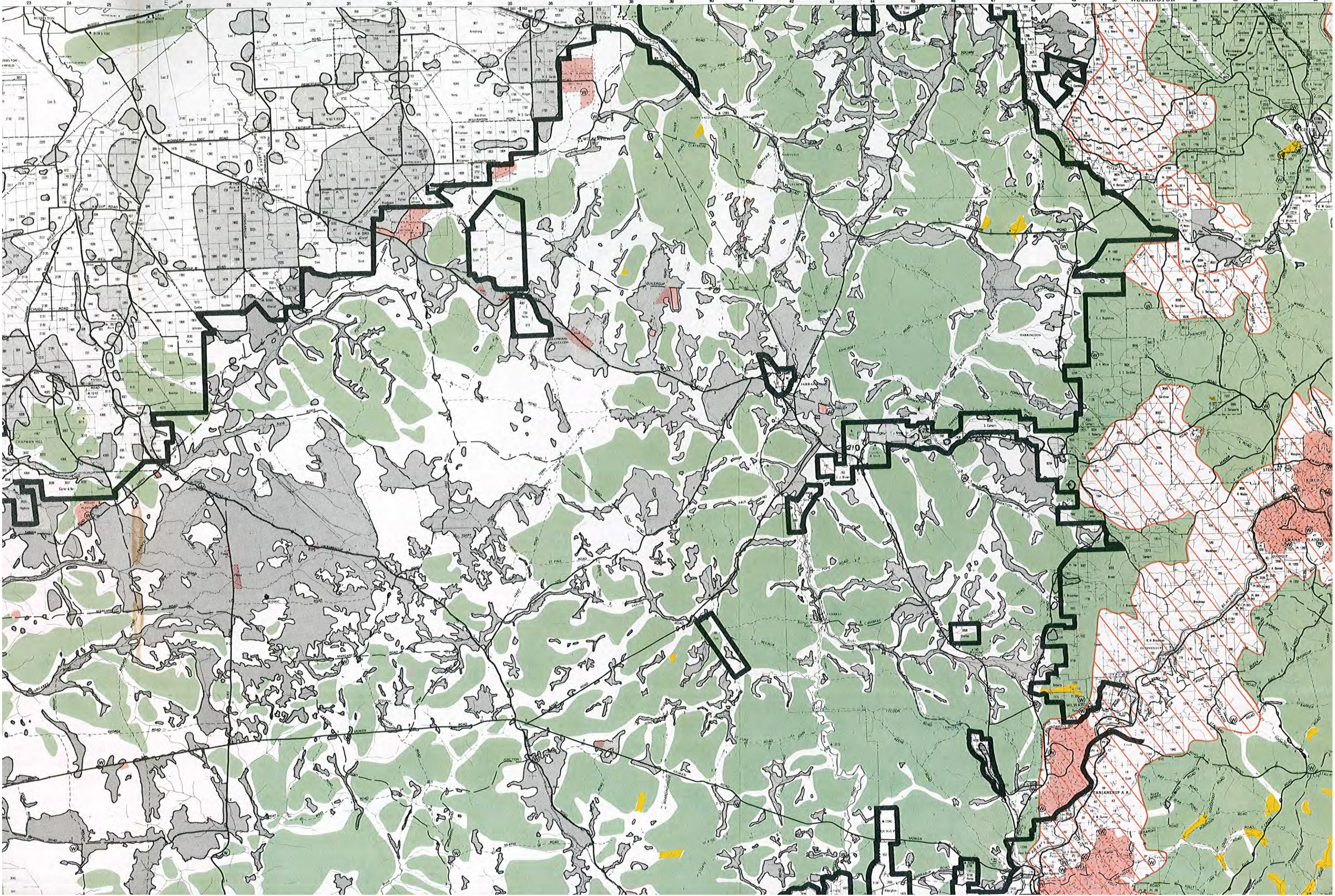
PROVEN AND SUSPECT DIEBACK INFECTIONS 1973

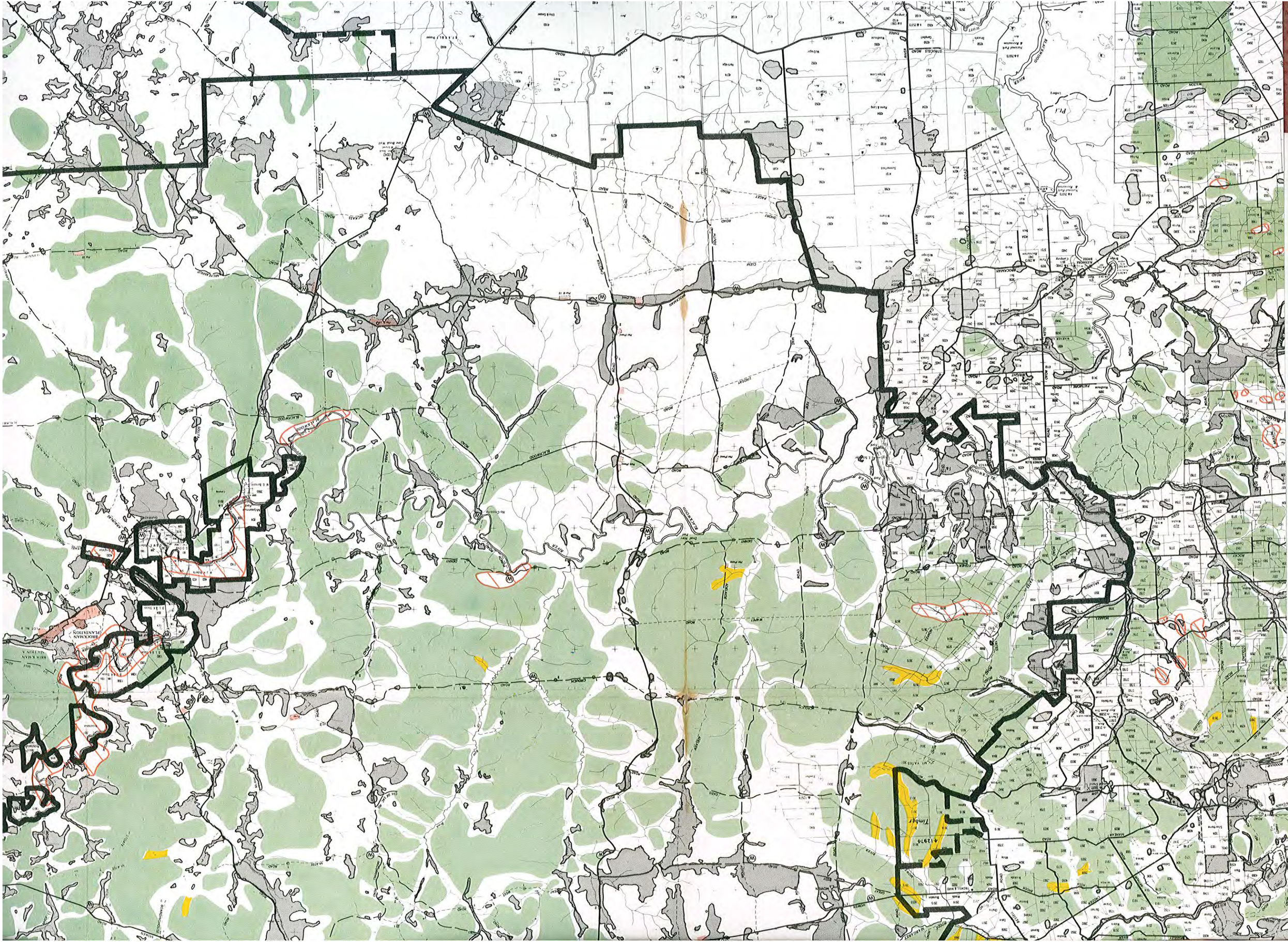
STATE FOREST, TIMBER ⅄ (FORESTS ACT)
& FREEHOLD LAND IN THE NAME OF CONSERVATOR

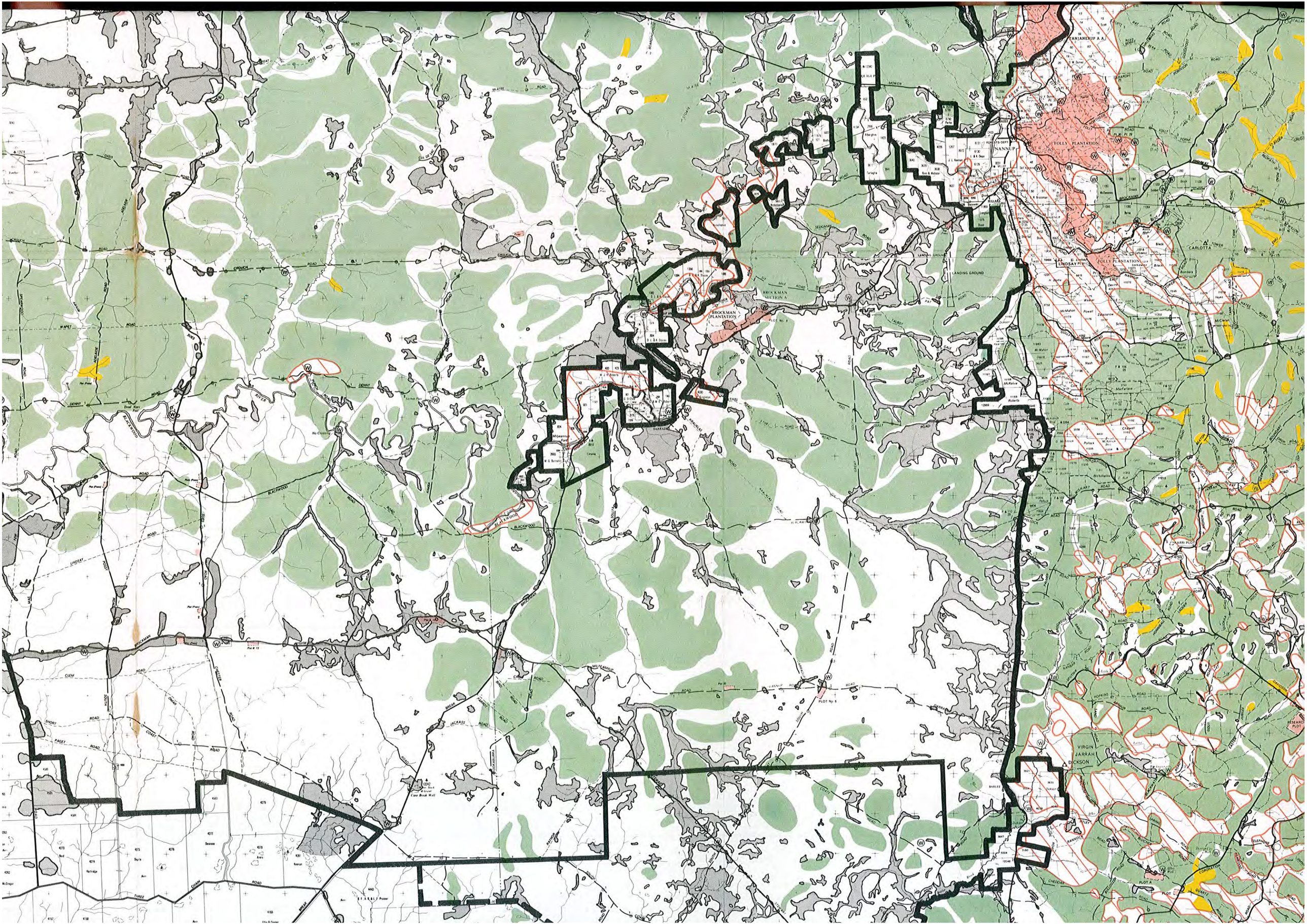
TIMBER RESERVES (LAND ACT) & CROWN LAND
REQUESTED FOR STATE FOREST OR TIMBER ⅄



DIEBACK RISK PLAN 4






BROCKMAN PLANTATION
BROCKMAN SECTION A
BLACKWOOD
TOLLY PLANTATION
LANDING GROUND
CARLOTTA
VIRGIN JARRAH
DICKSON
BOYANUP
FORESTS DEPT
WAPET ROAD
DENNY ROAD
BLACKWOOD ROAD
CROUCH ROAD
MOWEN ROAD
SEDGMAN ROAD
BROCKMAN ROAD
CLEM ROAD
SHORT ROAD
PAGET ROAD
COAST ROAD
THREE CHAIN ROAD
LINDSAY FOREST ROAD
CHESTER ROAD
JACKASS ROAD
MILLSTANNUP ROAD
HOPKINS ROAD
WISHART ROAD
FORMOSA ROAD
PLOT No 6
PLOT No 8
PLOT A
RESEARCH PLOT

KEY TO SYMBOLS

Sealed Road
1st Class Road
2nd Class Road
3rd Class Road
Powerline
Block Boundary
Private Property

Forests Dept. Headquarters
Sawmill
Lookout Tower
Survey Reference Tree Theodolite
Survey Reference Tree Compass
Loading Ramp
Permanent Water Supply
Permanent Water Supply Developed

1 : 126720

Kilometres
Miles

B. J. BEGGS
CONSERVATOR OF FORESTS
AUGUST 1975

LEGEND

DIEBACK AND SUSPECT DIEBACK
NOT PROTECTABLE FROM DIEBACK
PROTECTABLE BUT HIGHLY SUSCEPTIBLE
PROTECTABLE (MODERATELY SUSCEPTIBLE)

RESISTANT ?
PLANTATION OR MINING
STATE FOREST, TIMBER & FREEHOLD LAND IN
TIMBER RESERVES, LAN REQUESTED FOR STATE

DIEBACK RISK PLAN

PLAN 4

LEGEND

DIEBACK AND SUSPECT DIEBACK

NOT PROTECTABLE FROM DIEBACK

PROTECTABLE BUT HIGHLY SUSCEPTIBLE

PROTECTABLE (MODERATELY SUSCEPTIBLE)

RESISTANT ?

PLANTATION OR MINING

STATE FOREST, TIMBER ↟ (FOREST ACT)
& FREEHOLD LAND IN NAME OF CONSERVATOR

TIMBER RESERVES (LAND ACT) & CROWN LAND
REQUESTED FOR STATE FOREST OR TIMBER ↟

1 : 126720

Kilometres

Miles

B. J. BEGGS
CONSERVATOR OF FORESTS
AUGUST 1973

OCEAN

SCOTT RIVER

WHITE POINT

BOLGAMUP

NELSON

LAKE QUITUP

FOURACRES

VIRGIN JARRAH DICKSON

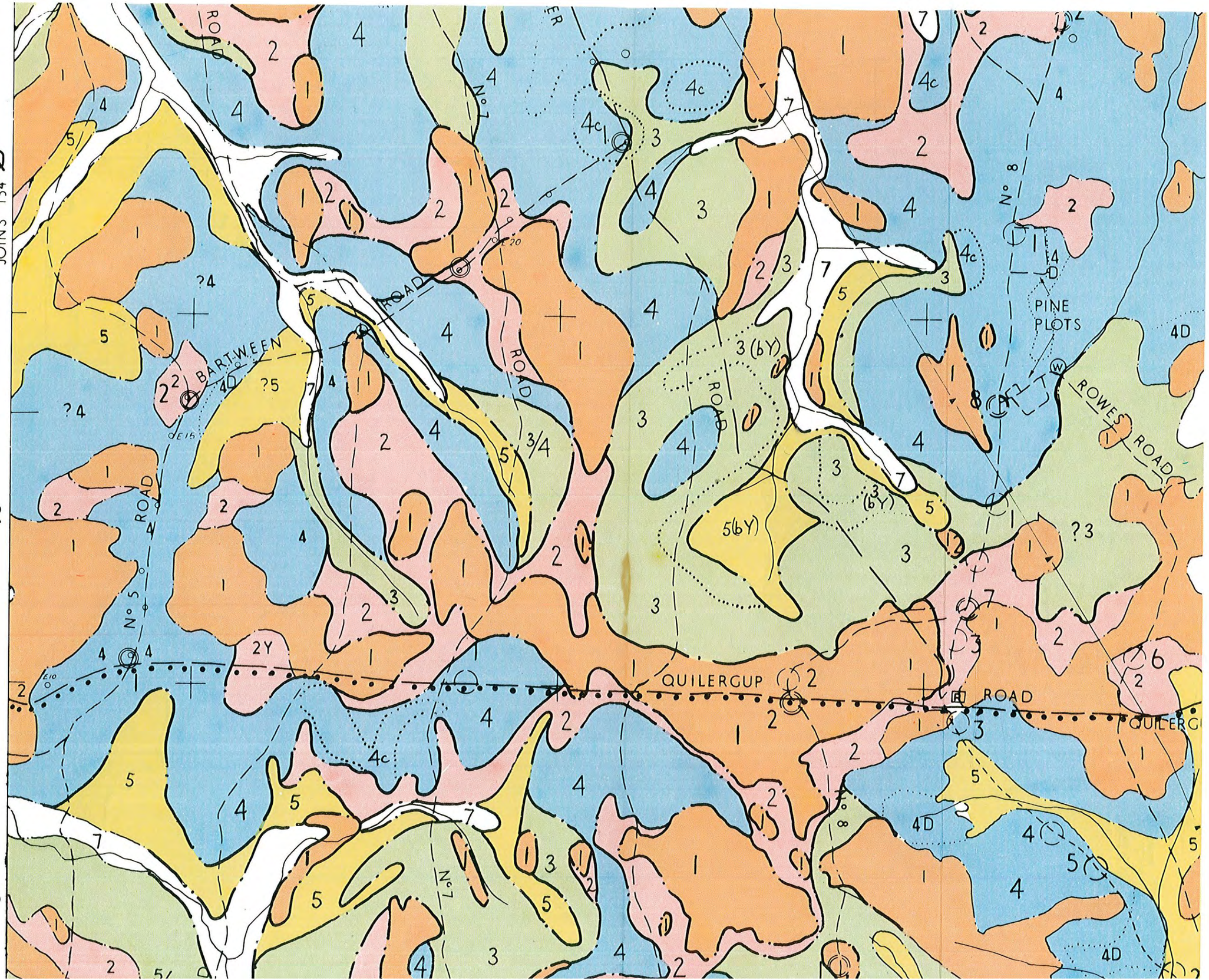
DONNELLY RIVER

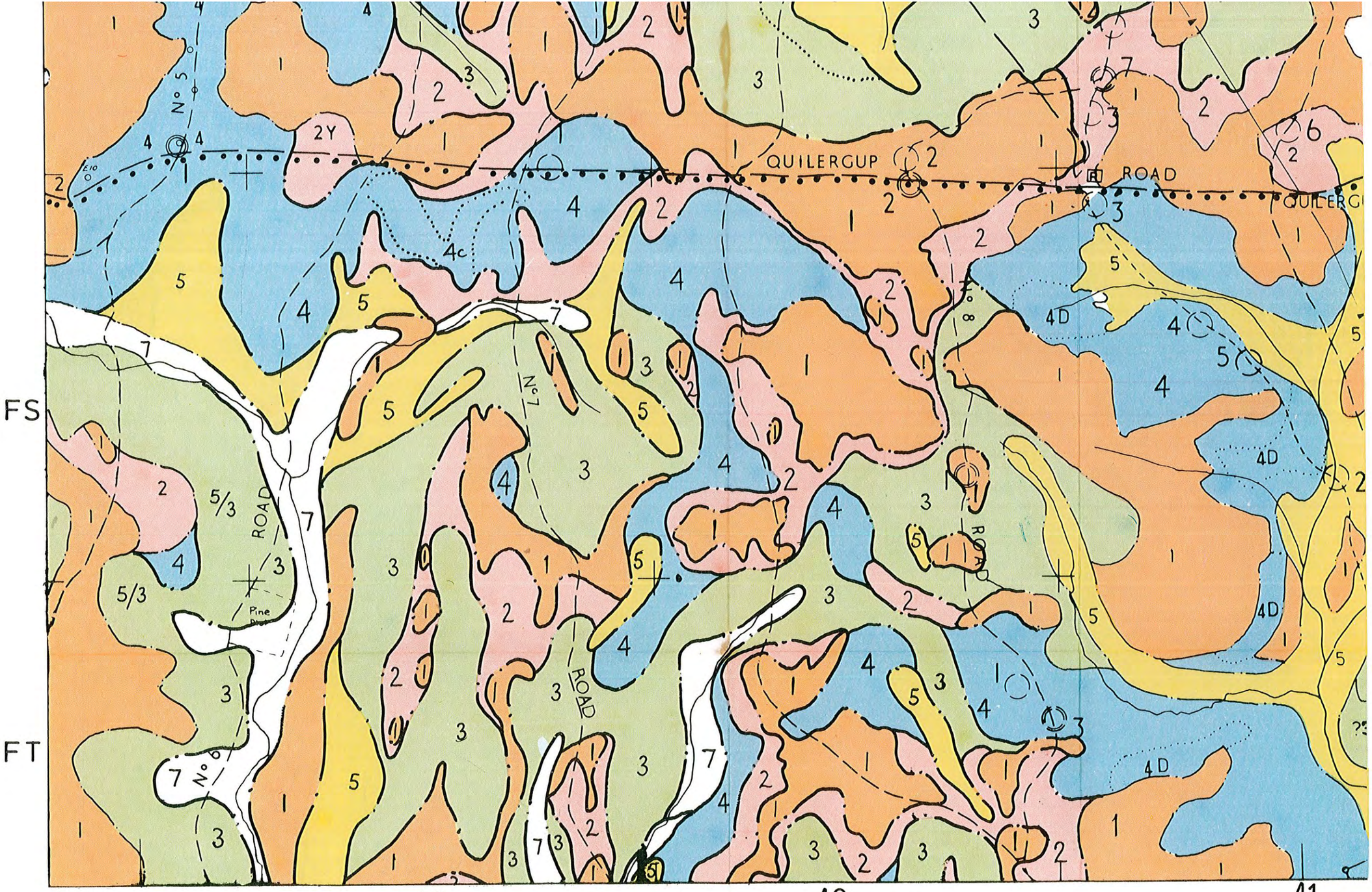
FQ

JOINS 154

FR

FS





COLOUR CODE	CODE NO	TYPE	COLOUR CODE	CODE NO	TYPE
	1	lateritic		4	light greyish brown sand >50cm
	2	sand over lateritic <50cm		5	yellow brown sandy loam
	3	yellow brown sand >50cm		7	alluvial soils

SCALE: 1:15840

20 10 0 10 20 30 40 50

SOIL PLAN [EXAMPLE]

Pt. 173/20

PLAN 5

PLANTABLE SOILS PLAN 6

FQ

FR

FS

JOINS 154

BARTWEEN ROAD

ROAD

ROAD

ROAD

N° 1

N° 5

N° 7

N° 8

PINE PLOTS

ROWES ROAD

QUILERGUP ROAD

QUILERG

FR

FS

FT

QUILERGUP

ROAD

QUILERG

38 39 40 41

LEGEND

Unplantable

Plantable

SCALE 1:15840

20 10 0 10 20 30 40 50

PLANTABLE SOILS PLAN [EXAMPLE]

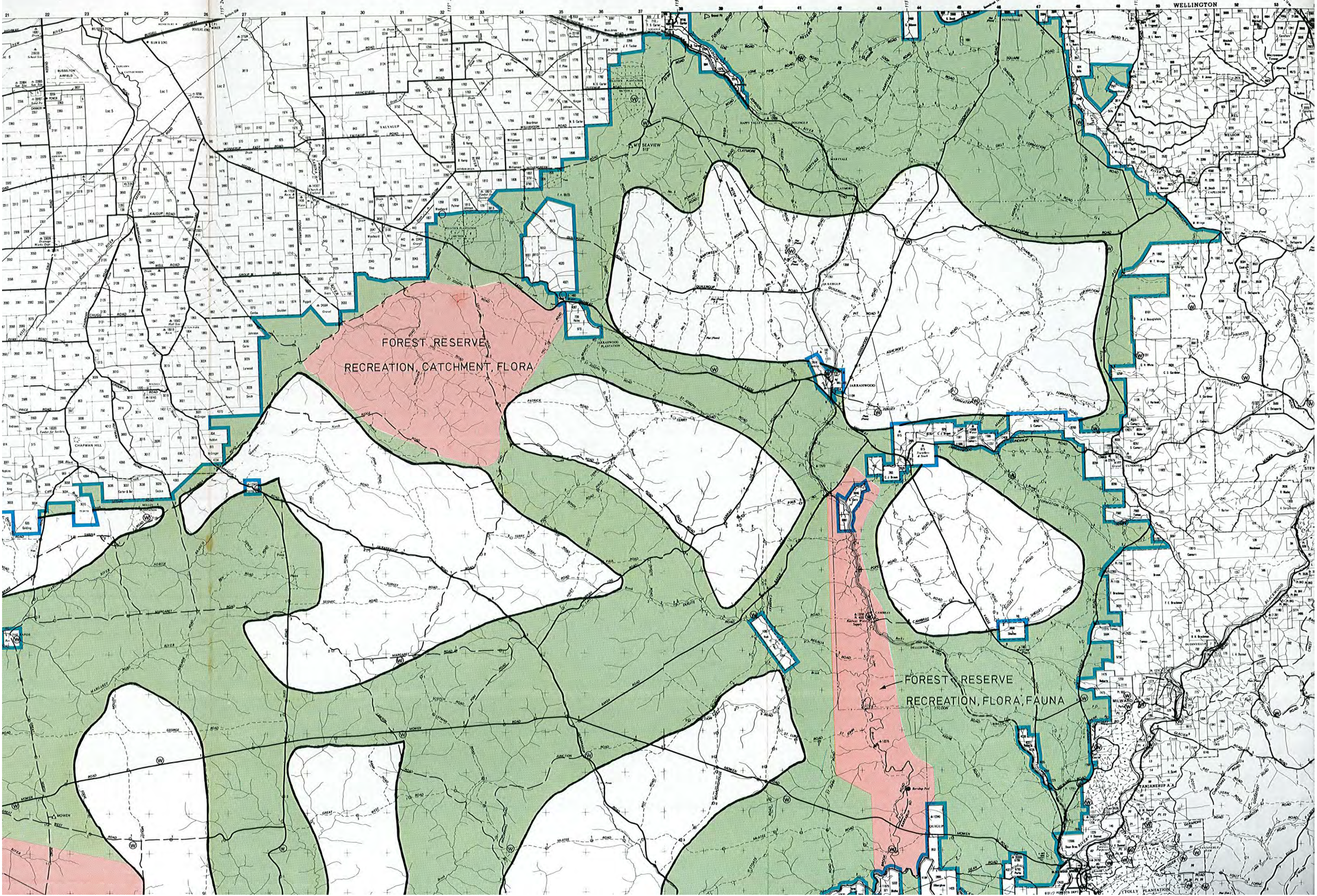
Pt. 173/20

PLAN 6

FOREST RESERVE

RECREATION, CATCHMENT, FLORA

DEVELOPMENT PLAN 7.



FOREST RESERVE

FOREST RESERVE

RECREATION

MILYEANNUP
BIOLOGICAL RESERVE

FOREST RESERVE
VIRGIN KARRI OUTLIER

FOREST RESERVE

FOREST RESERVE

RECREATION

MILYEANNUP
BIOLOGICAL RESERVE

FOREST RESERVE
VIRGIN KARRI OUTLIER

MILYEANNUP
BIOLOGICAL RESERVE

FOREST RESERVE
VIRGIN KARRI OUTLIER

SOUTHERN OCEAN

FLINDERS BAY

LEDGE POINT

SCOTT RIVER

WHITE POINT

NELSON

115° 06' 115° 12' 115° 18' 115° 24' 115° 30' 115° 36'

KEY TO SYMBOLS

Sealed Road		Forests Dept. Headquarters	■
1st Class Road		Sawmill	●
2nd Class Road		Lookout Tower	△
3rd Class Road		Survey Reference Tree Theodolite	⊙2
Railway W.A.G.R.		Survey Reference Tree Compass	○2
Telephone Line		Post Office	■PO
Powerline		Loading Ramp	
Block Boundary		Permanent Water Supply	◯
Land District Boundary		Permanent Water Supply Developed	(W)

1:126720

Kilometres 0 1 2 3 4 5 6 7

Miles 0 1 2 3 4 5

LEGEND

BOUNDARY OF STATE FOREST AND TIMBER ↟ (FOREST ACT)

PLANTATION CELLS (APPROXIMATE)

RESERVES

HARDWOOD FOREST

PREL

MILYEANNUP
BIOLOGICAL RESERVE

FOREST RESERVE
VIRGIN KARRI OUTLIER

OCEAN

1:126720

LEGEND

BOUNDARY OF STATE FOREST AND TIMBER ⋔ (FOREST ACT)

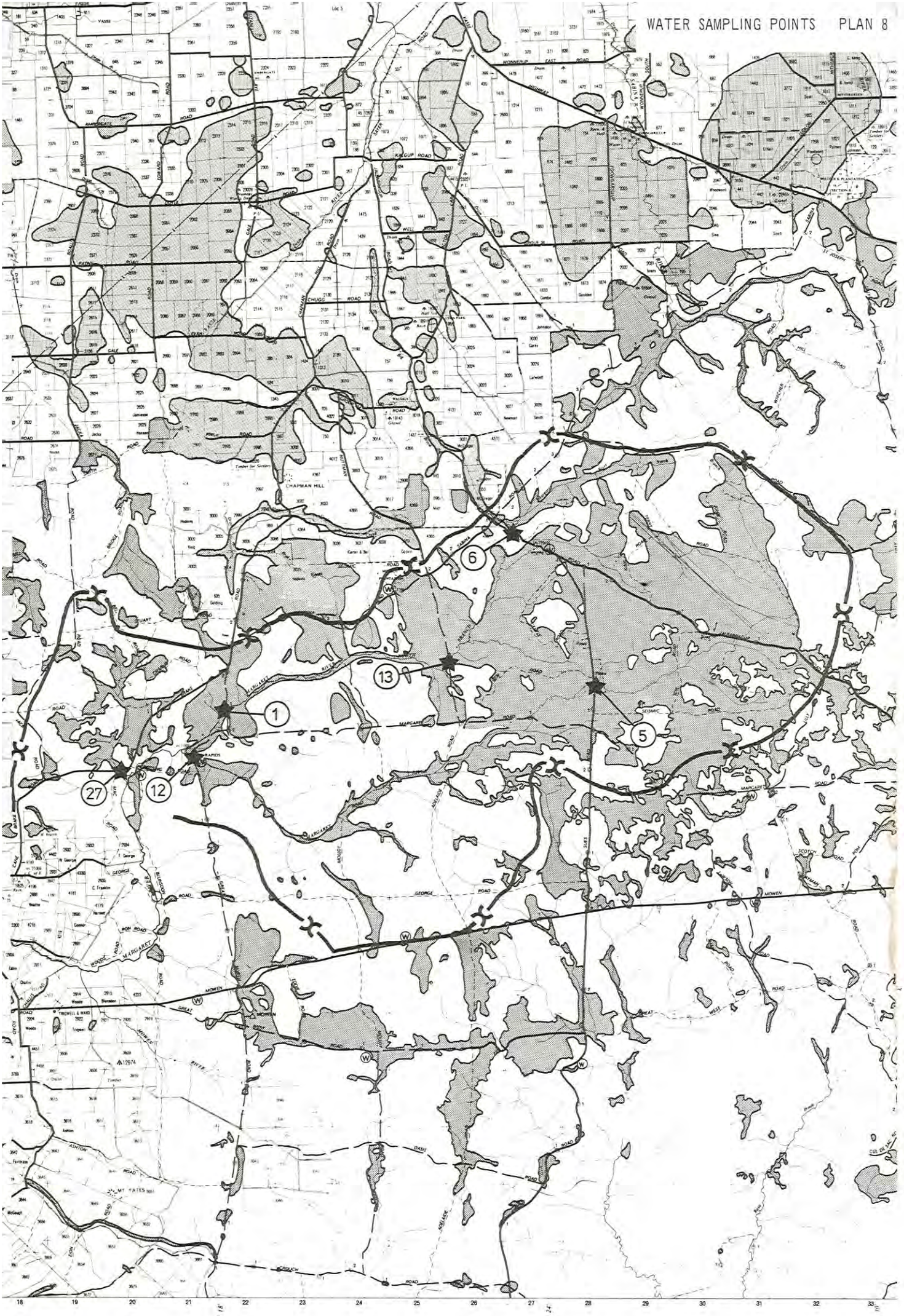
PLANTATION CELLS (APPROXIMATE)

RESERVES

HARDWOOD FOREST

PRELIMINARY BROADSCALE SUNKLAND DEVELOPMENT

PLAN 7.



CATCHMENT BOUNDARY

WATER SAMPLING POINTS

PROVEN AND SUSPECT DIEBACK INFECTIONS 1973

WATER SAMPLING POINTS MARGARET RIVER CATCHMENT

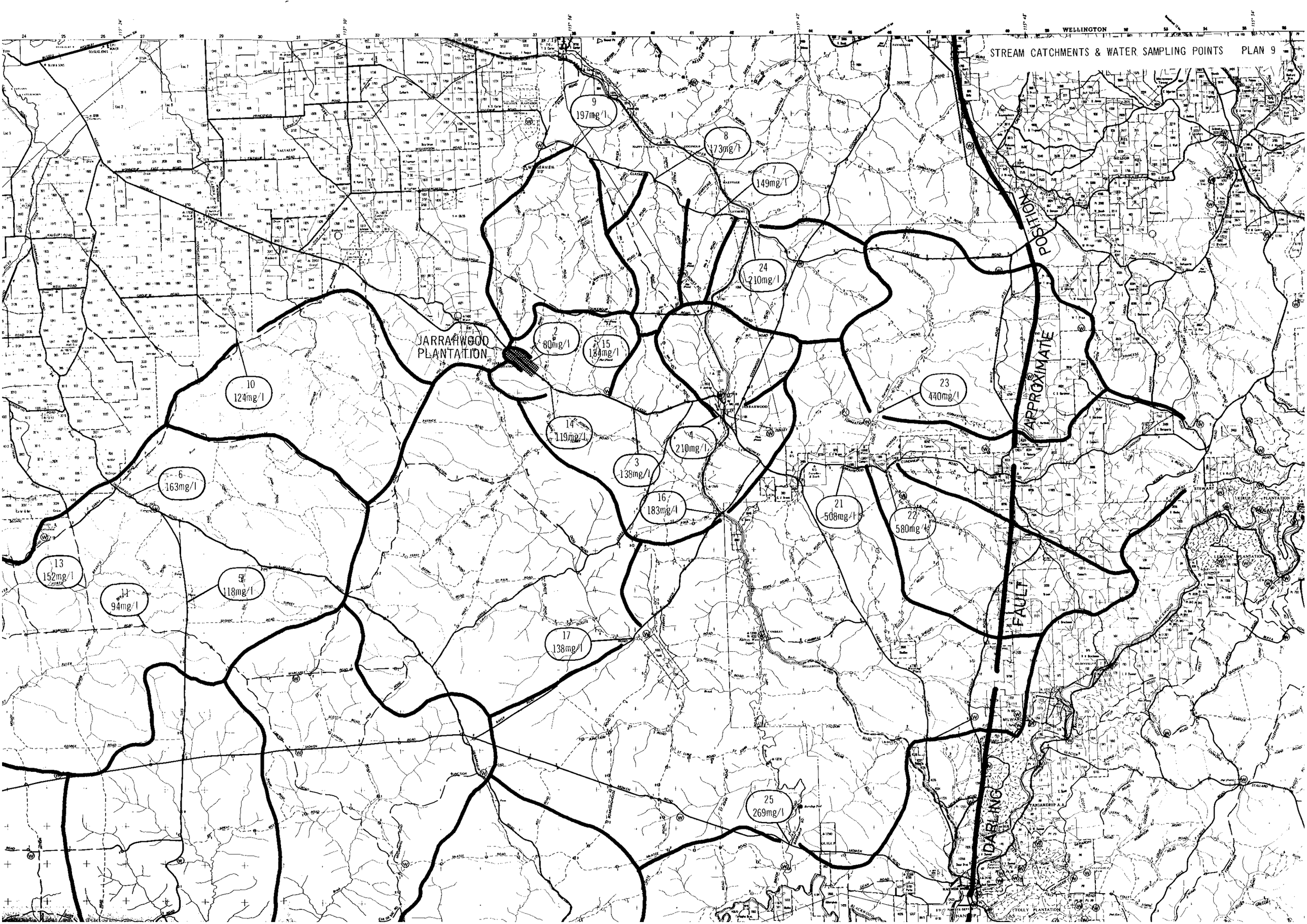
SCALE 1 : 126720

PLAN 8

JARRAHWOOD PLANTATION

1 166mg/l
2 80mg/l
3 138mg/l
4 210mg/l
5 118mg/l
6 163mg/l
7 149mg/l
8 173mg/l
9 197mg/l
10 124mg/l
11 94mg/l
12 145mg/l
13 152mg/l
14 119mg/l
15 184mg/l
16 183mg/l
17 138mg/l
21 508mg/l
22 580mg/l
23 440mg/l
24 210mg/l
25 269mg/l
26 137mg/l
27 127mg/l

STREAM CATCHMENTS & WATER SAMPLING POINTS PLAN 9



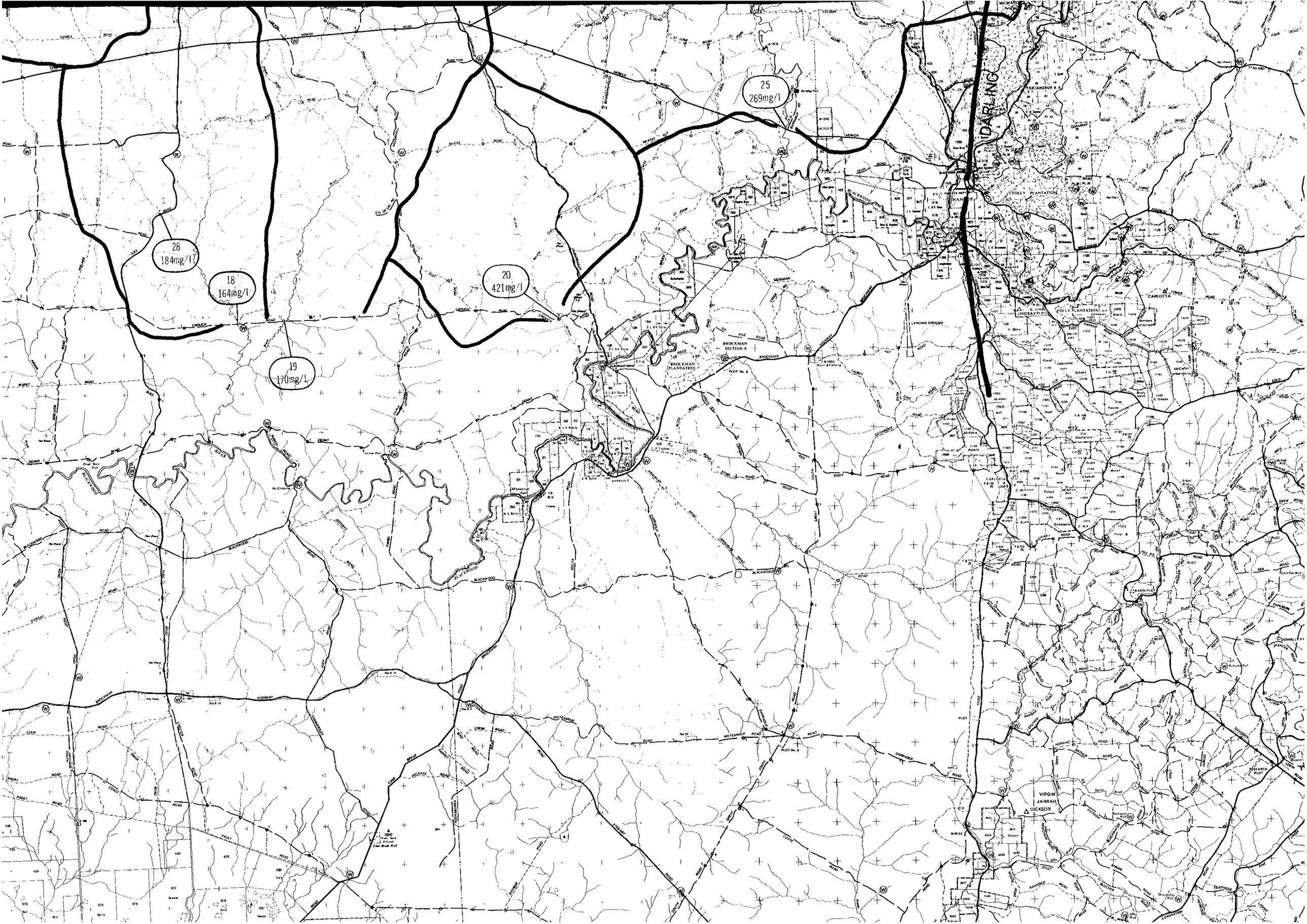
25
269mg/l

20
421mg/l

19
170mg/l

18
164mg/l

28
184mg/l


25
269mg/l
20
421mg/l
28
184mg/l
18
164mg/l
19
170mg/l
DARLING
BROCKMAN
SECTION A
BROCKMAN
PLANTATIONS
PLOT No 8
PLOT No 6
TOLLY PLANTATION
CARLOTTA
LANDING GROUND
VIRGIN
JARRAH
DICKSON
BLACKWOOD
BROCKMAN
HIGHWAY
MILYEANNUP
ROAD
STEWART
ROAD
GREAT
SOUTH
ROAD

SOUTHERN OCEAN

SCOTT RIVER

MOLLOY ISLAND

LEDGE POINT

WHITE POINT

NELSON

STREAM CATCHMENT BOUNDARIES

WATER SAMPLING POINTS

20
421mg/l

KEY TO SYMBOLS

- Sealed Road
- 1st Class Road
- 2nd Class Road
- 3rd Class Road
- Powerline
- Land and District Boundary
- Telephone Line
- Block Boundary
- Private Property

- Forests Dept. Headquarters
- Sawmill
- Lookout Tower
- Survey Reference Tree Theodolite
- Survey Reference Tree Compass
- Loading Ramp
- Permanent Water Supply
- Permanent Water Supply Developed

1:126 720

Kilometres

Miles

B. J. BEGGS
CONSERVATOR OF FORESTS
ALBANY SEPT 1973

OCEAN

WHITE POINT

NELSON

LAKE QUITOR

DONNELLY RIVER

VIRGIN JARRAH

DICKSON

STREAM CATCHMENTS & WATER SAMPLING POINTS

MEAN TOTAL SOLUBLE SALTS

PLAN 9

STREAM CATCHMENT BOUNDARIES

WATER SAMPLING POINTS

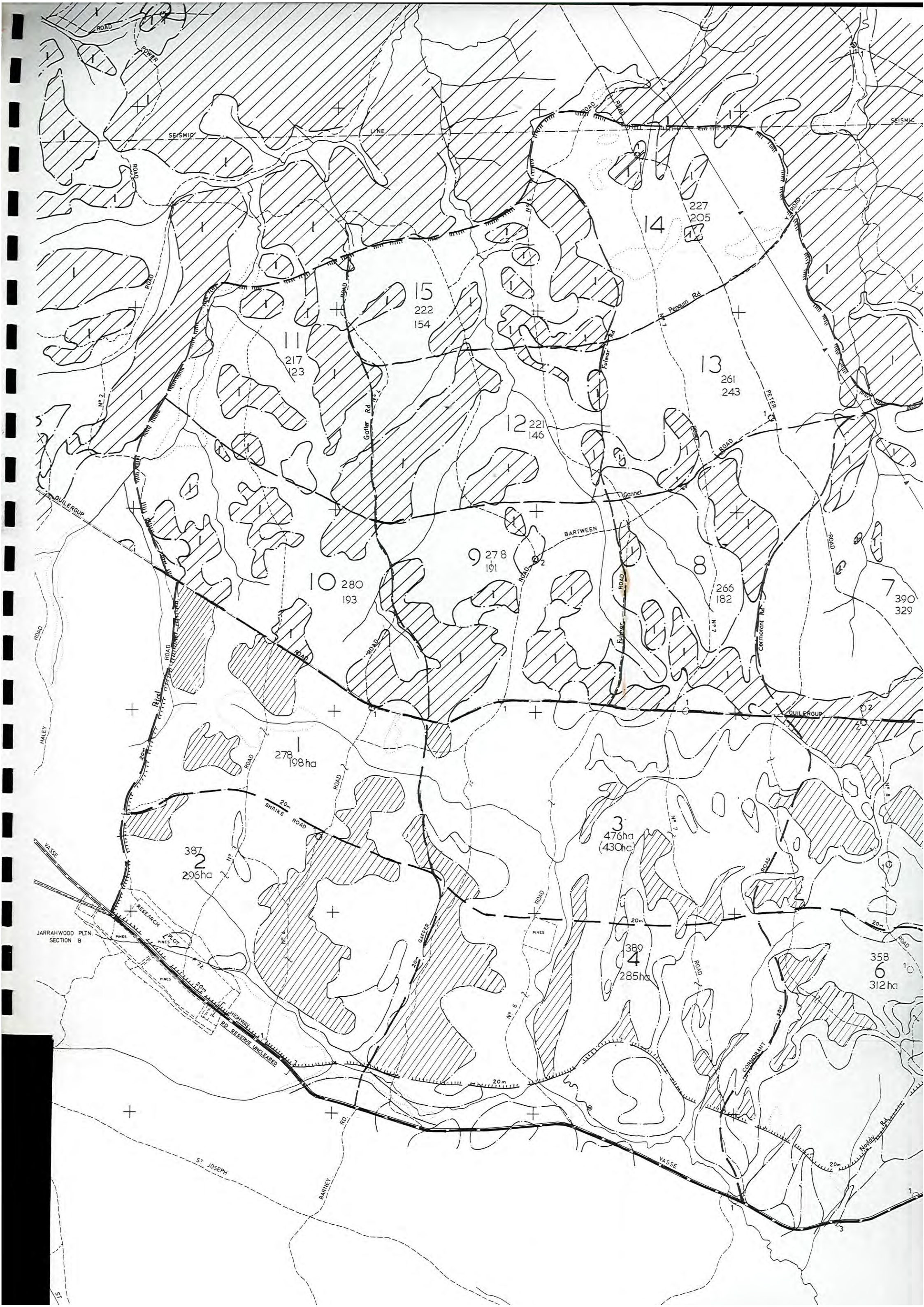
20
421mg/l

1:126 720

Kilometres

Miles

D. J. BEGGS
CONSERVATOR OF FORESTS
AUGUST 1971


SEISMIC LINE
ROAD
POWER
No 6
14
227
205
15
222
154
11
217
123
13
261
243
Penguin Rd
Fulmar Rd
PETER
12
221
146
Gannet
BARTWEEN
9
278
191
10
280
193
8
266
182
7
390
329
QUILERGUP
Petrel
HALEY
1
278
198ha
20m
SHRIKE
No 2
No 3
No 4
No 7
No 8
Gaffer Rd
Cormorant Rd
2
387
296ha
3
476ha
(430ha)
4
389
285ha
6
358
312ha
JARRAHWOOD PLTN
SECTION B
RESEARCH
PLOT
PINES
HIGHWAY
RD RESERVE UNCLEARED
ST JOSEPH
BARNEY
RD
VASSE
Noddy Rd
CORMORANT
GAFFER

MARYVALE

MARYVALE

SEISMIC LINE

ROAD

CLAYMORE

CLAYMORE

ROAD

ROAD

ROAD

ROAD

ROAD

Petrel Rd

ROAD

ROAD

ROAD

ROAD

GOODWOOD

CLAYMORE

STOCK

ROAD

ROAD

ROAD

ROAD

Albatross

PINES

ROWES

ROAD

W.A.G.A. 15 Hr

Gull Rd

17
479
356

18
293
222

7
390
329

16
335
294

DUILERGUP

DUILERGUP

ROAD

DUILERGUP

ROAD

GOODWOOD

19
54
43

382
5
253ha

20
359
322

PIT

ROAD

MILL

368
268
25

223
21
190

Shrike Rd

OLD

ASHCROFT

24
414
366

358
6
312ha

TIMBER
21611
1271

ROAD

Albatross

BROOK

1281

Noddy Rd

GOODWOOD

Noddy Rd

23
450
374

HIGHWAY

JARRAHWOOD

1179

184

VASSE

ROAD

BROOK

HALLEY


ROAD
MORLEY
ROAD
ROAD
MORLEY
CHARLIE
FORMATION
GOODWOOD
CLAYMORE
STOCK
ROAD
27
465
365
CHARLIE
29
341
280
534
422
28
338
285 Pt
19
548
433
Prion Rd
STOCK
ROAD
317
212
26
BRUSH
ROAD
LITTLE
FORMATION
28
196
136 Pt
BROOK
368
268
25
Shrike Rd
ASHCROFT
ROAD
HARRINGTON
Ironstone Rd
24
414
366
Ironstone Rd
Pelham Rd
BROOK
ROAD
FORMATION
STOCK
HALLEY
HALLEY

JARRAHWOOD PLANTATION
PLAN Nº 10

11 217 123

222 154

12 221 146

13 261 243

10 280 193

9 278 191

8 266 182

7 390 329

1 278 198ha

2 387 296ha

3 476ha (430ha)

4 389 285ha

6 358 312ha

QUILERGUP

BARTWEEN

Gannet

Penguin

Fulmar Rd

Gaffer Rd No 1

PETER

ROAD

Fulmar

Cormorant Rd

HALEY

Petrel

SHRIKE

VASSE

JARRAHWOOD PLTN. SECTION B

RESEARCH PLOT

PINES

HIGHWAY

RD RESERVE UNCLEARED

GAFFER

ST JOSEPH

BARNEY

ST PAUL

TERRY

Noddy Rd

LOG

No 1

No 2

No 3

No 4

No 6

No 7

No 8

20m

10m

SUBDIVISION LEGEND

MAJOR ACCESS ROAD

TRAFFICABLE ROAD ALL VEHICLES

TRACK

PLANTING BOUNDARY

NON TRAFFICABLE BREAK

WIDTH OF BREAK

PERMANENT WATER

POOR DRAINAGE BOUNDARY INTERNAL

UNCLEARED AREAS ENCLOSED BY TRACK

CREEKS BOUNDED BY TRACK MINIMUM OF 10m RESERVE

1st CLASS ROAD

2nd CLASS ROAD

3rd CLASS ROAD

UNMAINTAINED ROAD

LOADING RAMP

REFERENCE TREE - THEODOLITE

REFERENCE TREE - COMPASS


ROAD
Petrel Rd
17
479
356
18
293
222
7
390
329
16
335
294
19
548
433
20
359
322
382
5
253ha
21
223
190
25
368
268
358
6
312ha
24
414
366
23
450
374
22
223
Albatross
ROWES
ROAD
WAGR
Gull Rd
QUILERGUP
GOODWOOD
CLAYMORE
STOCK
PINES
No 9
No 8
8 Ha
PIT
MILL
OLD
Shrike Rd
ASHCROFT
Noddy Rd
Noddy R.
HIGHWAY
JARRAHWOOD
VASSE
BROOK
LOG
HALLEY
TIMBER
A 21611
1271
2654
1281
1179
1184
A 615
8235
3485
20m
TOTAL
SCALE 1:25000
500 0 1000 2000 Metres
20 10 0 20 40 60 80 100 Chains
1st CLASS ROAD
2nd CLASS ROAD
3rd CLASS ROAD
UNMAINTAINED ROAD
LOADING RAMP
REFERENCE TREE THEODOLITE
REFERENCE TREE COMPASS

TOTAL AREA OF COMPTS. : 12 188 ha
PLANTABLE AREA OF COMPTS. : 9315 ha

JARRAHWOOD PLANTATION
DETAILED SUBDIVISION PROPOSALS
(SAMPLE ONLY)

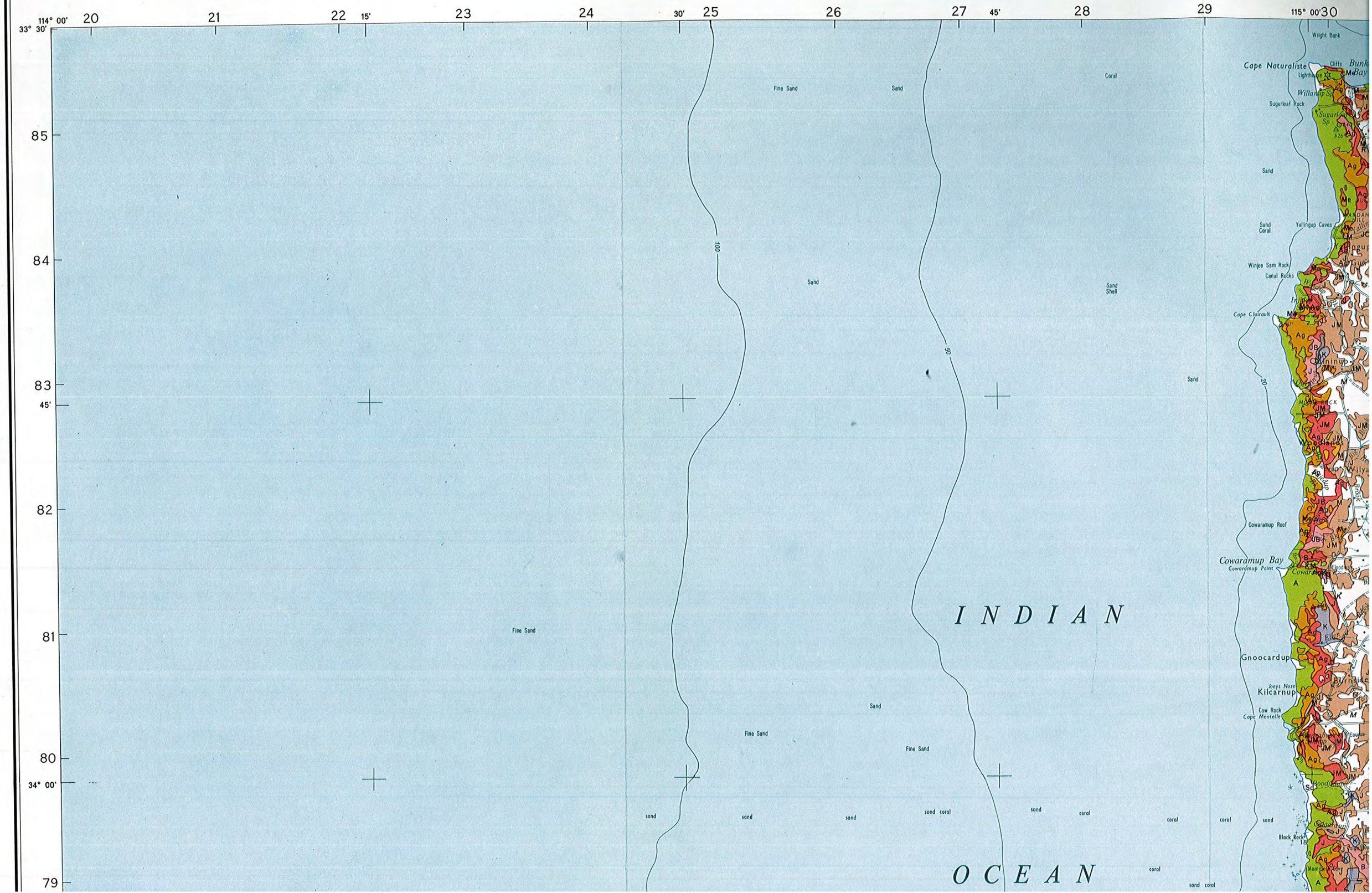
COMPTS. : 12 188 ha
E AREA OF COMPTS. : 9 315 ha

PLAN NO. 10

JARRAHWOOD PLANTATION
DETAILED SUBDIVISION PROPOSALS
(SAMPLE ONLY)

AUSTRALIA 1:250,000

BUSSELTON AND AUGUSTA

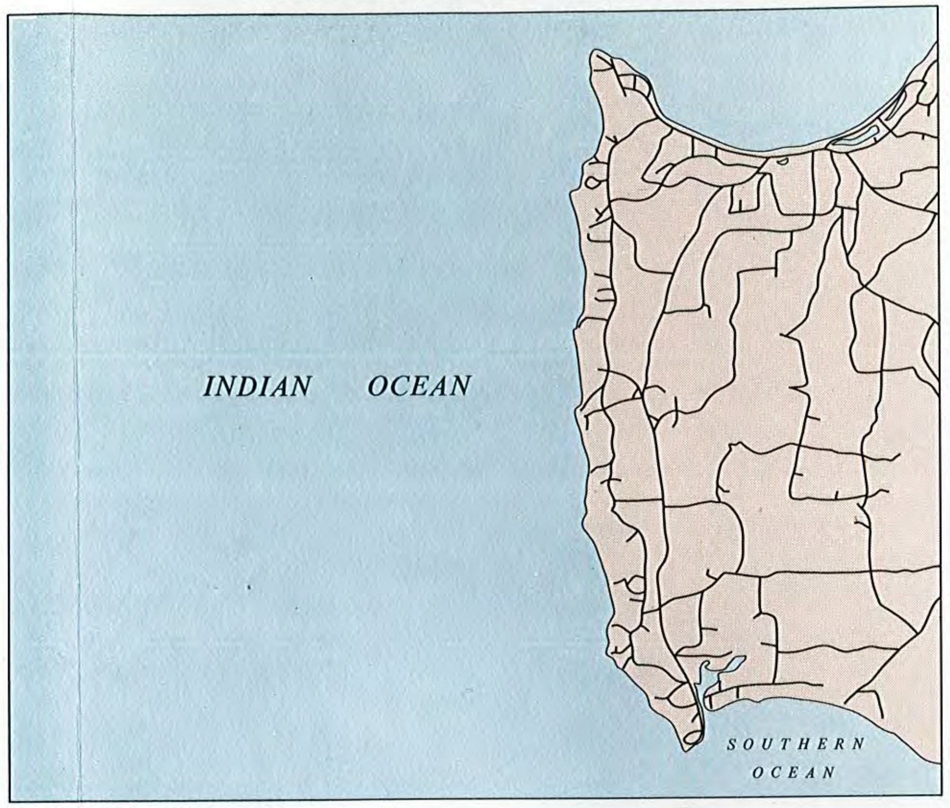


JGUSTA

REFER TO THIS MAP AS:

SI 50-9 & SI 50-5 VEGETATION

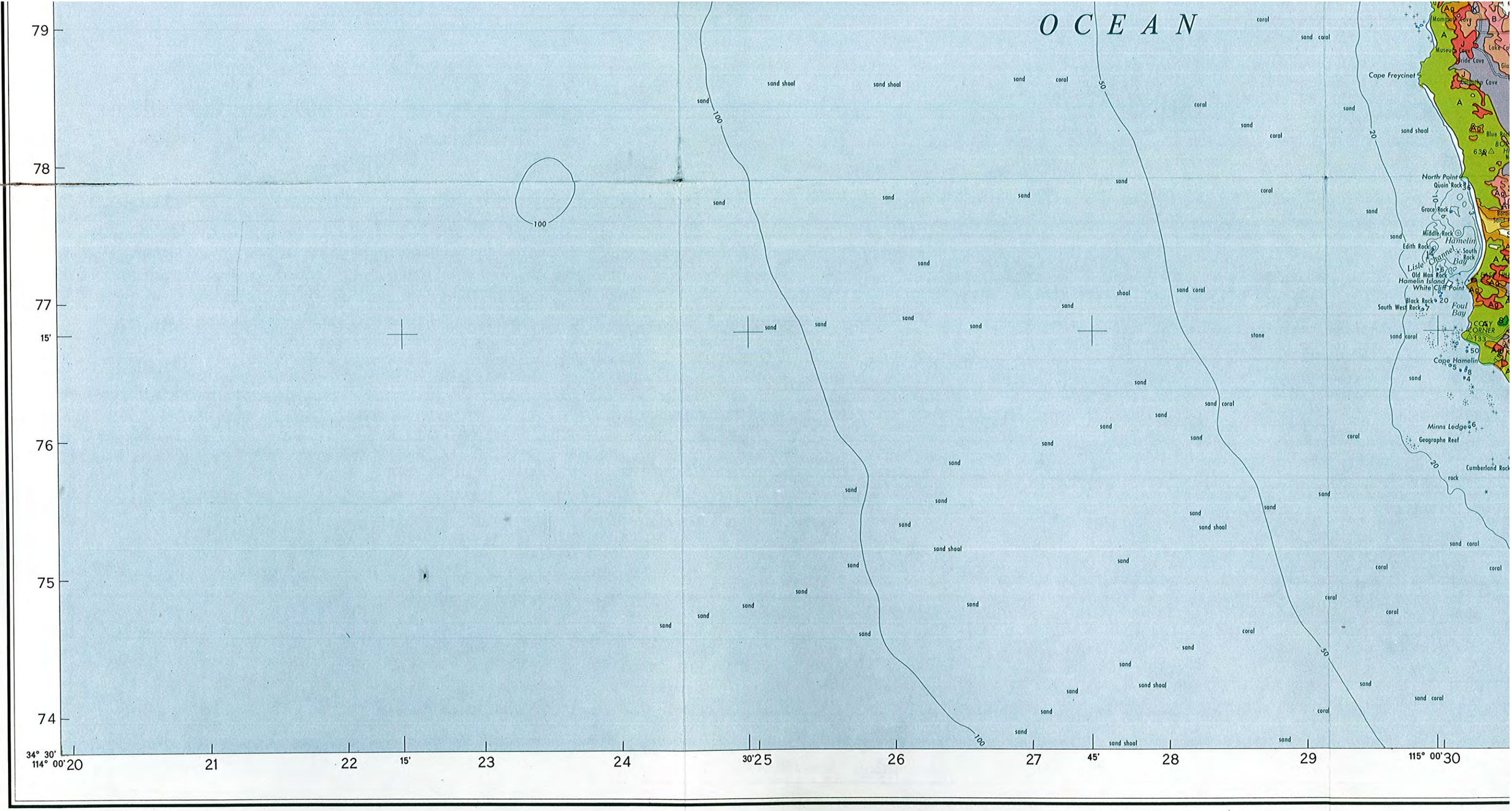
VEGETATION SURVEY TRAVERSES



LEGEND

VEGETATION STRUCTURE

LIFE FORM AND HEIGHT OF TALLEST STRATUM	FORMATION	PROJECTIVE FOLIAGE COVER OF TALLEST STRATUM, PER CENT
TREES (Above 30 metres)	High closed forest	70-100
	High open forest	30-70
	High woodland	10-30
	High open woodland	BELOW 10
TREES (10 to 30 metres)	Closed forest	70-100
	Open forest	30-70
	Woodland	10-30
	Open woodland	BELOW 10
TREES (Below 10 metres)	Low closed forest	70-100
	Low open forest	30-70
	Low woodland	10-30
	Low open woodland	BELOW 10
SHRUBS (Above 2 metres)	Closed scrub	70-100
	Open scrub	30-70
	High Shrubland	10-30
	High open shrubland	BELOW 10
SHRUBS (Below 2 metres)	Closed heath	70-100
	Open heath	30-70



Compiled by Dr. Francis G. Smith, in accordance with the requirements of the Western Australian Vegetation Survey Committee from aerial photography flown 1967, Forests Department Aerial Photo Interpretation plans, and field surveys carried out by the Author from June 1971 to August 1972.
Drawings prepared under the direction of the Surveyor General, Department of Lands and Surveys, Western Australia, on base maps made available by courtesy of the Director of Military Surveys, Department of the Army, Canberra, and printed by the Government Printer of Western Australia.

Scale 1:250,000

5 0 5 10 15 20 25 Statute Miles

5 0 5 10 15 20 Nautical Miles

10,000 0 10,000 20,000 30,000 Yards

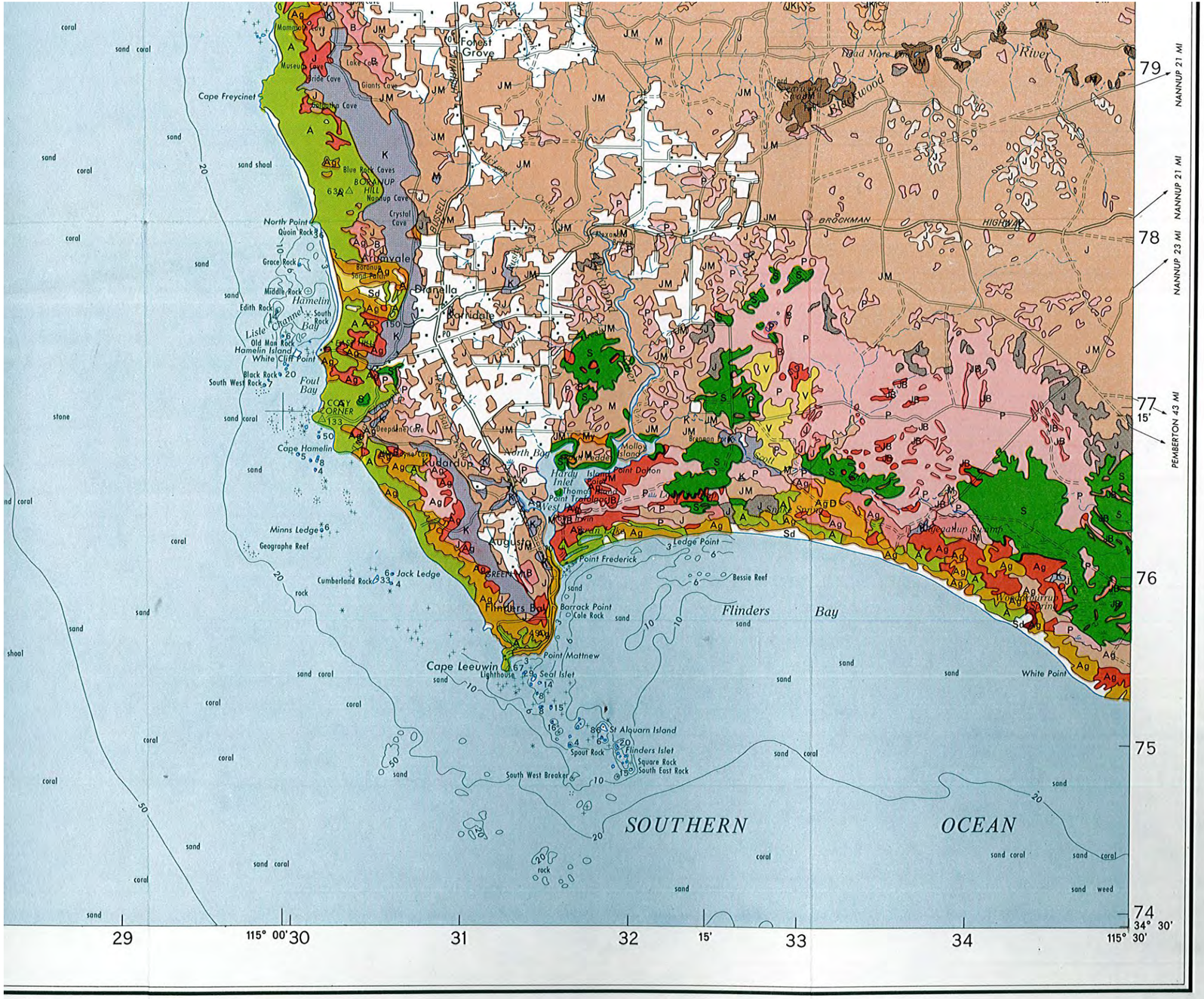
5 0 5 10 15 20 25 Kilometres

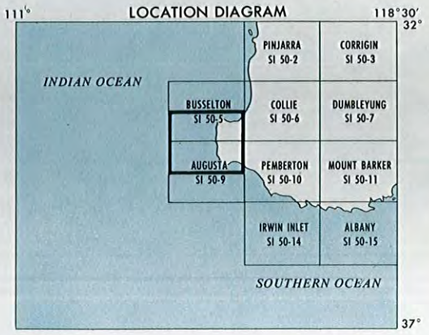
ELEVATIONS SHOWN IN FEET
VERTICAL DATUM IS BASED ON MEAN SEA LEVEL, FREMANTLE

TRANSVERSE MERCATOR PROJECTION
HORIZONTAL DATUM IS BASED ON PERTH OBSERVATORY, LATITUDE 31°57'09.63"S LONGITUDE 115°50'26.10"E

GRID NUMBERS INDICATE THE 10,000 YARD TRANSVERSE MERCATOR GRID, ZONE I (AUSTRALIA SERIES), CLARKE 1858 SPHEROID
THE LAST FOUR DIGITS OF THE GRID NUMBERS ARE OMITTED

1968 MAGNETIC DECLINATION FOR THIS SHEET VARIES FROM 5°30' WESTERLY FOR THE CENTRE OF THE WEST EDGE TO 4°30' WESTERLY FOR THE CENTRE OF THE EAST EDGE. MEAN ANNUAL CHANGE IS NEGLIGIBLE.





ITUDE 115°50′26.10″E

ISTRALIA SERIES), CLARKE 1858 SPHEROID

ENTRE OF THE WEST
E IS NEGLIGIBLE.

	Open heath	🟩
	Low shrubland	🟨
	Low open shrubland	🟨
HERBS	Closed herbland	🟩
	Herbland	🟩
	Open herbland	🟩
HUMMOCK GRASSES	Hummock Grassland	🟩
	Open Hummock Grassland	🟩
BARREN	Sand Dunes	Sd
CLEARED LAND		☐

PLANT ASSOCIATIONS

	Acacia decipiens	A
Peppermint	*Agonis flexuosa*	Ag
	Banksia species	B
	Casuarina fraserana	C
	Dryandra sessilis	D
	Eucalyptus haematoxylon	H
Jarrah	*E. marginata*	J
Karri	*E. diversicolor*	K
	Kingia australis	Ki
Marri	*E. calophylla*	M
	Melaleuca species	Me
Myrtaceae		My
	Olearia axillaris	O
Paperbark	*Melaleuca species*	P
Pine Plantations		Pi
Flooded Gum	*E. rudis*	R
Sedgeland		S
Samphire	*Arthrocnemum species*	Sa
Tuart	*E. gomphocephala*	T
	Viminaria juncea	V
Yate	*E. cornuta*	Y

Remnants of plant associations on cleared land are shown in Italics.

Waterhole; water tank; dam: dry lake
Lake; river or stream perennial
Lake; river or stream intermittent
Dam or weir; falls; rapids
Drain or ditch perennial, intermittent
Spring perennial, intermittent, ricefields
Marsh or swamp; mangroves

VEGETATION
BUSSELTON AND AUGUSTA
WESTERN AUSTRALIA

VEGETATION SURVEY OF WESTERN AUSTRALIA

VEGETATION MAP

BUSSELTON SI 50 - 5

AUGUSTA SI 50 - 9

1973

WESTERN AUSTRALIAN DEPARTMENT OF AGRICULTURE

VEGETATION MAP OF BUSSELTON and AUGUSTA

Latitude 33°30′ to 34°30′

Longitude 114°00′ to 115°30′

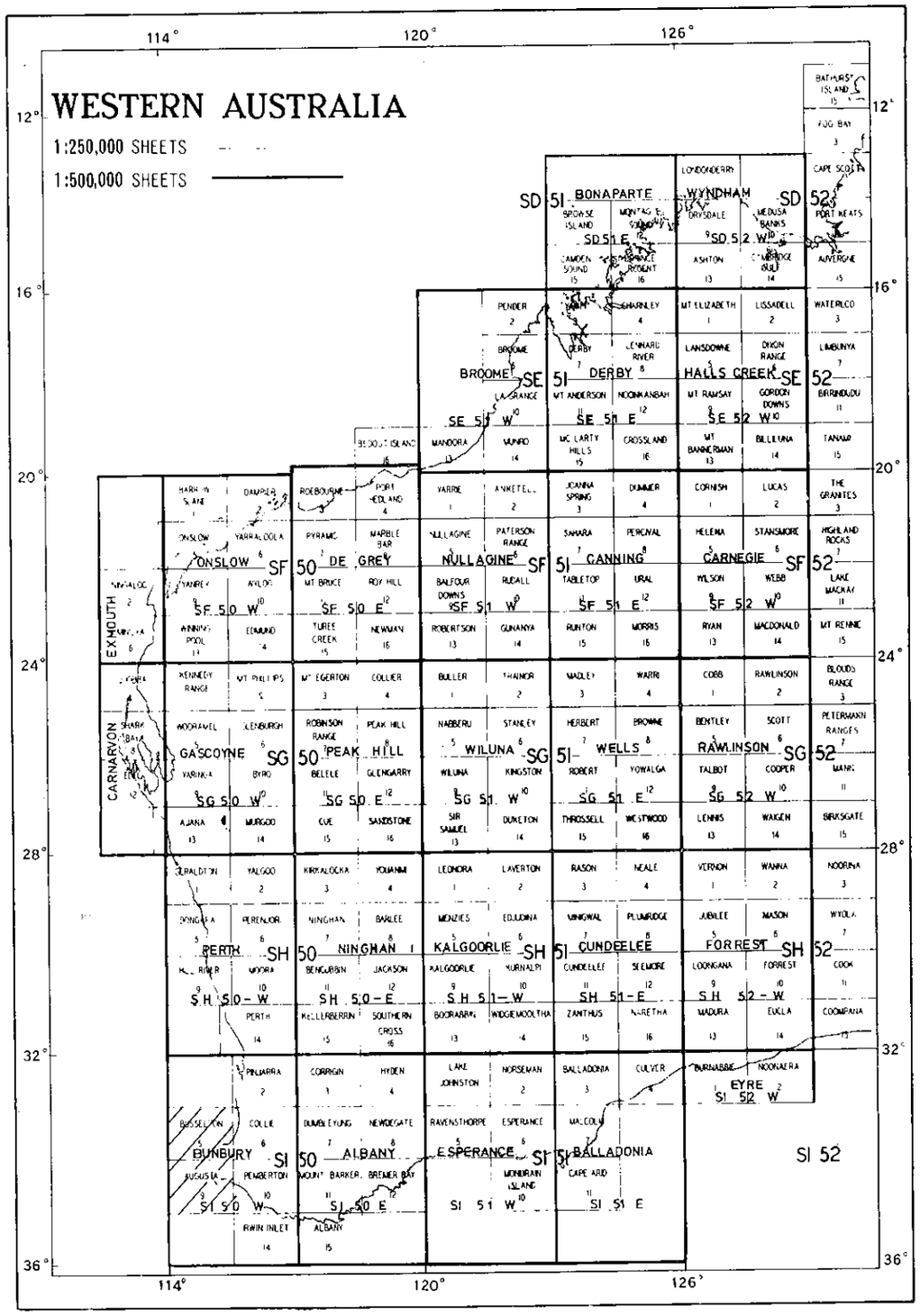
Scale 1:250,000

by

Francis G. Smith, D.Sc., B.Sc.(Forestry)

1973

WESTERN AUSTRALIAN DEPARTMENT OF AGRICULTURE


WESTERN AUSTRALIA
1:250,000 SHEETS
1:500,000 SHEETS
114°
120°
126°
12°
16°
20°
24°
28°
32°
36°
SD 51 BONAPARTE
SD 52
BROOME SE 51
DERBY
HALLS CREEK SE 52
ONSLOW SF 50
DE GREY
NULLAGINE SF 51
CANNING
CARNEGIE SF 52
GASCOYNE SG 50
PEAK HILL
WILUNA SG 51
WELLS
RAWLINSON SG 52
PERTH SH 50
NINGHAN
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COMPILATION AND CLASSIFICATION

The Vegetation Map of the Busselton-Augusta area has been compiled and drawn by the author in accordance with the requirements of the Western Australian Vegetation Survey Committee. Sources of information were 1967 aerial photographs at a scale of 1:40,000 and the Forests Department's A.P.I. Plans which provided some additional information on vegetation structure and principal trees occurring in forested areas.

Traverses by motor vehicle and on foot were made during the period June 1971 to August 1972 covering the routes illustrated on the border of the vegetation map.

Plant material was identified in the field by the author or, in the case of unfamiliar material, was named at the Western Australian Herbarium.

Photographs illustrating this text were taken and processed by the author.

Vegetation has been mapped on the basis of structural criteria of the tallest stratum. Structural formations are indicated by colours. Subdivisions of these formations are on the basis of plant associations which are indicated by means of symbols.

Criteria used in the structural classification are life-form, height and density. There are three height classes for trees—over 30 m, 10 to 30 m, and under 10 m. There are two height classes for shrubs—over 2 m, and up

Standard descriptions used for each structural class

Life-form and height of tallest stratum	Projective foliage cover of tallest stratum, per cent	Description	Reference code
Trees over 30 m	70–100	High closed forest	A1
	30–70	High open forest	A2
	10–30	High woodland	A3
	under 10	High open woodland	A4
Trees 10–30 m	70–100	Closed forest	B1
	30–70	Open forest	B2
	10–30	Woodland	B3
	under 10	Open woodland	B4
Trees under 10 m	70–100	Low closed forest	C1
	30–70	Low open forest	C2
	10–30	Low woodland	C3
	under 10	Low open woodland	C4
Shrubs over 2 m	70–100	Closed scrub	D1
	30—70	Open scrub	D2
	10–30	High shrubland	D3
	under 10	High open shrubland	D4
Shrubs up to 2 m	70–100	Closed heath	E1
	30–70	Open heath	E2
	10–30	Low shrubland	E3
	under 10	Low open shrubland	E4
Herbs	70–100	Closed herbland, grassland, sedgeland, etc.	F1
	30–70	Herbland, grassland, sedgeland, etc.	F2
	10–30	Open herbland, grassland, sedgeland, etc.	F3

to 2 m. Herbs, which include grasses, sedges and hummock grasses, form the other life-form class.

There are four density classes based on projective foliage cover. Crown area cover is not used because it does not allow for the difference in the amount of light passing through the canopy of forests of similar crown cover but vastly different foliage cover. Because the amount of light passing through the main or top canopy has a big influence on the structure of the understorey, the use of projective foliage cover should give a better basis of comparison of plant formations.

Life-form—height classes are indicated by different colours: tall trees—purple; medium trees—brown; small trees—red; tall shrubs—orange; small shrubs—yellow; and herbs—green. Density of cover is indicated by different shades of colour; the darkest for the most dense and the lightest for the most open.

TOPOGRAPHY

A substantial part of the Busselton-Augusta area consists of a low, undulating plateau at one time extensively capped by laterite. This plateau extends westwards from the foot of the Darling-Nannup escarpment and is dissected by the westward flowing rivers Blackwood and Margaret. The altitude of most of the plateau is between 100 m and 140 m rising to 180 m in the northwest. It slopes downward from east to west and from north to south. On the plateau, the two branches of Margaret River form flood plains, and some large swamps occur above the headwaters of one of its tributaries, Mowen River. A feature of this plateau is that adjacent to some of the deeper river valleys, the convex hills slopes are covered with clayey loam. Lateritic outcrops and gravels may occur on the higher slopes above the clay areas.

The western part of this plateau is deeply dissected by Margaret River as it continues its westward course, by Carbunup River flowing northwards, and by Chapman and Upper Chapman Brooks flowing southwards to join the Blackwood, which itself turns south to flow into the Hardy Inlet, and thence to Flinders Bay.

Along the west coast, between Cape Naturaliste in the north and Cape Leeuwin in the south, stands a high steep-sided ridge of granitic gneiss, secondary limestone (aeolionite) and sand dunes, rising to over 200 m in parts. Margaret River penetrates through the centre of this ridge to the sea. A series of brooks cuts through the ridge draining the western end of the plateau. The southern third of the ridge, which includes the massive Boranup Hill, 193 m high, is penetrated only by Turner Brook which flows through a spectacular limestone gorge at Deepdene.

To the north of the pateau, and eastwards from Dunsborough, a broad coastal plain slopes down gently from 60 m at the foot of the plateau to a narrow belt of estuaries and marshes behind the low coastal sand dunes bordering Geographe Bay. This plain is drained by a series of north-flowing rivers which have their headwaters in the northern edge of the plateau. The principal rivers are the Ludlow, Abba, Sabina and Vasse which flow into lakes forming the Wonnerup and Vasse Estuary, and the Buayanup, Carbunup and Mary Brook which flow into Broadwater Lake to the west of Busselton. A few small brooks drain eastwards into Geographe Bay from Naturaliste Downs, which forms the northern end of the west coast ridge and rises to a height of 220 m. The coastal plain contains large areas of land once subject to periodic flooding but a series of drains have been cut to supplement the rivers in draining those areas and Broadwater Lake.

To the south, the plateau falls gently to another coastal plain which has a substantial range of sand dunes between it and the Southern Ocean. The plain consists of peaty sand and is characterised by the presence of low sand ridges and hillocks of lateritic gravel. In the plain there are areas of ironstone covered only by a thin layer of sandy soil. The coastal dunes prevent free drainage into the ocean and give rise to large areas of swamp, the waters of which are collected by the Scott River which flows westwards to empty into the estuary of the Blackwood River.

Mean annual rainfall ranges from about 800 mm in the north-eastern corner of the sheet to 1400 mm on the higher part of the plateau south of the Margaret River and on the southern part of the west coast at Deepdene. Most of this rainfall occurs in winter, but in the south as much as 300 mm occurs in summer.

VEGETATION SYSTEMS

In the region covered by the Busselton-Augusta sheet, five separate series or systems of plant associations can be recognised. The plant associations within a series or system form a sequence or pattern linked to topographic or edaphic factors. I have given to the vegetation systems the names which have been applied to the corresponding soil combinations or systems. The Chapman, Boranup and Scott River vegetation systems have the same boundaries as the soil combinations of the same name described by R. Smith (1951). The Pinjarra Plain and Spearwood vegetation systems cover the areas of soil systems of the same names described by McArthur and Bettenay (1960).

I have not designated their Quindalup Dune Soil System as a separate vegetation system because, in the area covered by this map, the vegetation is not characteristic of that system as described by those authors, but being dominated by Peppermint *Agonis flexuosa* (Spreng.) Schau., has an affinity with the Spearwood system and may be regarded as a part of the Boranup system.

Chapman system

Most of the region, in particular the lateritic plateau, is covered with Jarrah open forest (B2). The best development of purely Jarrah *Eucalyptus marginata* Sm. open forest occurs on the lateritic gravels of the hills, but in the valleys and richer sandy soils, Marri *E. calophylla* R. Br. becomes an important component giving rise to closed forest (B1) on the most favourable sites, particularly along the Blackwood river. In the valleys of the lower Blackwood, lower Margaret, and near the west coast, Peppermint *Agonis flexuosa* (Spreng.) Schau. becomes a component of the top canopy. In the deep valleys near Margaret River, there are limited areas of high open forest (A) of Jarrah and Marri and occasionally of Karri *E. diversicolor* F. Muell.

The broad valleys of the upper reaches of the Margaret River and the swamps of the higher parts of the plateau support sedgeland (F1). Also on the plateau are large areas of clayey loam in which the Jarrah forest degenerates into open woodland (B4) or even high open shrubland (D4) characterised by the presence of *Kingia australis* R. Br. On the grey earths in the broader western valleys of the plateau, Marri becomes the more frequent component of the open forest.

On high ground near the northern edge of the plateau on sandy lateritic gravels, the Jarrah becomes sparse, forming woodland (B3) with an understorey of small trees, Mountain Marri *E. haematoxylon* Maiden. In some localities, Jarrah is more or less absent, and the Mountain Marri with *Banksia* spp. form low woodland (C3).

Boranup system

The Naturaliste-Leeuwin ridge, presenting great variation in exposure to the prevailing winds, rising from sea level to over 200 m and then dropping steeply on the eastern side to less than 100 m, and being composed of granitic rocks, limestone and sand, has a rapidly changing and complex vegetation system. On the exposed western slopes, the vegetation is open heath (E2) which in areas of better development, or less frequent fires, and also where the limestone is near the surface, becomes open scrub (D2) or even closed scrub (D1) as between Yallingup and Cape Clairault, north of Cowaramup Bay and north of Cape Mentelle. With decrease in exposure, Jarrah, Peppermint and Banksia low open forest (C2) or Banksia or Peppermint low woodland (C3) or low open woodland (C4) occur. With further decreases in exposure the Jarrah becomes taller developing into open forest (B2). In the lee of the high ground, particularly in the south and more rarely in the northern part of the ridge, Karri high open forest (A2) occurs. Where the escarpment is particularly steep, as to the east of Boranup Hill, the change from open heath (E2) to Karri high open forest (A2) is abrupt, without intervening zones of low woodland or open forest. Stands of Karri high open forest are also associated with limestone caves and deep hollows at the foot of the escarpment. At the northern end of the escarpment, in the lee of the Naturaliste Downs, Yate *E. cornuta* Labill. open forest (B2) occurs on the richer brown soils and in valleys is accompanied by Marri, Flooded Gum *E. rudis* Endl. and Peppermint.

Extending along the shores of Flinders Bay the Boranup System covers extensive sand dunes up to 4 km wide. On the seaward side the dunes are covered with open heath (E2) and open scrub (D2). Further inland there is Peppermint low open forest (C2), Peppermint low woodland (C3) and Jarrah open forest (B2). In the lee of a sand blowout near White Point there is a small area of Peppermint low closed forest (C1). On some undulating sand dune country, tall shrubland (D3) occurs, composed of Banksias, Parrot Bush *Dryandra sessilis* (Knight) Domin. and Peppermint.

Pinjarra Plain system

The northern coastal plain was formerly covered with Marri open forest (B2), now mostly cleared, with some Jarrah in higher areas where lateritic gravel is present. With

the Marri near rivers, Forest Blackbutt *E. patens* Benth, occurs, while along the rivers Flooded Gum is also found with Paperbark *Melaleuca rhaphiophylla* Schau. and Peppermint; the latter occurring particularly closer to the coast.

There are very extensive areas of land with impeded drainage, formerly covered with Paperbark low woodland (C3) and in some places, low open woodland (C4) with a few Christmas Trees *Nuytsia floribunda* (Labill.) R. Br. ex Fenzl. and *Kingia*. On more sandy sites, low open forest (C2) of *Banksia* spp. with Christmas Trees and some *Melaleuca* occur as extensions of the Bassendean system.

Spearwood system

Between the north coastal plain and the sea, coastal sand dunes and low limestone ridges give rise to another vegetation system. Extending north-westwards from the region of the Sabina River Tuart *E. gomphocephala* DC. high woodland (A3), with a small patch of high open forest, occurs on sandy soil overlying a low limestone ridge. In the region of the Sabina River, the Tuart tails off westerly into what are now merely remnants of Yate open forest (B2). Peppermint forms the main understorey of the Tuart high woodland, occurring also on the coastal dunes as low open forest (C2) and extending westwards from Busselton along the coast to Dunsborough as open forest (B2). Between the Tuart high woodland and the Peppermint low open forest of the sand dunes there are expanses of flats bordering the Vasse and Wonnerup Estuaries, covered with low succulent salt tolerant Samphire shrubs *Arthrocnemum* spp. forming open heath (E2).

In the swamps between and behind the dunes, myrtaceous closed scrub (D1), open scrub (D2) or Paperbark low open forest (C2) occur. Along the inland edge of the Tuart high open woodland, are narrow belts of Jarrah open forest (B2), Banksia low open forest (C2), and Paperbark low open woodland (C4) in the wet areas, with occasional stands of Paperbark low closed forest (C1).

Scott River system

South of the Chapman system occur extensive areas of low open woodland (C4) on acid peaty sand. The small trees are Paperbarks, Jarrah and Banksias, the understorey being composed of small shrubs and sedges. The wetter areas are mainly sedgeland (F1). Arising above the low open woodland and sedgeland flats, small lateritic hillocks have Jarrah low open forest (C2) and sandy ridges have Banksia low woodland (C3). At and to the north of the Scott River, there are areas of low shrubland (E3) over ironstone.

Along the Scott River there are some occurrences of Karri high open forest (A2) and Jarrah-Marri open forest (B2).

FORMATIONS AND PLANT ASSOCIATIONS

A2 HIGH OPEN FOREST

Karri Forest (K)

High open forest dominated by Karri *Eucalyptus diversicolor* F. Muell. occurs mainly on the eastern escarpment of the Naturaliste-Leeuwin ridge, particularly between Calgardup Brook and Flinders Bay. There is an outlying stand north of the Margaret River at Ellen Brook and another, the most northerly, above Quininup Brook. Elsewhere, Karri forest occurs in valleys near Karridale, up Boojidup Brook, in the vicinity of the town of Margaret River and up Scott River. Karri grows on light soils, deep brown sands, derived from granite and gneiss, mostly on hillsides and along valleys. It may be associated with aeolianite outcrops, caves and sink holes. Mean annual rainfall is over 1,000 mm and summer rainfall usually exceeds 300 mm, and the sites are sheltered from prevailing westerly winds.

Karri grows to 80 m tall with 45 m of clean trunk and a wide, spreading and somewhat open crown. In Arumvale forest there are extensive areas of evenly aged Karri with close grown tall straight stems and closely packed crowns. More isolated stands of Karri, in small valleys at the foot of the escarpment and on the slopes above Quininup Brook, are shorter stemmed with heavy branches and wide crowns. Where Karri occurs, it is in pure stands, intermingling with Jarrah *E. marginata* Sm. and Marri *E. calophylla* R. Br. only at the edges of stands. Both these species, either separately or together, form high open forest in small areas along rivers, particularly near Margaret River.

In more open parts of virgin Karri forest understorey trees occur, particularly *Banksia grandis* Willd., *Casuarina decussata* Benth., *Agonis flexuosa* (Spreng.) Schau., *Agonis juniperina* Schau., and *Banksia littoralis* R. Br. The two *Agonis* species and *B. littoralis* occur mainly in the bottoms of valleys. Shrubs may form a closed understorey up to 5 m high. Common species are *Acacia pentadenia* Lindl., *Bossiaea laidlawiana* Tovey & Morris, *Chorilaena quercifolia* Endl., *Hibbertia tetrandra* (Lindl.) Gilg., *Hovea elliptica* (Sm.) DS., and *Trymalium spathulatum* (Labill.) Ostf. Where the scrub has been reduced by periodic burning, Bracken *Pteridium esculentum* (Forst. f.) Nakai thrives in its place. *Albizia lophantha* (Willd.) Benth. and *Templetonia retusa* R. Br. occur at Dianella.

A3 HIGH WOODLAND

Tuart Forest (T)

High woodland (A3) dominated by Tuart *Eucalyptus gomphocephala* DC., starts in the area of Sabina River east of Busselton and extends in an almost continuous narrow belt on limestone formations of the coastal plain, northwest and then northwards. In the Sabina and Ludlow River areas Tuarts grow to 40 m in almost pure stands. Formerly, massive Tuarts, up to 8 m girth, formed high open forest in their most favourable areas, with crowns intermingled and only a low shrub understorey. Today, there is only a small area, just east of Sabina River and south of the rifle range, that resembles high open forest (A2). The remainder of the Tuarts are more openly spaced, forming at the best a high woodland (A3) with a fairly dense understorey of *Agonis flexuosa* (Spreng.) Schau. Around Ludlow, some remnants of Tuart forest have been underplanted with pine plantations (Pi). Natural regeneration of Tuart is not very apparent, but the Forests Department has established an experimental plantation.

B1 CLOSED FOREST

Marri Forest (M) and Jarrah-Marri Forest (JM)

Limited areas of prime Marri *Eucalyptus calophylla* R. Br. and of mixed Jarrah *E. marginata* Sm. and Marri closed forest (B1) occur along the Blackwood River. The understorey consists of very low shrubs or bracken. Near river banks *Agonis flexuosa* (Spreng.) Schau. further increases the density of the tree canopy, and only sedges form the understorey.

Pine Plantations (Pi)

Plantations of *Pinus* species established by the Forest Department have been mapped at Margaret River, Ludlow and on the Busselton-Nannup road due south of Ludlow.

B2 OPEN FOREST

Jarrah Forest (J)

An open forest (B2) dominated by Jarrah *Eucalyptus marginata* Sm. extends over most of the Busselton and Augusta areas on a low lateritic plateau. This forest extends westwards from the Darling escarpment to the eastern escarpment of the Naturaliste-Leeuwin ridge, where it is limited by exposure to westerly winds and the presence of Karri high open forest (A2).

On the plateau, the presence of clayey loam on some hill slopes reduces the forest to open woodland (B4) or, north of the Blackwood River, to high open shrubland (D4). Along rivers Jarrah is co-dominant with Marri *E. calophylla* R. Br. and a more dense forest occurs. Along lower reaches of rivers and in the deeper gullys *Agonis flexuosa* (Spreng.) Schau. adds a dense understorey which may extend upwards into the top canopy.

Common understorey trees are *Banksia grandis* Willd. and *Casuarina fraserana* Miq., the latter forming almost pure stands of open forest or low open forest on poor sites over massive laterite sheet. Other understorey trees are *Banksia littoralis* R. Br., *Persoonia longifolia* R. Br., *P. elliptica* R. Br., *Nuytsia floribunda* (Labill.) R. Br. ex Fenzl. and *Xylomelum occidentale* R. Br. In areas of open woodland (B4) or low open woodland (C4) and open high shrubland (D4) *Casuarina humilis* Otto et Dietr. and *Kingia australis* R. Br. are common. *Nuytsia floribunda* occurs particularly on flat wet sandy soils overlying clay on watersheds and outwash areas. *Xanthorrhoea preissii* Endl. and *Macrozamia riedlei* (Gaud.) C. A. Gardn. are common in parts and there is a continuous layer of a variety of low shrubs of *Podocarpus, Adenanthos, Grevillea, Hakea, Leptomeria, Acacia, Daviesia, Bossiaea, Hovea, Astroloma, Leucopogon* and *Agonis parviceps* Schau.

Jarrah open forest also occurs on sand hills between the swamps of Scott River and the south coast. In damper sites Bullich *Eucalyptus megacarpa* F. Muell. may occur. On the escarpment in the west between Dunsborough and Augusta, as altitude and exposure increase, Jarrah open forest becomes low open forest (C2) and then degenerates into open scrub (D2). In these situations *Banksia* and *Agonis flexuosa* may be co-dominant or dominant.

Jarrah-Marri Open Forest (JM)

On deeper more sandy soils, Marri becomes co-dominant with Jarrah. Jarrah-Marri open forest occurs mainly along river valleys; *Agonis flexuosa* may become an important constituent in the deeper valleys. Flooded Gum *E. rudis* Endl. ocurs on lower ground and along river

banks, and Forest Blackbutt *E. patens* Benth. may be present in damp areas.

Marri Forest (M)

On the leached grey earths of the broad coastal plain north of the low lateritic plateau and between the plateau and the escarpment of the Naturaliste-Leeuwin ridge, the open forest (B2) is dominated by Marri. Jarrah occurs but infrequently. In wetter sites, Forest Blackbutt is common and Flooded Gum occurs locally in a form with large leaves, buds and fruits. Yate *E. cornuta* Labill. occurs particularly around the Sabina River and at the foot of the Naturaliste Downs on moist brown sands. *Agonis flexuosa* and *Banksia* species are frequently important constituents and *Acacia cochlearis* Wendl. and *A. cyanophylla* Lindl. are prominent in the understorey.

Peppermint Forest (Ag)

Along the low coastal sand dunes bordering Geographe Bay between Dunsborough and Busselton and in small sheltered pockets on the west and south coasts such as at Deepdene and south of Milyeaanup Swamp, Peppermint *Agonis flexuosa* (Spreng.) Schau. grows to more than 10 m tall, forming open forest (B2). Where it is most dense the understorey consists only of the sedge *Lepidosperma gladiatum* Labill. Along the Geographe Bay coast the understorey consists of *Acacia decipiens* (Koen.) R. Br., *A. cochlearis* Wendl., *Acanthocarpus preissii* Lehm., *Anthericum divaricatum* Jacq., *Anthocercis littorea* Labill., *Leucopogon australis* R. Br., *Lepidosperma gladiatum* and *Pimelea argentea* R. Br.

Melaleuca Forest (Me)

North-west of Bunker Bay there is a small unique stand of *Melaleuca lanceolata* Otto up to 12 m tall forming open forest (B2). This species forms a patch of low closed forest (C1) just east of Cape Clairault and a very small stand of low open forest immediately north of Cape Leeuwin.

B3 WOODLAND

Jarrah Woodland (J)

Jarrah *Eucalyptus marginata* Sm. forms woodland (B3) along the southern edge of the main block of Jarrah open forest (B2) where it adjoins the peaty acid sands of the south coast flats. Typically Jarrah woodland has an understorey of smaller trees, *Banksia ilicifolia* R. Br., *B. grandis* Willd., *B. littoralis* R. Br., *Nuytsia floribunda* (Labill.) R. Br. ex Fenzl. and Paperbark *Melaleuca preissiana* Schau. Often Blackboys *Xanthorrhoea* species are common. The shrub layer is fairly open, except in the wetter parts where sedges become more numerous.

Jarrah-Mountain Marri Woodland (JH)

On high ground at the northern edge of the lateritic plateau on more sandy soil, Jarrah forms another type of woodland characterised by the presence of a small tree, Mountain Marri *Eucalyptus haematoxylon* Maiden. Other small trees present are *Banksia grandis* Willd. and *B. attenuata* R. Br. On similar sites Jarrah may be absent or occur only as a small tree, and Mountain Marri with the Banksias forms low woodland (C3).

B4 OPEN WOODLAND

Jarrah Open Woodland (J)

On clayey sites south of Blackwood River, a few scattered Jarrah *E. marginata* Sm. occur with shallow root systems impeded by the clay. The understorey consists of somewhat thinly distributed *Hakea, Banksia grandis* Willd., *Kingia australis* R. Br., *Casuarina humilis* Otto et Dietr. *Xanthorrhoea species* and *Dasypogon hookeri* Drumm. On some sites the Jarrah is short and spindly. Hard clay-covered ant nests housing large black ants are a common feature of the clayey areas.

C1. LOW CLOSED FOREST

Peppermint Low Closed Forest (Ag)

Only two small areas of Peppermint *Agonis flexuosa* (Spreng.) Schau., low closed forest (C1) have been mapped. One is in the lee of a sand blowout on the south coast near White Point and the other is on the northern edge of Tuart forest north of Ludlow.

Melaleuca Low Closed Forest (Me)

One small area of *Melaleuca lanceolata* Otto low closed forest (C1) has been mapped west of Cape Clairault. A small patch of the same species occurs at Cape Leeuwin, but is more open. A larger area, also more open and consisting of larger trees occurs at Bunker Bay.

Paperbark Low Closed Forest (P)

In and around swamps and lakes on the inland side of the Tuart limesone ridge there are small very dense stands of Paperbark *Melaleuca rhaphiophylla* Schau.

C2 LOW OPEN FOREST

Jarrah-Marri Low Open Forest (JM)

On the higher ground of the Naturaliste-Leeuwin ridge as exposure to westerly winds

increases, Jarrah open forest grades down into a low open forest (C2). The main constituents are Jarrah *Eucalyptus marginata* Sm., Marri *E. calophylla* R. Br., *Banksia* species, including *B. grandis* Willd., *Casuarina, Agonis flexuosa* (Spreng.) Schau. and occasional *Xylomelum occidentale* R. Br. In parts *Jacksonia furcellata* DC. is a common shrub.

Peppermint Low Open Forest (Ag)

Above the Jarrah and Karri forests on the Naturaliste-Leeuwin ridge, in valleys and sheltered hollows on the seaward side of the ridge, along the coastal sand ridges eastwards from Busselton, in parts west of Busselton, and in sheltered parts of the south coast sand dunes covering large areas, Peppermint *Agonis flexuosa* (Spreng.) Schau. forms low open forest (C2). The understorey is subdued and consists mainly of *Lepidosperma gladiatum* Labill. Inland from Hamelin Bay, *Melaleuca huegelii* Endl. is co-dominant with Peppermint.

Jarrah-Banksia Low Open Forest (JB)

At the western end of Long Swamp, east of Augusta, and to the east of Long Swamp on sand ridges, Jarrah and *Banksia ilicifolia* R. Br. form low open forest (C2).

Banksia Low Open Forest (B)

On slightly elevated sandy areas inland from the Tuart limestone belt and other sandy areas in the coastal plain north of the main Jarrah open forest, low open forest (C2) occurs composed of *Banksia attenuata* R. Br. and *B. ilicifolia* with some *Nuytsia floribunda* (Labill.) R. Br. ex Fenzl.

Paperbark Low Open Forest (P)

Paperbark *Melaleuca rhaphiophylla* Schau. forms low open forest (C2) in and around swamps, particularly inland from the coastal sand dunes along the shore of Geographe Bay, on the flats between the Jarrah open forest and the south coast sand dune system and, more rarely, along the eastern escarpment of the Naturaliste-Leeuwin ridge. Paperbark also occurs along banks of streams and rivers and may be accompanied by *M. acuminata* F. Muell. south of Busselton. In very narrow belts between the Tuart forest and Wonnerup and Vasse estuaries, Paperbark is accompanied by Flooded Gum *Eucalyptus rudis* Endl. and, less frequently, by Peppermint.

C3 LOW WOODLAND

Jarrah Low Woodland (J)

On higher ground on the Naturaliste-Leeuwin ridge, particularly where granitic rock is close to the surface, as well as on some of the lower slopes of the eastern escarpment, Jarrah *Eucalyptus marginata* Sm. forms low woodland (C3), usually with a high proportion of *Banksia* species. Marri *E. calophylla* R. Br. may also be present, or *Casuarina* may be co-dominant.

Banksia Low Woodland (B)

On high ground with sandy soils, particularly between Naturaliste Downs and Dunsborough and on other sandy sites at the foot of the eastern escarpment of the Naturaliste-Leeuwin ridge, south of Calgardup Brook, *Banksia* species form low woodland (C3). Other areas occur both east and west of Augusta.

Jarrah-Banksia Low Woodland (JB)

Jarrah and *Banksia ilicifolia* R. Br. form low woodland on sand ridges in the flats of the south coast plain. In situations closer to the south coast sand dunes Bullich *E. megacarpa* F. Muell. may occur.

Peppermint Low Woodland (Ag)

Southwards from Deepdene on high ground west of the Karri forest, and again on the south coast sand dunes, Peppermint *Agonis flexuosa* (Spreng.) Schau. forms areas of low woodland in situations which are less sheltered from winds than those in which Peppermint low open forest thrives. There are, however, indications that burning or pasture improvement may be responsible for thinning out the open forest.

Eucalyptus haematoxylon Low Woodland (H)

On high ground near the northern edge of the lateritic plateau on fairly sandy soil, Mountain Marri *E. haematoxylon* Maiden together with *Banksia grandis* Willd. and *B. attenuata* R. Br. form low woodland (C3). Understorey shrubs include *Casuarina humilis* Otto et Dietr. and *Banksia sphaerocarpa* R. Br.

C4 LOW OPEN WOODLAND

Paperbark Low Open Woodland (P)

An open woodland in which Paperbark *Melaleuca preissiana* Schau. appears as a small tree, scattered or in small groups, covers large areas of open flats of leached sand subject to seasonal flooding. The largest areas occur south of the main block of Jarrah open forest and north of the sand dunes of the south coast and either side of the lower reaches of the

Blackwood River. Small areas occur on hollows and at the side of drainage lines in the Jarrah forest. Similar areas occur on the northern coastal plain, but here *Melaleuca rhaphiophylla* Schau. is the more common Paperbark. A frequent co-dominant is Swamp Banksia *B. littoralis* R. Br. Stunted Jarrah may also be present and Blackboys may be frequent. *Nuytsia floribunda* (Labill.) R. Br. ex Fenzl. also occurs.

The understorey is a closed heath with closed sedgeland in wetter parts. The shrubs *Astartea fascicularis* (Labill.) Dc., *Agonis parviceps* Schau. and *Melaleuca preissiana* are particularly abundant with *Leptospermum firmum* (Schau.) Benth., *Agonis marginata* (Labill.) Schau., *A. juniperina* Schau., *Kunzea recurva* Schau. and *Beaufortia sparsa* R. Br. Common small sedges are *Lepidosperma longitudinal* Labill. and *Mesomelaena tetragona* (R. Br.) F. Muell. *Boronia* species also occur.

Included in the low open woodland (C4) are swamps with Paperbark low closed forest (C1) or low open forest (C2), closed scrub (D1), closed heath and sedgeland (F1) too small to be mapped. Narrow ridges and small hillocks of Jarrah and Banksia low open forest and low woodland (C3) are also included in the low open woodland areas of the south coast flats.

Peppermint Low Open Woodland (Ag)

An area of low open woodland (C4) occurs on the Naturaliste-Leeuwin ridge south of Deepdene. This is quite different from the Paperbark low open woodland as Peppermint *Agonis flexuosa* (Spreng.) Schau. is the dominant tree. As in the case of open woodlands (C3) in nearby areas, fires are suspected as being the main cause of the open character of this vegetation.

D1 CLOSED SCRUB

Myrtaceous Closed Scrub (My)

Along drainage lines and flat banks of streams and rivers in higher rainfall areas where the soil is damp most of the time, and at head waters of streams closed scrub grows up to 4 m high.

The species vary from area to area; along river banks at Tetron *Agonis linearifolia* Schau. is most abundant; in Chapman Valley *A. linearifolia* is accompanied by *Melaleuca polygaloides* Schau. whereas in seepage areas in the foothills of the lateritic plateau near Quindalup *Agonis juniperina* Schau. and *Kunzea ericifolia* Reichb. occur.

Melaleuca huegelii Closed Scrub (Me)

On the Naturaliste-Leeuwin ridge facing the ocean on sites where limestone appears near the surface closed scrub is formed by *Melaleuca huegelii* Endl. This is most noticeable near Yallingup, Canal Rocks and Cape Mentelle. At Injidup Springs *M. huegelii* is accompanied by *Dryandra sessilis* (Knight) Domin.

Peppermint Closed Scrub (Ag)

In similar situations on coastal sand, possibly where there is a little more shelter, Peppermint *Agonis flexuosa* (Spreng.) Schau. forms closed scrub, accompanied by *Dryandra sessilis* north of Cape Leeuwin where limestone occurs, and with *Boronia elata* Sm. near Deepdene.

Acacia decipiens Closed Scrub (A)

In the lee of the Boranup Sand Patch at the upper edge of the Karri forest closed scrub occurs, consisting mainly of *Acacia decipiens* R. Br.

D2 OPEN SCRUB

Peppermint Open Scrub (Ag)

While closed scrub (D1) usually consists of only one dominant species, and at the most two species, open scrub (D2), which occurs widely on coastal sands and limestones, may contain more species.

On the sand hills of the south coast, open scrub typically consists of Peppermint *Agonis flexuosa* (Spreng.) Scbau., *Jacksonia horrida* DC., and *Acacia decipiens* R. Br. On the Naturaliste-Leeuwin ridge, the presence of limestone allows the inclusion of Parrot Bush *Dryandra sessilis* (Knight) Domin.—at Cape Mentelle, Injidup Springs, Canal Rocks, Boranup, Cosy Corner and north of Cape Leeuwin —and of *Melaleuca huegelii* Endl—at Cape Mentelle and Injidup Springs. While Peppermint seems always to be present, *Acacia decipiens* can become the most common species and the flora may be enriched by the presence of *Eucalyptus megacarpa* F. Muell. Blackboys, *Xanthorrhoea* spp., *Melaleuca acerosa* Schau., *Hakea nitida* R. Br., *Spyridium globulosum* (Lab'll.) Benth. and *Leucopogon* species may also be present in the understorey.

Near Cape Naturaliste Peppermint open scrub includes Marri *Eucalyptus calophylla* R. Br. and Jarrah *E. marginata* Sm. as tall shrubs, and in parts Peppermint may be accompanied by *Banksia* species.

Paperbark and Peppermint Open Scrub (PAg)

South of Busselton, in low lying areas, Paperbark *Melaleuca rhaphiophylla* forms open scrub with Peppermint.

D3 HIGH SHRUBLAND

Peppermint-Parrot Bush High Shrubland (AgD)

South of Scott River near the south coast, there occur areas of moist flats and hollows with sandy ridges. Peppermint *Agonis flexuosa* (Spreng.) Schau. occurs on the moister sites while Parrot Bush *Dryandra sessilis* (Knight) Domin. occurs on the ridges, forming high shrubland (D3).

D4 HIGH OPEN SHRUBLAND

Jarrah-Kingia High Open Shrubland (JKi)

On the low lateritic plateau north of Blackwood River a form of high open shrubland (D4) occurs on convex hill sides and valley slopes which are covered with a yellowish clay loam. The vegetation consists of scrubby Jarrah *E. marginata* Sm., *Kingia australis* R. Br., *Dasypogon hookeri* Drumm., *Banksia grandis* Willd., *Hakea* sp., *Casuarina humilis* Otto et Dietr. and *Xanthorrhoea* species. The vegetation is similar to Jarrah open woodland south of the Blackwood but lacks trees.

E2 OPEN HEATH

In exposed situations on the west and south coasts open heath occurs in which the principal species are *Acacia decipiens* R. Br. and *Jacksonia horrida* DC. On the west coast *Scaevola crassifolia* Labill. and *S. nitida* R. Br. are locally abundant. Other important species are *Spyridium globulosum* (Labill.) Benth. and *Leucopogon parviflorus* (Andr.) Lindl. Near the sea the grey leaved *Olearia axillaris* (DC.) F. Muell. ex Benth. becomes common. *Melaleuca huegelii* Endl. may occur in limestone areas. Where limestone occurs near the surface *Dryandra sessilis* (Knight) Domin. is common. Other species are *Melaleuca acerosa* Schau., *Hibbertia, Hardenbergia* and *Pimelea.*

Towards the northern end of the Naturaliste-Leeuwin ridge, *Acacia pulchella* R. Br., *Calothamnus* species and *Casuarina humilis* Otto et Dietr. are of local occurrence with *Calothamnus, Hakea* and *Xanthorrhoea* being predominant near Dunsborough.

Samphire Open Heath (Sa)

On the flats adjoining Vasse and Wonnerup estuaries subject to flooding with salty water a highly specialised form of low open heath occurs. The principal plants are *Arthrocnemum bidens* Nees., *A. halocnemoides* Nees. var. *halocnemoides* and other *Arthrocnemum* species.

E3 LOW SHRUBLAND

Coastal Shrubland (O)

Close to the sea and on mobile sand dunes and blowouts the open heath and scrub of stable dunes give way to a low shrubland characterised by the grey leaved shrub *Olearia axillaris* (DC.) F. Muell. ex Benth. which grows to between 1 and 3 m tall. Other constituents in the south and west are *Spyridium globulosum* (Labill.) Benth., *Acacia cyclops* Cunn. ex Don., *A. decipiens* R. Br., *Hibbertia cuneiformis* (Labill.) Gilg., *Exocarpos sparteus* R. Br., *Pimelea clavata* Labill., *Helichrysum cordatum* DC., *Calocephalus brownii* (Cass.) F. Muell., *Scaevola crassifolia* Labill., *S. nitida* R. Br. and *Scirpus nodosus* Rottb.

On the north coast, Geographe Bay, changes are apparent in the constituents. *Olearia axillaris, Spyridium globulosum* and *Scaevola crassifolia* continue to be important, while *Acacia cochlearis* Wendl. becomes of equal importance in frequency with *O. axillaris.* Other species are *Acanthocarpus preissii* Lehm. and *Alyxia buxifolia* R. Br.

Ironstone Shrubland (V)

In the southern coastal plain adoining and north of Scott River there are quite extensive areas of ironstone or ferruginous sandstone plain covered with only a very thin layer of soil. The vegetation consists of a low shrubland in which the principal shrubs, 1 m to 1.5 m tall, are *Viminaria juncea* (Willd.) Hoffm., *Grevillea synapheae* R. Br., *Acacia myrtifolia* (Sm.) Willd. and *Loxocarya flexuosa* (R. Br.) Benth.

F1 CLOSED HERBLAND

Sedgeland (S)

Towards the south coast, inland from the coastal dune system and on the black peaty sands of flats subject to prolonged flooding and waterlogging, there are extensive areas of sedgeland (F1). In some areas it merges with closed heath forming pockets of sedgeland in the wettest parts of low open woodland (C4). In other areas shrubby plants and herbaceous plants are so intermixed it is difficult to determine whether the formation should be called heath or sedgeland. Sedgelands also occur

along broad river valleys such as the upper reaches of the Margaret River and in poorly drained hollows in the Jarrah forest. Plants characteristic of sedgelands on the south coast flats are *Evandra aristata* R. Br. (up to 1 m tall), *Anarthria prolifera* R. Br., *A. scabra* R. Br., *Restio applanatus* Spreng., *Leptocarpus scariosus* R. Br., *Leptosperma persecans* S. T. Blake and *Lysinema conspicuum* R. Br.

Shrubs most frequently associated with sedgelands are *Leptospermum firmum* (Schau.) Benth., *L. oligandrum* Turez., *L. ellipticum* Endl., *Astartea fascicularis* (Labill.) D.C., *Agonis linearifolia* Schau., *Leucopogon gilberti* Stschegl., *L. pendulus* R. Br., *Andersonia caerulea* R. Br., and *Beaufortia sparsa* R. Br.

On low narrow sand ridges *Banksia ilicifolia* R. Br., *Banksia attenuata* R. Br. and occasionally small Jarrah *Eucalyptus marginata* Sm. form low open woodland, low woodland or even low forest, included in sedgeland. Swamp vegetation, in parts very extensive, is included in sedgeland as mapped. On the flats of the Margaret River typical plants are *Leptocarpus tenax* (Labill.) R. Br., *Stylidium imbricatum* Benth., *Restio ustulatus* F. Muell. ex Ewart & Sparman, *Beaufortia sparsa, Hakea ceratophylla* (Sm.) R. Br., *Leptospermum ellipticum* Endl. and *Dasypogon hookeri* Drumm.

SWAMP VEGETATION

The permanent swamps are filled with rushes *Juncus* species standing in water. There may also be scattered Paperbarks *Melaleuca rhaphiophylla* Schau., but most frequently there is a narrow belt of low open forest around the edge of the swamp. On areas frequently flooded, the small trees are *M. rhaphiophylla* or *Agonis juniperina* Schau. On slightly higher ground *Melaleuca preissiana* Schau. and *Banksia littoralis* R. Br. may occur and near the north coast *Agonis flexuosa* (Spreng.) Schau. and *Eucalyptus rudis* Endl. are common associates. On damp and frequently flooded ground the understorey consists of *Gahnia trifida* Labill. or *Lepidosperma gladiatum* Labill.

PRIMARY INDUSTRIES

Earlier this century there was a flourishing timber industry centred on the Karri forests growing in the lee of the Naturaliste-Leeuwin ridge. The mill was at old Karridale, now abandoned, and the timber was exported from Hamelin Bay on the west coast in summer and from Flinders Bay in winter. Systematic logging continues in the Jarrah forest of the low plateau and pine plantations have been established at Margaret River and near Ludlow. The Ludlow plantations have a current production if about 3,000 m^3 a year. The narrow belt of Tuart forest just inland from the Wonnerup and Vasse estuaries provide valuable hardwood for building railway waggons.

The north coastal plain and the richer valleys and slopes between the plateau and the Naturaliste-Leeuwin ridge have been cleared of their natural vegetation and converted to pasture. The flats on both sides of the lowest reaches of the Blackwood River and much of the Scott River, as well as some of the high ground on the Naturaliste-Leeuwin ridge, have been cleared recently.

Of a total of 240 000 ha in the Augusta-Margaret River District, 55 000 ha have been cleared, 49 500 for pasture and 1 230 ha for crops, mainly green feed and silage. Some 20,000 cattle are kept for milk production and 26,000 for beef. There are also some 86,000 sheep and 6,300 pigs.

A greater proportion of Busselton District has been cleared. Of the total area of 133 000 ha, 70 400 ha have been cleared, 65 000 ha being under pasture and 2 200 ha under crops, mainly green feed and silage but also with some 230 ha under lettuce and 300 ha under potatoes. Over 46,000 cattle are kept for beef production and 15,000 for milk. There are at least 82,000 sheep and 3,400 pigs.

The beaches in the north, surf in the west and the fascinating limestone caves and delightful countryside attract numerous holiday-makers seeking relaxation and tourism provides the major industry for the towns of Busselton, Augusta and Margaret River.

Busselton and Cowaramup provide convenient bases for commercial honey producers who specialise in the production of honey and beeswax from Karri, Marri and Jarrah and, to a lesser degree, from Tuart, Yate and Peppermint.

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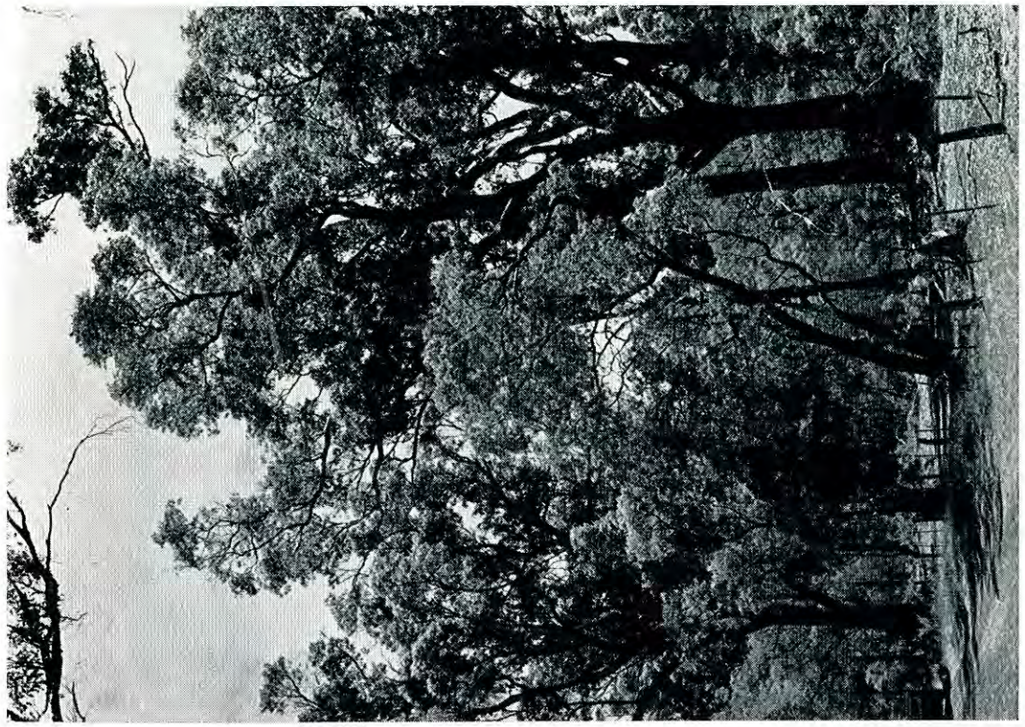
Smith, R. (1951): Soils of the Margaret River —Lower Blackwood River Districts, Western Australia. Bull. 262, C.S.I.R.O.



A3 T Tuart High Woodland *E. gomphocephala* with *Agonis flexuosa* understorey ; near Ludlow 343845

A2 K Karri High Open Forest *Eucalyptus diversicolor* ; Douglas Road, Arumvale 305779

A2 K Karri High Open Forest *E. diversicolor*, more open and heavily branched ; Quininup Brook 300833

B1 JM Jarrah—Marri Closed Forest *E. marginata* and *E. calophylla ;* north bank of Blackwood River, Denny Road 337791

B1 M Marri Closed Forest *E. calophylla ;* near junction of Rosa Brook with Blackwood River, Denny Road 342792

B2 JM Jarrah—Marri Open Forest *E. marginata* and *E. calophylla* with *Agonis flexuosa ;* near Margaret River, Lorry Road 312804

B2 M Marri Open Forest *E. calophylla ;* Lorry Road 312802

B2 JC Jarrah—Casuarina Open Forest *E. marginata* and *Casuarina fraserana ;* Oasis Road 332803

B2 MY Marri—Yate Open Forest *E. calophylla* and *E. cornuta* with *E. rudis* and *Agonis flexuosa ;* Naturaliste Downs 303850

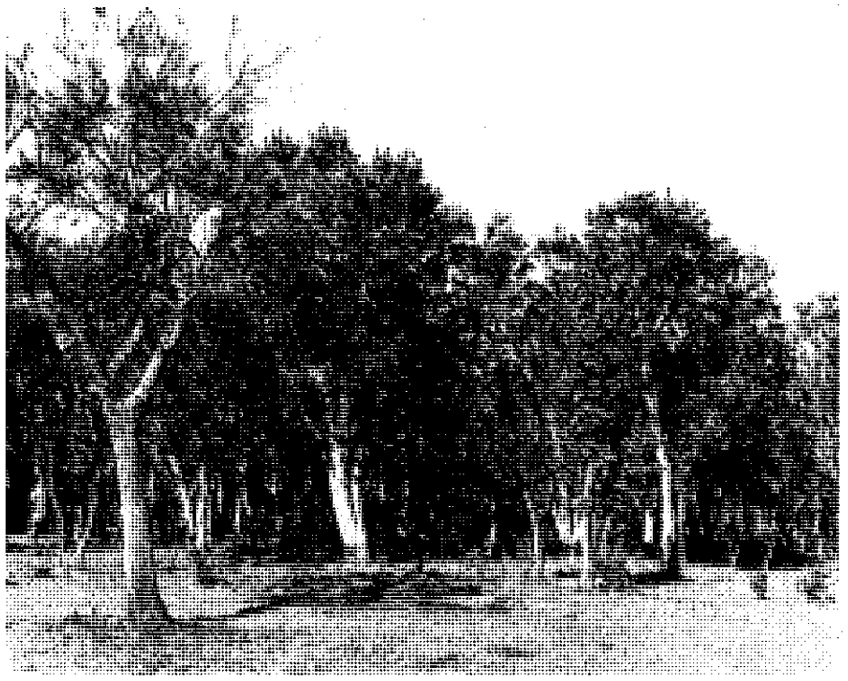
B2 Me Melaleuca Open Forest *Melaleuca lanceolata ;* north-west of Bunker Bay 302856

C1 Ag Peppermint Low Closed Forest *Agonis flexuosa ;* near Ludlow 348854

C2 Ag Peppermint Low Open Forest *Agonis flexuosa ;* near Augusta golf course 309762

C2 JM Jarrah—Marri Low Open Forest *E. marginata* and *E. calophylla* with *Casuarina fraserana, Jacksonia furcellata* scrub in foreground ; Cullen Road 299822

C2 J Jarrah Low Open Forest *E. marginata* with *Banksia grandis* and *Xylomelum occidentale;* Wyadup Road 298837



C2 B Banksia Low Open Forest *Banksia attenuata* and *B. ilicifolia* with *Nuytsia floribunda ;* near Ludlow 345844

C2 P Paperback Low Open Forest *Maleleuca rhaphiophylla ;* Quindalup 310845

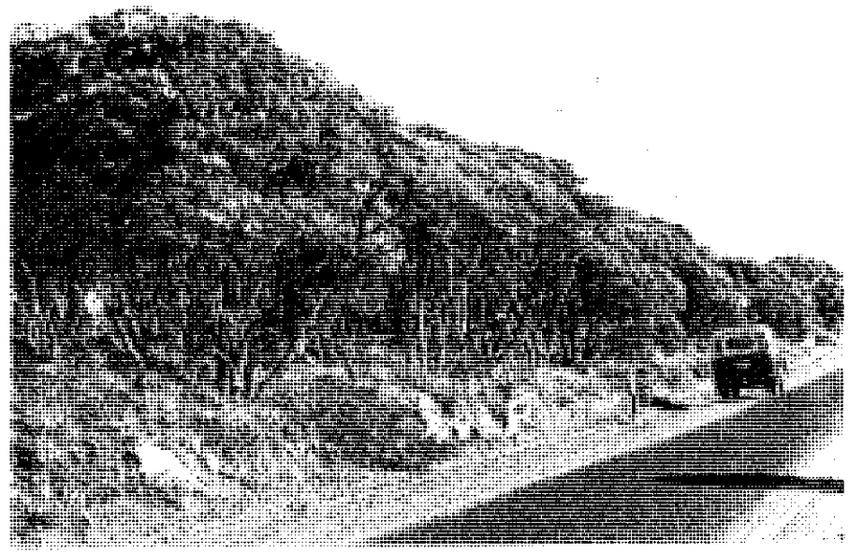
C3 J Jarrah Low Woodland *E. marginata ;* near Cape Naturaliste 302855

C3 H Mountain Marri Low Woodland *E. haematoxylon* with *Banksia* spp. ; Sabina Road 343827

C3 B Banksia Low Woodland *Banksia* spp. ; Meelup Spring 305849

C4 P Paperback Low Open Woodland *Melaleuca rhaphiophylla;* near Augusta 313766

D1 My Myrtaceous Closed Scrub *Agonis juniperina* and *Kunzea ericifolia* with *Melaleuca rhaphiophylla* in background ; south-west from Quindalup 308842



D1 Me Melaleuca Closed Scrub *Melaleuca huegelii ;* near Canal Rocks 297839

E2 A Acacia Open Heath *Acacia decipiens* with *Melaleuca huegelii* and *Leucopogon parviflorus ;* near mouth of Margaret River 297802

E2 O Olearia Open Heath *Olearia axillaris* with *Acacia decipiens, Spyridium globulosum, Scaevola nitida* and *Hibbertia* sp. ; near Cape Leeuwin 313755

E2 Ca Calothamnus Open Heath *Calothamnus quadrifidus* and *Hakea trifurcata ;* north of Dunsborough 308848

E2 Sa Samphire Open Heath *Arthrocnemum bidens* and *A. holocnemoides ;* Wonnerup Estuary 346852

E3 V Viminaria Low Shrubland *Viminariaj uncea* with *Grevillea synapheae*, *Acacia myrtifolia* and *Loxocarya flexuosa* ; ironstone plain north of Scott River 328768

F1 S Closed Herbland—Sedgeland ; upper Margaret River 337817

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