NOTES ON THE SILVICULTURE OF MAJOR N.S.W. FOREST TYPES

7. FLOODED GUM TYPE

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Forestry Commission of NSW
Sydney
6th September, 1985

NOTES ON THE SILVICULTURE OF MAJOR N.S.W. FOREST TYPES

7. FLOODED GUM TYPE

1. INTRODUCTION

The Flooded Gum[1] type is one of the forest types forming the Sydney Blue Gum/ Bangalay league (Forestry Commission of NSW, 1965). Different developments in its silviculture led to its exclusion from the review of the silviculture of most of that league in No. 1 of these Notes (Moist Coastal Hardwood types).

The type is widely distributed along the North Coast, extending into Queensland, though individual stands are often of limited extent. The dominant tree that gives the type its name is one of the most beautiful and majestic of the eucalypts, and its botanical name, *grandis*, has been well bestowed. Its wood is light for a eucalypt and is suitable for a wide range of uses. The tree is the fastest growing eucalypt in NSW, and it is commonly regenerated by artificial means for growth on a relatively short rotation.

Worldwide, well over half a million hectares of Flooded Gum plantation were reported in 1979 (F.A.O., 1979). Allowing for the confusion that frequently exists between Flooded Gum and the closely related Sydney Blue Gum in overseas planting projects, it is probably the most widely planted eucalypt in the world and has given rise to a fairly voluminous international literature, much of which was reviewed in the F.A.0. publication. Although not ranking high in terms of current wood production in NSW (in recent years it has averaged about 1½ to 2 per cent of the Crown hardwood log production), its potential production is much higher, and this, with the distinctiveness of the type, provides the justification for its inclusion in these Notes.

2. BOTANY AND ECOLOGY

2.1 Taxonomy and Identification

Flooded Gum (*E. grandis*, SECAB) is a member of the 'Eastern Blue Gum' group of eucalypts - subseries Saligninae, series Salignae, section Transversaria, subgenus Symphyomyrtus of Pryor & Johnson (1971). Sydney Blue Gum (*E. saligna*, SECAC) is also a member of this same group, and the two species, whose ranges substantially overlap in northern NSW and southern Queensland, have frequently been confused.

E. saligna was one of the earliest eucalypts to be botanically described (1797), and Flooded Gum was for a long time not recognised as being distinct from it, though as early as 1862 Walter Hill used the name *'E. grandis'* for it in a catalogue of Queensland timbers. In 1902 Baker & Smith described it as *E. saligna* var. *pallidivalvis*, and in 1918 J. E. Maiden finally formalised the catalogue name in his description of *E. grandis*, the full name of which is correctly *E. grandis* Hill ex Maiden.

In the meantime seed of the tree had been extensively distributed around the world as *'E. saligna'*, and this has been a major cause of the subsequent confusion in identity in overseas plantings[2]. The similarity of the two trees is of course the main cause of the problem back home.

[1] For botanical names of species mentioned in text, See Appendix 1
[2] C.E. Lane Poole, one of the leading pioneer foresters in Australia and long-time Acting Principal of the Australian Forestry School, claimed that in his early days as a young forester in South Africa he had been asked to raise a batch of "saligna" seed from Australia. After germination some of the seedlings developed basal swellings. Not being familiar with lignotubers, L-P misidentified the swellings as nemotode infection and had all affected seedlings destroyed. In this particular case, what presumably started out as a mixed batch of seed would have ended up as pure *grandis*.

Differences between the two species were summarised by Floyd (1958 & 1960b) for northern NSW and by the Wattle Research Institute (1972) for South Africa, with essentially identical results. More recently Burgess & Bell (1983) have also examined differences between individuals in the **grandis/saligna** group. Table 1, based primarily on these sources, indicates the main differences between these two very similar trees.

Despite the very great likenesses, the two species can usually be identified with fair confidence on the basis of bark colouration in the field. In NSW the two seem rarely to hybridise, presumably chiefly because of the different flowering times, though occasional individuals of apparently intermediate characteristics may be met. The study by Burgess & Bell, including the examination of allozyme frequencies, showed the occurrence of distinct 'core' populations of Flooded and Sydney Blue Gums, plus some central Queensland stands (extending inland to Carnarvon) with intermediate features.

Table 1

DISTINCTIONS BETWEEN FLOODED GUM AND SYDNEY BLUE GUM

	Flooded Gum	**Sydney Blue Gum**
Bark	Powdery white, sometimes greenish; rough bark at base often extending higher than on comparable Blue Gums.	Bluish, often with patches of darker blue-grey. Rough bark base less high than on Flooded Gum.
Crown	Leaves dark green, broader than in Blue Gum (5½ to 6½ times as long as broad); giving crown a denser appearance. Leaves similar colour both surfaces. Branchlets glaucous. Branches die off quickly under shade.	Leaves grey-green, narrower than Flooded Gum (6½ to 7 times as long as broad), crown appearing less dense. Leaves paler below. Branchlets not glaucous Branches more persistent under shade.
Fruits	Pear-shaped, slightly contracted at orifice; somewhat glaucous; gradually tapering to ill-defined stalk. Valves 4-6, mostly 5; pale, with blunt tips; incurved. Usually longer and coarser than Blue Gum.	Cylindrical, bell-shaped or conical, lacking contraction at orifice; not glaucous; tapering suddenly to stalk. Valves 3-4, mostly 4; same colour; tips sharp pointed; erect or curved out. Smaller and more delicate than Flooded Gum.
Flowers	Buds larger, with bluish bloom. Flowering season April-August.*	Buds smaller, less bloom. Flowering season January-April.
Cotyledons	Rather larger than Blue Gum. Petiole shortly tapering from cotyledon.	Smaller than Flooded Gum. Petiole long-tapering from cotyledon.
Seedlings	1st. pair of leaves oblong lanceolate. 1st. alternate leaves 2 to 2½ times as long as broad. Stem above 10 cm red, shiny. No lignotuber	1st. pair of leaves linear. 1st. alternate leaves 3 to 3.7 times as long as broad. Stem above 10 cm dull, with white bloom. Lignotuber by 8 months

* For South Africa the flowering season is given as July to December (Wattle Research Institute, 1972).

Unlike Sydney Blue Gum, the similarly closely related Roundleaved Gum (*E. deanei*, SECAA) does not appear to overlap in range with Flooded Gum. It can be distinguished by its generally broader leaves, almost round juvenile leaves, its smaller fruit, and the yellowish-cream tones usually present in its bark.

Although not so closely related, Dunn's White Gum often grows with Flooded Gum in its limited zone of occurrence, and in some sites has also been planted with Flooded Gum. It is again a very similar looking tree, though the botanical differences are quite marked with broad, heart-shaped, glaucous juvenile leaves and hemispherical fruit with valves raised up from a small, but distinct, level disc. The tree tends to have longer and more pendant leaves, and the bark usually shows cream tonings, compared with the rather more chalky whiteness of Flooded Gum.

In Nature Flooded Gum sometimes hybridises with Swamp Mahogany (another member of the Eastern Blue Gum group), and the resultant tree has been described as *'E. grandis var. grandiflora'*. In southern Florida, this hybrid out-produces either parent species by at least 50 per cent (Franklin, 1978). F.A.0 (1979) also reports that Flooded Gum may hybridise with Red Mahogany and with Forest Red Gum, the latter cross producing a very promising tree for use in parts of Africa. Hybrids with Timor Gum, reproduced vegetatively, are being used for commercial plantation establishment by a private company (Aracruz Celulose S.A.) in Brazil (Cromer & Pederick, 1980) **-** an enterprise that won the 1984 award of the (Swedish) Marcus Wallenburg Foundation for Promoting Scientific Research in the Forest Industry for four of the foresters involved (Anon., 1984b): see also Section 6.5.4 and Appendix 4.

2.2 Forest Types

These Notes are essentially concerned with what the Forestry Commission of NSW (1965) has recognised as a single type, described in the following terms:

48. Flooded Gum

Composition: Clearly dominated by Flooded Gum, usually as a pure stand but with occasional species such as Blackbutt, Tallowwood, Brush Box, Sydney Blue Gum and Turpentine. Develops an understorey of rainforest species that, in the absence of further disturbance, tend to replace the Flooded Gum type (frequently as the Booyong-Coachwood type).

Nature: Tall wet sclerophyll forest, commonly up to 45 m and occasionally exceeding 60 m. Occupies moist gully sites on the North Coast, usually at lower elevations but ascending to 750 m in a few localities. The type relies on catastrophic site disturbance (e.g. fire, cyclone) to regenerate, and normally occurs in the gullies in small, even-aged stands intimately mixed with stands of rainforest and Inland Brush Box types.

Occurrence: Confined to the North Coast, northwards from Port Stephens, but very widespread in suitable sites through this region. Examples include Wallingat S.F., Lansdowne S.F., Nambucca S.F., Pine Creek S.F., Wild Cattle Creek S.F. and Mebbin S.F.

The type, of course, extends northwards into Queensland.

Although not stressed in the description above, mixed stands including Flooded Gum as a co-dominant do occur. One distinctive such mixture occurs on Wallingat S.F. and involves Flooded Gum with Swamp Mahogany. Early descriptions of the Pipeclay Creek area on Landsdowne S.F. indicate that the original stand was a mixture of Flooded Gum, Tallowwood and Brush Box: subsequent disturbance has converted this to pure Flooded Gum regrowth. Such mixtures may have been generally much more widespread prior to European settlement.

In a few localities in the far north of the State, the Flooded Gum type occurs with, or is partly replaced by, the Dunn's White Gum type. To a minor extent this type is also included here, though the direct value of the White Gum type for wood production is very limited. (Its indirect value, as a source of seed and genetic material for planting and breeding programmes both within Australia and overseas, is considerably greater.) The description of this type is:

51. Dunn's White Gum

A type very similar in appearance to the Flooded Gum type, but with Dunn's White Gum constituting over 50 per cent of the stand. Common associates include Flooded Gum, Sydney Blue Gum, Tallowwood and Brush Box. There is usually a developing rainforest understorey to the type, while the overstorey may attain a height of up to 55m. It occupies areas of moist, fertile soil, usually though not invariably in gully and creek side locations (in the Tooloom Scrub Flora Reserve on Beaury S.F. the type occurs near the top of the range). The type is restricted to the northeastern section of the State, usually in somewhat elevated situations bet ween 300 and 750m. Typical examples are on Kangaroo River S.F., near Nymboida, on Donaldson S.F., Yabbra S.F. and Beaury S.F.

Other ecological workers on the North Coast have recognised these types in various ways. In the Upper Williams River - Barrington Tops area, Fraser & Vickery (1939) identified a Sydney Blue Gum-Turpentine[3] association, and noted that elsewhere Flooded Gum, among other species, occurred with these. Contemporaneously, Osborn & Robertson (1939), working in the Myall Lakes area, recognised a Flooded Gum community in gully silt flats, while in her broader review of eucalypt communities in eastern NSW Pidgeon (1942) established a Sydney Blue Gum-Blackbutt association which included a large number of types, many of them listing Flooded Gum as a dominant species - Blue Gum-Flooded Gum, Flooded Gum, Flooded Gum-Brush Box, Tallowwood-Flooded Gum-Blue Gum, and others. Baur (1962) recognised both a Flooded Gum and a Dunn's White Gum type from northeastern NSW In their State-wide review Specht et al. (1974), working from the thesis of Hayden (1971), listed a broad Sydney Blue Gum-Red Mahogany-Blackbutt alliance of wet sclerophyll forest (open-forest and tall open-forest), containing, among many other species, Flooded Gum. For Queensland, Specht and his colleagues merely recognised a broad “Tall open - forest alliance" which included Flooded Gum among even more species. Most recently Beadle (1981) has established a Flooded Gum alliance, with a sole Flooded Gum association, within his "Tall **Eucalyptus** Forests of the Eastern Coastal Lowlands", and also a Dunn’s White Gum association of the Sydney Blue Gum alliance in the same broader grouping; the Dunn’s White Gum community would probably better be included in the Flooded Gum alliance.

2.3 Environment

The basic features of the environment of the Flooded Gum type are outlined in the description of the type, quoted above, and can be well appreciated on a short drive through, for example, the Bruxner Park Flora Reserve or many other similar gully areas on forests throughout the North Coast. At Bruxner Park the road passes over a ridge of Blackbutt forest, and then dips down into a broad alluvial flat, with occasional low rises, sloping gently downward on either side of Bucca Creek. Along this flat the road passes through a constantly changing, and apparently random, mosaic of stands - well developed Booyong-Coachwood rainforest, showing few effects of selective logging 80 years ago; a patch of Flooded Gum regrowth, with dense lantana, maybe 30 years old; well structured, though still immature, rainforest overtopped by a few scattered, giant Flooded Gums over 60 m tall, and possibly 300 or more years old; an area dominated by Fig infested Brush Box above developing rainforest; more stands of Flooded Gum regrowth, clearly even-aged and some older, some younger than the previous stand. Occasional Gums will be seen growing away from the flats, with Blackbutt or mixed hardwoods, but the Flooded Gum type itself belongs to the valley bottom.

From this, two inferences can be drawn:

1. The type occurs on particularly favoured sites - deep soils with at least moderate fertility, ample moisture, but well drained. They are sites that, to a large extent, are indeed subject to occasional flooding, as the tree's common name implies; they are also sites that, if undisturbed, will ultimately support well-developed and productive rainforest.

[3] Most ecological workers have used botanical names in their classifications, but common names are used here for both consistency and stability.

2. The type, and the tree itself, in the words of Floyd (1962), is “a child of calamity”, depending on periodic massive disturbance of the stand, from fire, cyclonic storm or similar perturbation, for its continued presence. Without such disturbance, the tree cannot regenerate successfully and will ultimately be lost from the community that in turn will change to rainforest.

These inferences largely describe the conditions under which the Flooded Gum type occurs.

Climatic details for four stations representative of Flooded Gum sites are given in Appendix 2, using data adapted from Hall (1972). Taree and Coffs Harbour are located on the coastal lowlands, typical of most Gum stands; Brooklana is in the area of the fairly extensive stands on parts of the eastern Dorrigo, close to the natural altitudinal limits of Flooded Gum in NSW; and Urbenville is within the main area of the Dunn’s White Gum type, in a locality where Flooded Gum also occurs. Features of the climates shown by these stations include:

- Marked summer-autumn rainfall maxima.
- Annual rainfall exceeding about 1 000 mm.
- Generally warm temperate to subtropical temperature regimes.
- The presence of winter frosts, though the extent of these in forest areas would tend to be exaggerated in Appendix 2 because of the conditions under which weather details are recorded: whilst open sites (including regeneration coupes) near Brooklana undoubtedly experience an average of 62 frosts a year, adjacent forest areas are rather less severely affected.

Hall, Johnston & Marryatt (1963) observe that in tests at Canberra, well outside its natural range, Flooded Gum has shown resistance to much heavier frosts than would be experienced in Nature. Nonetheless winter temperatures appear to be the factor limiting the altitudinal range of the Gum type, and plantings in low-lying sites at high altitudes have been severely damaged by frost. Such sites on the eastern Dorrigo Plateau have in the past been sometimes planted with Dunn’s White Gum which, as discussed by F.A.0. (1979), ‘has been found to be one of the most cold resistant eucalypts’, or more commonly with Manna Gum.

There appears to have been no critical examination of the soil requirements of the Flooded Gum type. Hall et al. (1963) describe the tree as preferring friable or moist alluvial loams of good fertility, noting that it likes to be near water but will not grow on waterlogged flats. The soil can be derived from various parent materials, particularly alluvium or basalt, and the subsoil is usually clayey and moist, but not waterlogged. F.A.0. (1979), reviewing worldwide experience, states that it needs a deep, free-draining soil, doing best on fertile loam or clay-loam soils though also performing well on lighter sandy soils provided these are of adequate depth. These statements generally well fit NSW conditions for the type.

Floyd (1960a) gave details of the soils in three Flooded Gum sites being used for regeneration studies in the Coffs Harbour area. All were classed as yellow-brown podsolics, with moderately deep silty-loam or clay-loam A horizons, and they had been derived either from the local shales and slates or from alluvium ultimately derived from these. One site carried considerable quartz gravel on the surface, from quartz veins running through the local metamorphosed sediments. All appeared to have good moisture conditions, but to be well drained.

Turner & Lambert (1983) have reported on the nutrient cycling in a Flooded Gum stand in the Coffs Harbour area; the stand was 27 years old and carried a low but dense understorey of rainforest species. Of 453t/ha of aboveground organic matter present, 394t was in the Gum stand, 42t (9.3 per cent) in the understorey, and 28t in the forest floor. Specific nutrient contents in the organic matter were N 739 kg/ha, P 44, Ca 1254, Mg 247 and K 658. The undergrowth played a disproportionate role in nutrient accumulation and uptake. It contained 35%, 35%, 16%, 24% and 49%

respectively of the above nutrients, and accounted for 55%, 59%, 30%, 44% and 69% of their annual net aboveground accumulation. Fourteen per cent of the aboveground organic matter accumulation also occurred in the understorey. The annual net removal from the soil was 30, 1, 38, 5 and 31 kg/ha for N, P Ca, Mg and K respectively. Flooded Gum had very high accumulations of Ca in the bark, a feature shown by other smooth-barked eucalypts.

Several instances are known where previously good quality Flooded Gum sites, on low lying sites, have been clearfelled, and the subsequent regeneration has then failed with the sites being taken over by sedges and similar plants (e.g. close to northern boundary of Newry S.F. in late 1940s). In these cases clearing apparently allowed the watertable to rise, creating waterlogged conditions unsuitable for Gum growth. Mounding could have been a means for re-establishing Flooded Gum, but was apparently not tried. ('Bedding', apparently the equivalent of mounding, is used for establishing Flooded Gum on flat 'palmetto prairies' in southern Florida; Franklin, 1978.) Although intolerant of waterlogging, the tree will withstand short periods of flooding (Turnbull and Pryor, 1978).

Topographically, the Flooded Gum type in NSW occurs in the gullies and lower slopes though, as previously noted, individual stems of the tree may occur in higher topographic situations. By contrast, at its northern limits on the Atherton Tableland in North Queensland Flooded Gum *"is fairly widespread at altitudes above 600m, occurring.....in forest pockets within the rainforest belt. These pockets, which in some cases are up to 100 ha in extent, are commonly found toward the ridge tops, and it is rather confusing to anyone from NSW, on having 'Rose Gum' pointed out to them, to have to look up instead of down into the gullies"* (Baur, 1960). On the McPherson range and associated volcanic ranges of far northern NSW, Flooded Gum often occurs on elevated shelves that, however, possess many of the environmental features of gully sites.

As would be expected, the best growth of Flooded Gum usually occurs in the lower sites, and site quality diminishes up the slope. Whilst there appear to be no studies concerning the prediction of Flooded Gum site quality, Floyd (1960a, 1962) made use of the relationship in young seedlings in an effort to define the limits of the Flooded Gum type for satisfactory regeneration. In this case Floyd considered the site was satisfactory when the Gum seedlings had attained a top height of 60 cm or better in 4 months from direct seeding: this coincided with the area where Brush Box had occurred in the original forest stand.

Whilst climate, soil and topography all are factors in the occurrence and distribution of the Flooded Gum type, the major factor has to be **disturbance.** In the absence of disturbance, be it from fire, axe, tractor or cyclone, the Flooded Gum type is ultimately replaced by rainforest. A dense understorey appears at an early stage beneath stands of Gum regrowth - often initially of wattle or lantana, but soon supplemented by species from the rainforest - and this effectively precludes further regeneration unless some further form of disturbance opens it up. Floyd (1962) describes the position in these terms:

> *"Due to the fact that the Flooded Gum association is a disclimax arrested and perpetuated by fire and/or logging, the absence of these anthropogenic[4] factors gives rise to numerous seral communities. At one extreme, as the result of frequent fires and/or clearing, is produced grassland, whereas if the disturbances are less frequent, of the order of 20 to 200 years apart, the Flooded Gum disclimax is produced. If the undisturbed period exceeds about 200 years (approximating to the physical rotation of the species) then it is replaced by the more tolerant rainforest."*

In Nature, and in pre-European times, fire and storm would have been the usual instruments of disturbance, with deliberate Aboriginal burning likely to have been responsible for maintaining many of the Atherton enclaves within the rainforest, though such an explanation is less likely for NSW stands. White man has undoubtedly cleared much coastal Flooded Gum land for farming, but at the same time his logging and other activities would seem to have extended the Flooded Gum type within the remaining forest. It might be added that there is a close and inexorable connection between climate and fire occurrence, and some would hold that this connection is

[4] Big word, and not entirely correct; many perturbations (another big word) have occurred without any human influence.

sufficient to make any large scale replacement of Flooded Gum type by rainforest improbable, even though the type perimeter may expand or contract.

This reliance on disturbance is shared by Dunn's White Gum, and is of course a feature of a number of other eucalypt forest types of the more favourable moist sites, including much of the moist Coastal Hardwood types and, outside NSW, the Mountain Ash stands of Victoria and Tasmania.

2.4 Other Ecological Effects

The fauna of the Flooded Gum type does not appear to have been specifically studied, but the ground fauna could be expected to resemble that of the rainforest, while species typical both of eucalypt forest and of rainforest would be expected among the arboreal wildlife.

Provenance variation in Flooded Gum has been studied both in Australia and overseas. Pryor and Clarke (1964) reported at an early stage (2 years of age) on what appears to have been the first local trial, planted on a lowland site near Coffs Harbour and incorporating both a number of Australian sources plus seed from an elite stand in South Africa. They found that the stock from seed of good stands in the Coffs Harbour area was as good as, if not better than, the elite South African material, while seed from the southernmost natural source (Minmi, southwest of Hexham) gave the poorest results.

A later trial, incorporating some 20 seed sources representative of the species range in NSW and southern Queensland, was planted on two sites near Coffs Harbour in 1972 - one at low altitude (Wedding Bells, 15m) and one at high (Timmsvale, 550m), but both in areas where Flooded Gum has been commonly planted on a routine basis. Ades and Burgess (1980) have reviewed the results, which largely confirmed the earlier findings of Pryor & Clarke - low altitude coastal provenances from near Coffs Harbour and southern Queensland performed well on both sites, and the Minmi source was poor. However considerable variation was shown between Coffs Harbour sources where, for example, provenances from Orara East and Orara West were consistently excellent, one from Bellinger River uniformly poor, and sources from Tuckers Knob and Pine Creek gave rather variable results between the two sites (Tuckers Knob, at 8 years, was the best source at Timmsvale and the poorest at Wedding Bells). This variation has some international significance as the Coffs Harbour area is considered a valuable source for planting in both Brazil (Cromer & Pederick, 1980) and the eastern Transvaal (Darrow, 1983).

Ades & Burgess (1982) have also examined the gains to be achieved by selecting seed from elite local Flooded Gum stems. In this case batches of seed selected from 20 plus-trees in plantations near Coffs Harbour and Urunga were compared with a routine collection from the Coffs Harbour area and with 14 batches of open-pollinated seed from individual clones in a South African seed orchard. The progeny were planted at Wedding Bells S.F., and after 3 years the average relative volume of the local plus-tree progeny was 54 per cent larger than that of the local routine collection, and 43 per cent larger than from the South African seed orchard. This indicates considerable scope for improvement by selection from local stands, but little from the use of the more advanced South African Flooded Gum improvement programme. (South African figures suggest that a conservative volume growth improvement of 30 per cent can be achieved by selective breeding in Flooded Gum, a much higher gain than could be expected for any of the **Pinus** spp. used locally; (van Wyk and van der Sijde, 1983).

Though hopefully never of significance in Australia, the fungus *Cryphonectria* (syn. *Diaporthe*) *cubensis* is a serious disease of Flooded Gum in the more tropical parts of South America, and in Brazil the Atherton provenance has shown much greater resistance to this disease than NSW seed sources.

3. OCCURRENCE

The Flooded Gum type, following the distribution of the tree itself, occurs widely through the North Coast of NSW and in southern Queensland, and again in North Queensland at higher altitudes. As previously noted, in Central Queensland trees intermediate between Flooded and Sydney Blue Gums appear to take the place of Flooded Gum (Burgess & Bell, 1983).

In NSW the type is characteristic of the coastal lowlands from near Port Stephens to the Queensland border, but ascending to over 600m on the escarpment in a few areas, notably on the eastern Dorrigo Plateau. The southernmost occurrence of the tree is at Minmi, lying between, and to the north of, Wallsend and West Wallsend, on a creek system draining into the Hexham Swamp, but the type does not appear to have any significant presence until north of Port Stephens. Though widely distributed in suitable sites throughout the North Coast, areas of particularly good development of the type include Bulahdelah district, the Coffs Harbour area extending on to the eastern Dorrigo, and parts of Murwillumbah district.

Dunn's White Gum type has its main occurrence in the Urbenville area (Yabbra, Beaury, Donaldson, Koreelah S.F.s), with a small occurrence to the northwest of Coffs Harbour in Kangaroo River S.F. and nearby areas.

The area occupied by Flooded Gum type in NSW has not been accurately estimated. The inventory carried out in 1971-72 (Hoschke, 1976) included the type in a broader Moist Hardwood-Gully grouping, which showed 211 000 ha on State Forest and 600 000 ha in the State as a whole; an earlier 1963 estimate indicated that there were 102 000 ha of 'Flooded Gum and gully sites' on State Forests (see also discussion on the area of the Moist Coastal Hardwoods types; No. 1 of these Notes). As a very rough estimate, there could be 30 000 ha of Flooded Gum type on State Forests, and perhaps 80 000 ha in the State. To a greater extent than most other types, the area of Flooded Gum is likely to fluctuate over short periods, either as private forest is converted to pasture or crop or as suitable areas are converted or regenerate naturally to Gum: on Bulahdelah S.F. it is estimated that the area of Flooded Gum type has increased by 25 per cent over about 30 years. Whilst the areas involved are small in comparison with most other major type groupings, the productivity of the type is particularly high.

The type is not portrayed on the small-scale map of forest types in NSW (Forestry Commission of NSW, 1978), but features on individual State Forest type maps.

4. UTILISATION

The properties of the timber of Flooded Gum (which bears the standard trade name of 'Rose Gum') and of its more common associates are summarised in Appendix 3, from Bootle (1983). Of these by far the major species in the type is Flooded Gum, which yields a relatively light, pale, straight-grained timber with a coarse but even texture. It is easy to work, dries readily and glues well, though veneers are prone to end- splitting. Bootle notes that it is unsuitable for use as preserved poles because of the difficulty in obtaining preservative penetration in the vicinity of knots, and because of the poles' tendency to degrade from end-splitting. The appearance of the timber is sometimes marred (and perhaps occasionally enhanced) by gum veins, scribble marks caused by a borer, and grub holes made by a large wood moth. Some provenances or sites seem more prone to defect than others. Large stems are frequently very faulty.

The timber appears to have been regarded as rather inferior to the similar Sydney Blue Gum, though suitable stems have probably always been milled. However greater interest in the species on the North Coast seems to have developed in the 1930's, with markets for furniture and mouldings. At the same time it was also used for fruit cases, for which Flooded Gum is particularly suitable *"since the shooks can be stored for some time before use, even though in the green condition, without risk of serious fungal staining"* (Bootle, 1983). Another advantage of Flooded Gum for use in cases is its ability to be nailed close to the ends without splitting - a property that also in part accounts for its use in mouldings, feature panels and similar applications. Tests later proved its suitability for paper pulp, leading to the purchase and reforestation of large areas of former farmland in the Coffs Harbour area by Australian Paper Manufacturers Ltd. (Pryor et al., n.d. but about 1967). These plantations were subsequently (1984) purchased by the Forestry Commission. Flooded Gum has proved to be a very suitable species for certain forms of plywood production, and this use has increased following the phasing out of routine rainforest logging in northern NSW.

Commenting generally on the utilisation of Flooded Gum, one forester with long experience on the North Coast has commented:

> *"The versatility of the species is a feature that impresses me. While I was at Bulahdelah hardly a week would go by without someone (asking) where they could obtain regular supplies, for uses as diverse as furniture, handles, tiling battens, spools for barbed wire, mouldings, etc. It is still an easily marketed species."*

The wood properties of Flooded Gum were examined by Bamber et al. (1969), who found that in young plantation trees (20 years old) basic density, mean fibre length and polyphenol content of the heartwood increased with distance from the pith outwards at each of the four levels sampled (30cm, 8m, 15m and 23m from ground level). Excluding the lowest level, a positive correlation existed between fibre length and tree height. The 16-20 year wood from the young trees had lower basic density and shorter fibres than the outer wood of old, naturally growing trees.

Bamber et al. (1982) examined wood from very fast grown, young (2½ years) trees of Flooded Gum to determine whether this affected timber properties. The wood of the fast-grown trees was similar to that of the slower grown controls with respect to density and fibre dimensions, but vessels were fewer and smaller, and the ray volume greater in the fast grown trees. By contrast, Schönau (1974) found reduced specific gravity in the faster grown Flooded Gum trees in South Africa.

Although many stands contain only Flooded Gum, other useful timber species (perhaps most typically Brush Box) may also occur and be utilised.

An unusual associate of Flooded Gum on Wallingat S.F. is Cabbage Tree Palm, whose stems are highly valued for conversion to stakes used by the important local oyster industry. The management of this resource has been described by Bishop (1982). Some of the more northern stands often have Lawyer Cane, which has in the past been harvested for its cane, growing in the understorey, and Duboisia, which is spasmodically harvested for its drug-bearing foliage, commonly occurs in regeneration coupes and may persist along roadsides and in local openings.

The type, with its development of dense undergrowth, is normally unsuitable for grazing by domestic stock, though this may not be the case with plantations established on former pasture. The type is not one that is sought after by apiarists.

Occurring typically in the lower coastal creek gullies, the type appears to have only limited significance for general catchment protection, but is undoubtedly of importance in protecting stream banks. Because it is so much a type of the immediate creek-side strip, its management and utilisation may at times tend to conflict with the Standard Erosion Mitigation Conditions for Logging and Clearing in NSW - conditions that were not really designed for flood plain application.

The tall, spar-like stems with their stark white bark and their dense undergrowth have strong visual appeal, and must count among the State's most photogenic stands. The southern approach to Pine Creek S.F. along the Pacific Highway, much of the highway frontage to O'Sullivans Gap Flora Reserve, and the drive through Bruxner Park F.R. are representative of the more public sites where this visual value is particularly high. Unless clearings, picnic facilities or walking tracks have been provided and maintained the type is not particularly suited to recreational use on the ground because of its dense undergrowth, the prevalence of lantana and other thorny plants, and the frequency of leeches.

5. HISTORY OF USE AND MANAGEMENT

Despite the extensive clearing of river flats and their upstream extensions along the North Coast for farming, the Flooded Gum type is one type that has probably benefited from European settlement. Though the early accounts have not been examined, it seems likely that Flooded Gum was originally less prevalent than it is to-day, with scattered older stems and occasional patches of regrowth in a matrix of rainforest. Logging in the rainforest and efforts to clear the land would in many cases have provided excellent opportunities for regeneration. Certainly within areas still under forest, there would be a greater area of Flooded Gum present today than 200 years ago, and on many North Coast forests some of the best stands of Flooded Gum lie along the routes of the former logging tramways (e.g. Bulahdelah, Wang Wauk, Landsdowne and Orara East S.F.s). Internationally, of course, Flooded Gum has been the great success story of the eucalypts, with a major and undoubtedly permanent presence in Africa and South America - almost a reverse case of *Pinus radiata*.

Suitable stems of Flooded Gum would have been harvested, along with other coastal eucalypts, for milling through the latter half of last century, though as previously noted it was regarded as a rather inferior timber until about the 1930's.

The oldest known possibly deliberate regeneration treatment for Flooded Gum occurred on what is now Andersons S.F. between 1926 and 1928. The story of this area is worth recording, if only to illustrate that different times have different mores. During World War I the Forest Guard and the local Lands Surveyor at Kempsey carried out a joint inspection of some of the land up the Macleay River to determine its suitability for State Forest dedication. In the process they came on an area carrying a good stand of Red Cedar. Apparently rather than recommend this for dedication, they selected the land in their own names and sold off the Cedar. The Forest Guard then had his selection farmed for several years, after which it was allowed to regenerate, primarily with Flooded Gum. The regeneration may have occurred through direct seeding, as the species is not otherwise known to occur naturally within several kilometres of the site.

He then offered to exchange the now regenerated forest for an area of 'useless' land close to the ocean on Nambucca S.F. The Forestry Commission agreed to this exchange, and the area carrying the young plantation became an extension to Andersons S.F., which had been dedicated following the original inspection. Despite his entrepreneurial skills, the Forest Guard remained with the Commission, ultimately becoming District (now Regional) Forester at Kempsey and finally retiring in 1947.

An early planting of Flooded Gum occurred about 1932 on Craven S.F., beyond the natural occurrence of the species. In this case the planting was overtaken by natural regeneration of Sydney Blue Gum, and little if any Flooded Gum survived. Another planting of two Flooded Gum seedlings, which had been knocked out of the road batter during grading, took place on Tamban S.F. that same year, and a plaque at the base of the larger tree tells the story;

> *"This Flooded Gum was planted by Hector Jamieson, a long time local sawmiller, on 11th February, 1932 to celebrate the birth of his daughter, Heather Yarwood."*
>
> *"Measurement in 1982:*
> *Height 40.5 metres;*
> *Diameter Breast Height 95 cm,*
> *Bole Length 27 metres,*
> *Log Volume (est.) 16.2 m^3 gross."*

More or less routine efforts to regenerate Flooded Gum sites commenced in the late 1930's, following the development of a market for the timber in the joinery and moulding fields at Urunga. Initial efforts at natural regeneration gave rather unpredictable results, and in 1940 about 7 ha of the species were planted at Pine Creek S.F., using tubed stock. While natural regeneration continued to be used, planting was also employed over the next decade, both in the vicinity of Coffs Harbour and in the Murwillumbah district. Some planting in the Murwillumbah area was also carried out for, and on land owned by, the Banana Growers' Federation (B.G.F.), under the oversight of Mr. Tom Rummery, who had formerly been a local forester with the Forestry Commission. About 1950 direct seeding became widely accepted for Flooded Gum establishment. Initially broadcast sowing was used (hand throwing of a sand/seed mixture), but this was largely replaced by spot sowing ('pepper-shaker' technique) about 1960, and this continued through to the late 1960's, being adopted in areas throughout the NSW range of the species. In 1962 the area established artificially was 320 ha, but fears about the quality of the timber from the artificially established and fast growing stands became widespread, and establishment was curtailed for some years (Forestry Commission of NSW, 1966).

In the meantime Australian Paper Mills Forests Pty. Ltd. (A.P.M.) had been purchasing large areas of marginal farmland in the Coffs Harbour-Urunga-Nambucca region, and had started planting the cleared areas chiefly with Flooded Gum. Work by both the company and by the Commission, more or less in conjunction, led to the use of small pressed peat pots ('jiffy pots') for raising eucalypt seedlings, and these were used by the company for most of its planting (Pryor & Clarke, 1964; Pryor et al, n.d.).

The enthusiasm of the company for Flooded Gum, which at that time it saw as establishing the raw material resource for a future pulp mill, led to its planting some sites that were not particularly suited to Flooded Gum growth. This enthusiasm became contagious, and after several years' hiatus the Commission resumed the active establishment of Flooded Gum regeneration, often as part of broader eucalypt plantation schemes aimed now primarily at smallwood (pulpwood, mining timber) production, but with the expectation that a proportion of the crop would be grown on to larger size for veneer or possibly select grade sawlogs (Forestry Commission of NSW, 1972). Regeneration in these schemes was largely established by the planting of seedlings in jiffy pots (see section 6.5.2). The planting of Flooded Gum seedlings was also commonly employed on the North Coast as an enrichment technique along snig tracks and on log dumps, including some sites that did not originally carry Flooded Gum. The plantation programmes ceased about 1982, but jiffy pot planting remains a major technique for Flooded Gum regeneration.

The A.P.M. plantations were purchased by the Forestry Commission in 1984, and the former B.G.F. plantation in 1985, as additions to the State Forest estate.

6. REGENERATION REQUIREMENTS

6.1 Regeneration Establishment

Since the 1940's the emphasis in deliberate regeneration of the Flooded Gum type has been on the use of artificial means. Nonetheless throughout this same period natural regeneration has also been occurring in managed forests, though it has been the subject of little research and of few reports.

Both natural and artificial systems of regeneration rely upon certain basic features of the species - abundant and regular seed production, rapid germination and early growth, absence of lignotubers, intolerance of shading and of root competition. Artificial regeneration has been generally favoured because of its reliability and also, in the days when fire was the major means of site disturbance, because it provided greater flexibility in the conduct of operations. It has also allowed for the introduction of improved strains of seed, more regular spacing, and the use of fertilisers, leading to increased production on what are among the most favourable sites available for tree growth. Natural regeneration can be cheaper and, with mechanical site disturbance, has a strong likelihood of reliability, though spacing always is more irregular. It can also maintain a broader genetic base in the regrowth stands.

Both approaches result in the establishment of patches of even- aged regeneration, and their management beyond the early establishment phase is essentially the same in either case.

6.2 Seeding Habits

For northern NSW, Floyd (1961) records the flowering season of Flooded Gum as April to August.

The process of flowering and subsequent fruiting has been studied in greater detail by Hodgson (1975, 1976a & b) in South Africa. The study site was at somewhat lower latitude but higher altitude than northern NSW sites, but many of the basic features should be no less applicable to NSW conditions. The axillary inflorescence bud could be recognised from vegetative buds by its slightly swollen appearance when it was about 3mm long. From that time until flowering an average period of about 4 months (in some cases 5 months) elapsed. Hodgson identified three stages during this period - the first of about 6 weeks (range 3-9 weeks) before the bracts covering the inflorescence are shed; the second of about 6 weeks (3-11 weeks) until the outer operculum is shed; and the third of about 4 weeks (1-7 weeks) until the inner operculum is shed and the stamens unfold, most of the pollen being released within about 2 days. Stigmas were receptive for a period of about 7 or more days from the time the anthers open (anthesis), though pollen did not start to germinate on the stigma until the second day after anthesis. Maximum seed yield was obtained after cross-pollination done on the fifth day, at which time the stigmas were beginning to become swollen and sticky. In the South African site the main season of flowering was from April to June, though there was some flowering throughout the year; at a secondary study site at lower altitude (760m, c.f. about 1 300 m) the main season was February to March. Flowering occurred on plants of from 2 to 3 years of age, whether raised from seed or from cuttings.

Hodgson found that seed became viable at between 3 and 5 months after flowering, at a time when the capsules were turning brown and the seed extracted from them was dark brown in colour. He suggested that at least 5 months should elapse before capsules are harvested, and he noted that under these circumstances it is possible to complete a Flooded Gum generation in 3 to 4 years.

Floyd's observations suggested seed maturity in about 6 months (early in year after flowering), though natural seed shed normally did not occur till the next spring (slightly over a year after flowering; Floyd, 1961). There is thus viable seed held in the crowns of the trees throughout the year, with an overlapping of crops in the late spring and early summer. For routine seed collection, Boland et al. (1980) suggest the months of January to April as being best, though in the Urunga district, with a long history of successful seed collection, late November and December is the preferred time for collection. Floyd (1960a) indicated that seed was mature when the capsules changed from green to purple, which would be the equivalent of Hodgson's description of their turning brown.

Floyd also noted that Flooded Gum usually bears a good crop of capsules each year, though occasionally there is a light crop which makes seed collection uneconomical. He suggested that the seed crop was inversely correlated with the spring rainfall about 15 months earlier, when the inflorescences were first formed; a low spring rainfall would usually result in a good seed crop, but after successive dry springs the ensuing seed crops would be reduced due to the depletion of the trees' reserves.

Boland et al. (1980) give the average number of viable seeds of Flooded Gum as 652 000 ± 344 000 per kilogram of seed plus chaff; the highest number recorded (in 157 tests) was 2 100 000/kg.

The seed when collected contains a large proportion of infertile particles (chaff) and efforts to distinguish or separate these from the fertile seed have not been very successful, though Hodgson found that, by retaining only the seed plus chaff that would not pass through a sieve of gauge 500mm, 84 per cent of the viable seed was retained, the percentage purity was increased (i.e. proportionately more chaff was discarded), and the fraction of seed retained was the best as regards initial vigour and survival.

Floyd found considerable variation in both yield and viability of seed from different types of trees: his results are shown in Table 2. Seed from the dominant tree would provide 9 times as many effective seedlings as that from the poorer co-dominant.

Table 2

COMPARISON OF SEED FROM VARIOUS SEED TREE CLASSES
(adapted from Floyd, 1961)

Seed Tree Class	Dominant	Co-dominant-Crown Fair	Co-dominant-Crown Poor
Mean weight of seed/tree	2.41 kg	1.21 kg	0.82 kg
No. viable seeds/kg	833 500	663 700	432 200
Mean no. viable seeds/tree	2 010 000	800 000	350 000
Mean no. field germinates/tree	137 000	86 000	16 000

Seed for routine collection is normally obtained from previously selected superior stems. The trees are felled as part of a commercial logging operation during summer. Capsule-bearing branchlets, up to 1 cm or slightly more in diameter, are cut from the crown and placed in containers for transport back to the base. Extraction sheds have been built, allowing the branchlets to be spread, under shelter, on wire netting, where they are periodically shaken or turned over, allowing the seed to escape and fall on to a collecting tray below. Alternatively the capsules may be exposed in the sun each day on canvas sheets, the branchlets again being moved about to facilitate seed release. Extraction takes from about 3 days to 2 weeks, and the seed is then sieved to remove the coarser impurities, and placed into storage with an insecticide. Storage at a temperature slightly above freezing has proved best for Flooded Gum seed: after 17 years seed stored at 20ºC had not lost any of its viability or vigour. By comparison, seed stored at -4ºC deteriorated in vigour (though not in viability) after 12 years; seed stored at room temperature in sealed containers deteriorated after 4 years and was useless after 5 years; and seed in an unsealed container at room temperature was unfit to use after only 12 months (Forestry Commission of NSW, 1971-72).

Dunn's White Gum, the other species of major interest in this type, is in comparison with Flooded Gum a shy seeder. Boland and his colleagues record its flowering season as March to May, and list September to February as the most suitable months for seed collection. They note that it carries sparse seed crops and that the seed is difficult and costly to collect. It is also slower to come into seed production than Flooded Gum: Boland et al. quote some Rhodesian work where, in a 6 years old plantation, 64 per cent of the Flooded Gum trees carried flowers or flower buds, whereas there were none on the Dunn's White Gum trees.

The Dunn's White Gum seed is larger than Flooded Gum, averaging about 237 000 ± 125 000 viable seeds per kilogram.

The seeding habits of other species associated with this type are discussed in No. 1 of these Notes (Moist Coastal Hardwoods).

6.3 Seed Availability and Germination

Floyd (1960a, 1962) recorded the distribution of seedlings around a large Flooded Gum tree standing at the edge of a regeneration coupe. With its seed-bearing crown at a height of about 48m, effective regeneration was produced up to about 60m from the crown edge. The variation in the distribution of seedlings around the tree ranged from 0.55 to 1.28 times the height of the tree, from the edge of the tree. On this basis, four or five well-distributed seed trees per hectare would be ample to provide regeneration on a suitably prepared coupe.

Floyd also examined the germination requirements of Flooded Gum. All seed germinated at temperatures between 24 and 32ºC, but speed of germination was greatest at 26º, when effectively only 10 days were required to complete the test. Boland et al., using temperature quantum gaps of 5ºC, recommend a temperature of 25ºC for Flooded Gum, with the first count at 5 days and the last at

14 days; by comparison Dunn's White Gum is rather faster to germinate (first count at 3 days, last at 10 days), and its germination is equally effective at 25 and 30ºC.

Floyd also found that only about 45 per cent of the seed germinated in complete darkness; exposure to light was necessary before the remainder commenced germination. Floyd (1962) notes that this has some practical significance as some seed that is buried can remain dormant for a period (suggested by Floyd as 2-3 months, but possibly longer), even though germination conditions are otherwise suitable. Exposure to light (e.g. following soil movement in a storm) will then allow these dormant seeds to germinate.

Another study by Floyd showed that seed falling on a dry seed bed can lie there until conditions suitable for germination occur: in practical terms, if direct seeding is being used, sow straight after site preparation rather than delay sowing until rain has fallen. The dry seed can tolerate temperatures up to 66ºC.

In the field, under suitably moist conditions, some seed will have germinated after 4 days. If then subjected to dry conditions, these seedlings will die. If the dry conditions occur within less than 4 days of moist conditions, the viability of the seed is not affected but the subsequent germination of the seed is prolonged and may not be complete for more than 6 weeks: a short period of moist conditions, and then dry conditions, induces a form of dormancy in at least some of the seeds.

6.4 Site Preparation

Part of the reason for the changing methods of regeneration establishment with Flooded Gum relates to evolving methods of site preparation.

Early logging methods created insufficient site disturbance for adequate regeneration unless the site was burnt. This led to clear felling with retained seed trees, and the burning of the debris. Because of their intolerance to fire most of the seed trees were usually killed by the fire (though not before the seed was shed). Delaying the burn could result in being caught by an early wet season or facing a fire under bad bushfire conditions; too early a burn meant the seeds' falling in a dry spring, often with heavy loss.

Planting was a means of introducing much more flexibility and surety into the system, and of avoiding the loss of seed trees by fire.

As greater experience was gained with fire in the moist Gum sites, considerable skill was developed in burning successfully in the early summer, and direct seeding was introduced to reduce costs while still saving the waste of seed trees and ensuring a more even spread of seedlings; spot sowing replaced the earlier broadcast sowing to save seed, to reduce stocking to a more manageable level, and to utilise what were found to be the best microsites for seedling establishment. Subsequently jiffy pots proved to be little more expensive an establishment technique than sowing, and were more suitable than sowing on the difficult sites; their use became widespread both in the forest and on former pasture, where planting had always been necessary.

Meanwhile logging equipment became larger and more powerful so that it was feasible to create appreciable areas of suitably disturbed site in the course of logging, without the need for burning. This had the effect of delaying the onset of weed growth and reducing its quantity, thus allowing natural regeneration to establish over a longer period or, if desired, for artificial regeneration to be undertaken.

Floyd (1960a) has well described the importance of a suitable seedbed to the early establishment of Flooded Gum:

> *"The very small size of the Flooded Gum viable seed coupled with its exalbuminous character imposes several serious restrictions upon its successful germination. Unless the newly emerged radicle can quickly penetrate into moist soil, certain death through desiccation must result.*

Also, due to the absence of reserve food supplies, the young seedling must be able to obtain mineral nutrients from the soil very soon after its germination if growth is to be sustained. Therefore the type of seedbed encountered is of very great importance in the regeneration of Flooded Gum."

In Floyd's study best establishment occurred on sites where top soil had been accumulated, followed by sites where a layer of charcoal covered the soil and helped conserve its moisture, and then on areas of mineral soil, where the proximity of a log was an advantage. Unburnt (litter covered), scoured, stony and partly waterlogged sites were generally poorer, as might be expected. Subsequent height growth was not greatly influenced by seedbed type, though it was best on accumulated topsoil or where shaded by an adjacent log. However seedlings on charcoal sites (typical of burnt sites) had consistently greater weights than those from mineral soil (typical of mechanical site preparation), and also had better root development. Survival and growth also tended to be better on moist sites than on the more exposed sites.

Although burning generally produced the better growth, mechanical disturbance resulted in a satisfactory seedbed for regeneration from seed.

On former grassland and pasture sites, treatment to break up the grass sward is necessary. Floyd (1962, 1969) found little benefit from chipping the planting sites, while on A.P.M. land it was found that direct seeding was not satisfactory regardless of site treatment, but scalping following by planting and fertilising often led to excellent establishment (Pryor & Clarke, 1964; Pryor et al., n. d.). Weedicide treatment (e.g. Roundup), though apparently not tried for routine Flooded Gum planting, should also be a suitable means for controlling grass and permitting Gum establishment.

6.5 Artificial Regeneration

6.5.1 General

As previously noted, artificial regeneration of Flooded Gum has been widely employed and, over a period of about 30 years, has passed through a number of stages involving different approaches to both planting and direct seeding. Since about 1970 the use of jiffy pots has been almost universal where artificial regeneration is concerned, but some of the other techniques have an historic interest that warrants including a brief description of them.

6.5.2 Planting

The earliest recorded plantings were carried out using seedlings raised in **metal tubes.** Seed was sown into a seed tray or seedbed, and the seedlings dibbled into a 20cm x 4cm metal tube of soil when about 2 - 3cm tall. The tubed seedlings were then held, initially under shelter and then in the open, till the plants were ready for planting - usually at the start of the wet season, when about 15cm tall. It was essentially the same technique as is still used in the Commission's amenity nurseries, and it gave many excellent results both in reforesting forest sites and in planting grasslands. For difficult sites it continued to be used up to about 1965, but its cost - in producing seedlings, transporting them and planting them - was always a disadvantage.

Baur (1959) examined several methods of raising Flooded Gum seedlings. These included metal and wooden veneer tubes, seedlings raised in trays that were taken to the field, and pressed peat "jiffy pots". All gave good results, though the two tubes proved more costly to handle than the other methods. The jiffy pots, at that time available only as individual pots, were the most economical to plant as the whole pot was simply planted in a small hole, but they were awkward to handle in the nursery.

Baur also investigated **open-root planting,** but survival rates were poor. The most promising results, giving a 62 per cent survival rate in the field, involved seedlings that had been transplanted in the nursery when 10 weeks old, but growth of the survivors was consistently poorer than that of the container-raised seedlings. A later study (Horne, 1975-76) involved repeated rootwrenching at 3-4 weekly intervals for some 3-4 months, and the top-clipping of the seedlings: at the time of planting the seedlings were about 12cm high with a stem diameter of 4-6mm at ground level.

Planting took place in July, August and September under conditions respectively described as moist, dry and very dry. Survival after 3 months was:

July	93%
August	83%
September	67%

Such results are sufficiently encouraging to warrant further investigation. Open-root planting of Flooded Gum is not common on the world scene, though it is apparently used in Kerala State, India (F.A.O., 1979), while Meskimen (1974) has given an interesting account of the production of "washed" Flooded Gum and other eucalypt seedlings in southern Florida: the seedlings were raised in containers, and the container medium gently washed away to leave an intact root system on the seedlings before they were taken to the field for planting. Survival rates for mid-summer planting were comparable with those of container seedlings (over 95 per cent), and the early growth only slightly slower.

The use of **jiffy pots** was further developed in the APM plantings (Pryor & Clarke, 1964; Pryor et al., n.d.), particularly with the introduction of the small pots joined into blocks of 12: this gave the pots greater stability in handling, while allowing the ready separation of the pots for planting. In the Commission the new technique was initially developed for Blackbutt, as direct seeding was still the regeneration technique for Flooded Gum (Floyd, 1965), but it was soon being used along the North Coast for a number of species on a rather larger scale than some of the Commission's senior officers at the time could readily countenance.

The basics of the technique were described by Holmes and Floyd (1969), and more recently in updated form by Horne (1979). The account given by Horne still applies to the technique in current use, though as indicated by Horne there are local variations, e.g. some nurseries sow seed directly into the pots and subsequently thin out the germinates to one per pot, others raise the young seedlings in trays and dibble them into the pots.

The technique for site preparation and planting, as used at Coffs Harbour, has the following outline:

- Clear the site thoroughly and windrow with the windrows running up and down the slope during late winter (the dry period in this area).
- Use a large crawler tractor for this purpose. A Caterpillar D8 or D9 size is essential. If heavy equipment is used the material can be pushed uphill, away from rainforest gullies and away from existing clumps of retained vegetation. Thus when the windrows and stacked material are burnt no damage is done to this retained vegetation.
- Following clearing the area must be root-raked - this is important. Root-raking is undertaken across the slope, thus minimising any soil erosion. More importantly this raking is creating a ploughed effect that greatly assists in planting by reducing planting costs and guaranteeing the establishment of the crop.
- Burn windrows in early spring.
- Plant with the 'first summer rains'. If early storms occur in October and the soil is moist, plant immediately. Attempt to have all planting completed by Christmas. Cease planting if soil moisture is insufficient. Add fertilizer pill in close proximity to the plant, but not with it, during planting.

If these rules are followed plant survival will be in the vicinity of 90 per cent, and the plants will keep abreast of or above the prolific summer weed growth. By the following winter, when food stress becomes great for browsing animals, particularly wallabies, plants will be 60cm high and thus above browsing height.

The seed used is normally collected locally from superior stems and is held in cold store till required. In the more southern districts planting may start earlier or continue later, though later planting runs the risk of wallaby browsing.

Planting usually aims at a spacing of about 4 x 4m, and each seedling is fertilised at the time of planting by a 25 g sulphur-coated slow release fertiliser pill of the composition 13:11:0:25 N:P:K:S. (These pills are commonly known as 'Horne Pills' after R.R. Horne, who carried out much of the developmental work and who encouraged their commercial production.) The pill is inserted in the soil about 20-25cm upslope from the seedling (Mackowski, 1979-80a). The pill promotes more speedy early growth of the seedlings, as indicated by the mid-season height growth response figures given by Mackowski for Flooded Gum planted on Wild Cattle Creek S.F.:

Control (no fertiliser): - 14.4cm height growth since planting
Pill: - 55.8cm

Besides the use of planting for establishing open plantations, the technique has been commonly employed for enrichment along snig tracks and logging openings, for the rehabilitation of log dump-sites, and as an insurance in sites where prime reliance is on natural regeneration. It can be appreciated that the distinctions between obvious plantation and natural regeneration blur under these circumstances, even without the added complication of direct seeding regeneration, and consequently the Forestry Commission no longer maintains a register of Flooded Gum plantation areas. However when last published (Annual Report, 1980-81) this showed 2 070 ha of Flooded Gum on State Forest and 6 170 ha privately owned: the bulk of the latter were those established by APM, and now acquired by the Commission.

6.5.3 Direct Seeding

Direct seeding came into vogue about 1953, initially using a **broadcast sowing** technique. It appears to have started in Urunga district, probably on Pine Creek S.F., but was soon adopted elsewhere. It was this technique that spurred much of the early work on Flooded Gum regeneration by Floyd (1960a, b). As described by Floyd, the basic system was to mix 1 lb. (0.45 kg) of Gum seed with 8 shovelfuls of damp fine beach sand: the sand mixture provided a more even distribution of seed, and also increased the range of each sower as the light seed adhered to the heavier damp sand. The mixture was used to sow 1 acre (0.40 ha): in metric terms the mixture would have been roughly 1 kg of seed in about 20 shovelfuls of sand per hectare. The mixture was carried in a canvas or hessian bag slung over the shoulder, and a gang of workers would move across the regeneration coupe, each sower throwing the sand/seed mixture by hand to reach the extremity of the next worker's sowing.

The technique produced some spectacular - at times embarrassingly so - successes. It distributed between half and one million viable seeds per hectare, and produced stands ranging from 35 000 to 125 000 stems per hectare, with mean top heights of about 4.5m at age 18 months.

Floyd investigated the effects of reducing the sowing rate. One noticeable effect was that on good sites a less amount of seed produced almost as many plants as a much greater quantity, and could give better growth. Floyd noted that seedling distribution was always irregular, with seedlings clumped in the more favourable sites; *"... even a heavy rate will not reduce the spacing between groups, but merely aggravate the overcrowding on the more favourable spots"* (Floyd, 1960b). Floyd was able to recommend variable sowing rates, ranging from 140g of seed per hectare on the best sites to 2.5 kg on the most difficult. At the same time Floyd investigated the possibility of spot sowing, using a quantity of seed designed to carry about 50 viable seeds sown within a 30cm diameter circle at a spacing of 2.4 x 2.4m: this was equivalent to about 140g of seed/ha. The results were excellent (Floyd, 1960a, b), and led to further work which resulted in the adoption of spot sowing on a routine scale for Flooded Gum regeneration over much of the North Coast. An early account of the technique used was given by Floyd (1961) and a somewhat later version by the Forestry Commission of NSW (1966):

> *"Sites to be established are cleared of existing forest cover during the spring, summer and early autumn, usually by mechanical means (eg bulldozer with tree-pusher). The debris from the clearing is burnt from mid-summer through to late autumn, and sowing is carried out immediately following the burn and before any weed growth can become established. Where large areas are to be established, clearing and burning are often carried out progressively so that individual sections of the coupe may be sown over a period of six or more months.*
>
> *Seed is sown from hand-carried containers (screw-topped jars or plastic containers), with the lid perforated with holes through which the seed can be shaken, but will not flow freely. The holes are calibrated to yield 110 g of seed from 680 shakes[5] (70 holes of 1.5 to 2.0 mm diameter). Spots sown are spaced about 2.4 m by 2.4m, but the spacing is kept flexible so that advantage can be taken of locally favourable microsites (local accumulations of loose topsoil, soil enriched by ash and charcoal, etc.). Sowing rates vary with site from 280-550 g seed per hectare, distributed over these small (up to about 20cm diameter) spots at the specified spacing."*
>
> The seed used is not normally treated in any way before sowing, except for storage.

(Although the above account states that seed was not treated in any way, in some districts an insecticide was added to the seed to deter possible removal by ants, particularly where sowing extended any distance up the slope.)

Floyd's account noted that the 'pepper shakers' yielded a constant weight of seed per shake, provided the shaker was not more than 75 per cent nor less than 25 per cent full. The shakers carried about 250 g of seed when three-quarters full. Sowing was carried out by a gang of men walking abreast 2.4m apart, and sowing a spot of seed approximately every 2.4m, but with discretion to vary the spacing by 60cm in any direction to take advantage of the most suitable site.

On most occasions the results were excellent. The individual shake was meant to deliver about 125 viable seeds per spot. Sometimes these remained **in situ,** sometimes they would wash and be spread by rain, but usually distinct clumps of seedlings would appear, and when these reached a height of about a metre (usually about 8 months from sowing) they were thinned to the best single stem by the use of a cane knife or machete. As Floyd pointed out, this thinning of the established stems had advantages over a culling of unthrifty plants in the nursery, and the thinning of the clumps was much cheaper than the thinning of broadcast sown stands (about a sixth the cost).

Relying as it did on the germination and growth of plants from seed, direct seeding in either form ran a real risk of being overtaken by weed growth if there was any delay between the onset of growing conditions after site preparation (particularly by burning) and the sowing of the seed. Part of the trick was to sow as quickly as possible: as previously noted, seed sown into dry conditions would remain until moisture was available for their germination, whereas the rapid development of weeds meant that a delay of a fortnight in sowing the Gum on a moist seed bed would result in failure. The weed problem is further examined in Section 6.7.

Spot sowing was the main means of regenerating Flooded Gum during most of the 1960's, but was subsequently replaced by jiffy pot planting as the costs of planting were reduced. It tended to be less reliable in more southerly parts of the North Coast and in the Central Coast than it was further north (Floyd, 1969), apparently due to the less reliable wet season. It resulted in some excellent stands of Flooded Gum, achieved at relatively low cost.

[5] In Imperial measure the basic rate was 4 oz. per acre, distributed at a spacing of 8 ft. by 8 ft., which equals 680 spots per acre.

6.5.4 Vegetative Reproduction and Tree Improvement

Coppice in Flooded Gum will be briefly considered in Section 6.6; here the emphasis is on the propagation of vegetative clones of the tree, a subject that has been reviewed by F.A.0. (1979). This notes that graft incompatibility is a common problem with Flooded Gum, and for this reason the use of cuttings tends to be preferred. It is, of course, also much simpler.

Selected trees are felled and allowed to coppice. *"Coppice shoots from the stumps will strike quite readily under standard mist spray from most trees, giving at least 50 per cent success in Australia if taken during spring or early summer*" (F.A.O., 1979). This technique has been used on a routine scale in the Aracruz Cellulose plantations in Brazil, using both Flooded Gum and particularly the hybrid with Timor Gum:

> *"... the company has embarked on a programme of raising cuttings for operational planting. Climatic conditions are ideal for rooting throughout the year, shade and water being the only additional requirements. Outstanding individual trees are selected in the field, felled and allowed to coppice. The coppice shoots are then removed, cut into lengths, dipped in rooting hormone and set into a sand/clay medium. Shade is removed after 40 days and the cuttings are ready for planting after another 40 days. Growth rate of cuttings is quite phenomenal, the best E. grandis hybrid clones in one test being 24 m high and 17cm DBH at 4 years. Planting continues throughout the year with seedlings or cuttings being watered in to ensure high survival. The company intends to have its entire establishment programme of 7 000 ha per year based on cuttings by the beginning of 1981. French delegates at the Symposium reported on a similar programme with eucalypt cuttings in the Congo (Cromer & Pederick, 1980.)."*

A more detailed description of this project, by Boland (1984), is included as Appendix 4.

Other approaches to vegetative propagation have involved tissue culture (Cresswell & de Fossard, 1974), which may find a place in the cloning of mature trees. However its relative ease would suggest that the cutting technique is the most likely approach to be used where vegetative reproduction is required; eg in breeding programmes or possibly even, as in the Brazilian example, for the mass production of particularly high yielding or otherwise desirable clones.

The improvement programmes involving Flooded Gum are well under way in a number of countries where the species is an important exotic (eg South Africa; Hodgson, 1975; van Wyk & Roeder, 1979).

A start to such a programme has been made in NSW and a review of this programme has recently been reported (Forestry Commission of NSW, 1983a):

> *"Trials established in the 1960s and early 1970s identified provenances from coastal areas around the town of Coffs Harbour as the most suitable for planting in New South Wales. Approximately 150 plus trees were selected in plantations in this region and these have formed the basis of the current breeding programme. They were selected for volume growth, stem straightness and effective self-pruning and occlusion of branch stubs. Open pollinated seed was collected from plus trees and was subsequently used to establish two seedling seed orchards.*
>
> *A progeny trial was also established using this seed. Its primary aim was to estimate the gain resulting from plus tree selection but it also tested a number of improved seedlots imported from the Republic of South Africa which could potentially be used in the local breeding programme.*
>
> *Twenty plus trees were randomly selected from the 150 available. Four different, mixed seedlots were then made up, each consisting of equal weights of seed from five of these trees. This was done as the mixtures were considered to provide more realistic comparisons with other seedlots than would single families. These were compared in the trial with a "'routine' and a "poor form" seedlot as well as the South African families.*

The "routine" seedlot was collected in the same area as the plus trees but the parents were chosen at a much lower intensity of phenotypic selection. It was used for routine plantation establishment in 1977 and is typical of the seedlots used in recent years. The "poor form" seedlot was collected from a single vigorous tree, again near Coffs Harbour, but the parent had very large persistent branches. The South African families were all progeny of individual clones in the Zomerkomst Seed Orchard.

(In this trial) the four Coffs Harbour Plus Tree Mixes show a mean gain of 54% over the routine seedlot. This is particularly encouraging at this early stage in the breeding programme. The trees now in the seed orchard should have the same genetic value as those in the field trial but this should be increased further when the seed orchard is culled within and between families.

The South African families generally grew more slowly than the Coffs Harbour Plus Tree progeny. It appears that there would be no benefit in terms of growth rate from the introduction of this material into the local breeding programme. The performance of the South African families may improve however when other characters are considered. At present further studies are under way in this trial to investigate longitudinal growth stresses and the occurrence of kino veins."

The progeny trial referred to above has been discussed by Ades & Burgess (1982).

6.6 Coppice

In NSW Flooded Gum is sometimes regarded as a non-coppicing species, though any forester familiar with the tree would realise that this is not so: stumps will indeed coppice, and reference to this as a source of cutting material was made above. A photo in Floyd's thesis (1960a) shows a 2.5 years old stand of Gum, thinned a year earlier from 75 000 to 1 700 stems per hectare: the one select stem that can be recognised is amid a sea of foliage up to 3m high, described by Floyd as *"weak coppice growth from the stumps of the thinnings".* He notes that this coppice was completely shaded by canopy closure two years after thinning, and subsequently died out.

Overseas, for most types of produce, *"one seedling rotation, followed by at least two coppice rotations, is common practice"* (F.A.O. 1979), with the rotations ranging from 4 to 12 years. The coppice rotations normally yield more timber than the seedling ones. Boland (1984) observes that in South Africa Flooded Gum can be managed over 5 coppice rotations, though the gain in MAI per stool in the second rotation is subsequently offset by a loss of coppicing stools.

Coppicing ability appears to be strongly influenced by season. Turnbull & Pryor (1978) observe that at Coffs Harbour the period September to January is most satisfactory for the percentage of trees coppicing and for the growth rate of the coppice, though coppicing has not been as successful as overseas. In Florida Geary et al. (1983) report a drop in the Flooded Gum stumps that coppice from 80 - 90 per cent in winter (October - March) to less than 40 per cent in summer (July - August). Geary and his co-workers noted that trees grown from South African seed coppiced with twice the frequency of trees from Australian seed, and also observed a tendency for the fastest growing Flooded Gum trees to produce progeny with below average coppicing ability.

Coppice has not been used in the management of Flooded Gum stands in NSW, though some invariably is present in areas being managed for natural regeneration. A major reason for the disinterest has been the desire for long rotation crops, while coppice is better suited to stems felled at smaller size. However if ever stands were to be managed locally for small wood production, the use of coppice would need to be closely considered.

6.7 Damage to Regeneration

Flooded Gum seedlings are very susceptible to damage by **fire,** and are normally destroyed by it without any recovery.

As previously noted, seeds that have commenced germination are killed by **dry weather,** but those that have not commenced will survive the dry spell, though possibly with some subsequent dormancy (Floyd, 1960a). Turnbull & Pryor (1978) observe that seedlings of Gum can withstand drought during cool weather, but there is high mortality in hot conditions. However once the seedlings are well rooted, they appear to be moderately tolerant of dry conditions.

Frost can limit the planting range of Flooded Gum, though seedlings can withstand much lower temperatures than the tree's subtropical distribution would at first suggest, as was noted by Hall et al. (1963) - not to mention by successive classes at the former Australian Forestry School, where a specimen was growing in the open - at Canberra. Floyd (1960a) noted that winter temperatures below -7ºC did not damage Gum seedlings about 30cm high at Cascade, though most weeds and seedlings of Blackbutt and Tallowwood were killed or badly damaged. At Yarraman (Qld), Flooded Gum was used as a nurse crop for Hoop Pine in frost hollows during the 1950s and 60s.

On the other hand temperatures of -10ºC have killed Flooded Gum (Mackowski & Horne, 1979-80): the particular frost-hollow studied was found to experience frosts most nights from May to October. On this site the effects of both fertiliser and the use of alternative species were examined. Phosphate fertilising helped make seedlings more frost hardy; nitrogen with phosphorus initially made the seedlings more susceptible to frost in the first season, though its ultimate effect appeared beneficial. The most practicable solution to reforesting local frost hollow sites in this district (Dorrigo Plateau) was to use a change of species, and both Dunn’s White Gum and Manna Gum survived without frosting. At one stage practice on such frosty sites was to use Dunn’s White Gum where the soils were moderately fertile, and Manna Gum on the less fertile sites (Forestry Commission of NSW, 1983b). However Manna Gum is now regarded as the best species for use on all such sites, producing plants up to 4m in height after two years, and growing well through grass, bracken and other ground cover.

Weed growth is a major factor in the establishment and early development of Flooded Gum. As Floyd (1960a) says:

Due to the fertility of the site, weeds rapidly appear over the entire area and exhibit growth almost as luxuriant as that of the Flooded Gum. These weeds may commonly reach a height of 3m in 12 months and make access on foot very difficult indeed. Because of the marked intolerance of Flooded Gum to competition, it must keep pace with the weed growth, or else be eliminated. Consequently the nature of the various weeds assumes greater importance in the regeneration of this species than with many other eucalypts.

The development of a dense and species-rich undergrowth, which gradually progresses towards rainforest, is of course a feature of Flooded Gum sites, but most of the species present are not weeds of the regeneration. The weeds at this stage are those species which germinate and grow rapidly so that they provide direct competition and shading with the Gum seedlings. Floyd recognised four classes of weeds:

1. Climbers and creepers
2. Large-leaved woody shrubs
3. Small-leaved woody shrubs and trees
4. Non-woody shrubs.

Soldier Vine is probably the worst of the climbers, though it tends to be more common on the slopes rather than in the typical Gum gully. The seeds can survive for long periods in the soil, and then germinate following fire; the plant tends to over-winter as a sprawling mat about 60cm in diameter, and then to shoot away in the spring, twining around and enveloping everything in its path, including the seedlings, which are either permanently bent (usually producing a new leader from the kink) or killed. Nonetheless, enough seedlings usually recover from heavy Soldier Vine infestations to produce satisfactory regrowth stands. Mechanical clearing, rather than burning, tends to limit Soldier vine occurrence.

Wandering Jew is sometimes a weed in the moist gullies, particularly if the Gum has to germinate from seed. It is severely knocked back by winter frosts.

Hibiscus and Brush Kurrajong are among the large-leaved weeds, usually occurring in dense though rather localised clumps. They can readily shade out the intolerant Gum if they get ahead of it in growth.

The small-leaved woody weeds include many of the most typical plants of a Flooded Gum regeneration coupe, including Hop Bush, Two-veined Wattle and various Black Wattles. Provided they do not germinate ahead of the Gum these usually tend to act as a nurse crop, rather than a weed, keeping more or less up with the Gum for a number of years and encouraging its height growth, straight form and small branches. At the higher altitudes they are more frost susceptible than the Gum. Floyd however records one case where light rain after the debris burn triggered Black Wattle germination ahead of the Gum, and allowed the Wattle to gain an advantage and so hamper the Gum growth. As with Soldier Vine, their frequency is much reduced by mechanical clearing. Both the wattles and Soldier Vine, as legumes, probably play a useful role in contributing to the nitrogen balance of regenerating areas.

The non-woody shrubs, including Inkweed and various Solanum spp., are usually of limited importance during the first autumn only, though in areas such as Mebbin and Whian Whian S.Fs., with their mild winters, Inkweed can be a more serious weed, causing suppression of the Gum.

Lantana is rarely a weed of the young regeneration, though existing clumps, surviving in areas logged for regeneration, can prevent seedling establishment over appreciable tracts of land. It can persist beneath Gum stands, and may hinder subsequent management.

Tractor clearing is the major method in limiting weed competition and, where natural regeneration is sought, keeps the seed bed receptive for a longer period. With burning it is essential to obtain seed fall or to sow seed almost immediately (within 2 weeks), and to plant seedlings over only a slightly longer period, if suppression by weed growth is to be avoided.

Besides these weeds of forest areas, grass and other pasture species can offer extremely severe competition to young Flooded Gum. As previously noted, scalping or similar treatment is needed if planting into grassed sites, and even then subsequent grass growth can retard the seedlings, delay canopy closure and predispose the seedlings to insect attack. Adequate site preparation and fertilising to promote rapid early growth minimise this problem, and the use of suitable weedicides warrants trial.

Even weeds that act as nurse crops can be expected to compete with Gum seedlings and reduce their growth, and an early examination of this effect was carried out at Whian Whian S.F., where an 18 months old plantation was given both brushing and grubbing treatments. For the next two years both grubbed and brushed plots showed a distinct reduction in height growth, and were also subject to severe psyllid attack, while the untreated plots were less severely attacked. After two years the treated plots showed similar height growth to the control, though the loss in height was permanent. Grubbing produced a small, but not significant, increase in diameter growth over the other treatments, and both treatments, six years after treatment, carried more actively growing stems than the control. Treated plots showed much heavier branching during the two years after treatment than the control. Obviously the study did little to promote the cause of early weed control (Floyd, 1960a).

More recently Mackowski (1979-80b) has carried out a similar study on Wild Cattle Creek S.F., comparing unweeded with limited and complete weeding. Whilst complete weeding showed increased volume growth at age 5, the difference was not significant. However in the “superculture” study (see Section 6.8), a response to weeding was obtained.

Browsing by animals can cause severe damage to young Flooded Gum. Cattle are sometimes a local problem, being attracted to regeneration by certain weeds, including Soldier Vine and *Solanum* spp., and then trampling or accidentally chewing the Gum.

More significant is the damage caused by wallabies. On one Eastern Dorrigo site, *"no trees had exceeded their initial height 2 years after planting and browsing was still continuing up to at least 400m from the forest edge"* (Forestry Commission of NSW, 1971-72). Subsequent study showed the problem to be both more widespread and more deleterious than had been previously recognised, with most damage occurring within 100 m of the plantation edge, and to plants less than 60 cm tall at the onset of winter. Plantation design to minimise edge effect (i.e. compact blocks, rather than long, thin ones), and early planting to produce seedlings taller than 60 cm by winter are measures that can be taken to reduce substantially the incidence of wallaby attack (Horne, 1973-74; 1975).

Young Flooded Gum is subject to attack by a number of **insects,** with the effects more marked in plantations established on grassland than where the regeneration has occurred in a formerly forested site (Pryor et al., n.d.; Turnbull & Pryor, 1978). This led to A.P.M.'s sponsoring research on the subject, the work being largely carried out by P. B. Carne of the C.S.I.R.O. The results of this work have been conveniently summarised by Carne & Taylor (1978). Scarabs and chrysomelids caused major damage in the young plantations:

> *"E. grandis plantations in north coastal New South Wales have been monitored since 1967, and low numbers (of 2 species of Chrysomelid) were recorded annually until autumn 1972, when populations of Chrysophtharta cloelia markedly increased and caused severe defoliation of trees 1 - 3 years old. In late 1974 populations declined to 'normal' levels, and this was associated with an abnormal spring drought that inhibited the production of the new foliage necessary for the survival of the overwintered adults.*
>
> *The conditions that led to the 1972 outbreak of C. cloelia have not been identified but trials during 1972-74 showed that up to 60-70% of the potential annual height increment of the trees could be lost. More than half the trees died in the following 2 years in severely affected plantations.*
>
> *Many species (of scarab) belonging to the genus Anoplognathus (Christmas beetles) feed on the leaves of eucalypts, but severe damage tends to be restricted to woodland species that are not of forestry significance. In recent years, these beetles have caused concern to foresters developing plantations of eucalypts for pulpwood production. In the Coffs Harbour area of New South Wales, A. chloropyrus and A. porosus occasionally cause conspicuous defoliation of large numbers of the young E. grandis in midsummer. Carne et al. (1974) found that the growth of E. grandis is not affected by losses of 40-60% of the fully expanded leaves on which the beetles feed. Higher levels of defoliation were restricted to low-lying areas where the more gregarious of the two species, A. chloropyrus, predominated. Christmas beetles have far less severe effects on tree growth than insects such as Chrysomelids, which feed preferentially on terminal leafy shoots and destroy the apical buds. Damage to E. grandis may be minimised by silvicultural practices that accelerate the growth of the young trees and lead to early canopy closure, or by the interplanting of E. dunnii which is a preferred food plant of A. chloropyrus and which tolerates extensive defoliation for several successive years."*

(Most foresters with experience of interplanting Dunn's White Gum have little regard for its results. One suggests that its main effect was to attract vast numbers of scarabs that, having defoliated the White Gum, then moved on to attack the Flooded Gum. The same forester, however, remarks that on some of the sites better results would have been achieved by using only Dunn's White Gum, rather than using a mixture or pure Flooded Gum.)

Psyllids (lerp insects) can also attack and damage young Flooded Gum (see comments above concerning the Whian Whian weed control study), but are more appropriately considered in relation to older stands (see Section 8).

Wood-borers are also more usually considered as pests of older trees, but can lead to considerable damage in young plantations:

Substantial losses may occur in young plantations of *E. grandis* in NSW where Yellow-tailed Black Cockatoos prey upon the larvae of the cossid *Xyleutes boisduvali*, which commonly occur in the lower trunks of the trees. The Cockatoo removes a large wedge shaped segment of wood in order to extract the larva, and trees up to 18cm in diameter may be weakened structurally and blown over by strong winds. In some of the worst-affected plantations, up to 25% of the trees have been lost; if trees that had been weakened by the birds and were susceptible to wind throw were taken into account, the potential loss in some plantations was as great as 40%. Galleries not found by the birds are usually occluded by scar tissue following moth emergence and the tree remains standing.

Stress induced in the young trees by grass competition appears to pre-dispose the saplings to such cossid attack.

Ants, which can be significant removers of eucalypt seed in some forest types, have never been recorded as a problem in the typically moist, low lying Flooded Gum sites, but they may remove seed where direct seeding extends significantly up-slope from the gully sites. Ants can also harvest appreciable quantities of seed from the broadcast sowing of banks of jiffy pots in the nursery: in such cases treatment of the seed or spraying insecticide on the ground adjacent to the nursery banks may be necessary.

6.8 Early Development

The early development of Flooded Gum regeneration from spot sowing was outlined by the Forestry Commission of NSW (1966):

The spots usually germinate as distinct clumps, and the better stems in each spot attain a height of about 30cm within 3 months. Thereafter growth accelerates, and heights of about 2m can be expected at age 12 months. On particularly favourable sites heights in excess of 3.5m are sometimes encountered at this age, and these stems may continue to average 30cm a month in height growth (faster in summer, slower in winter) for up to 5 or even more years. However average growth rates on the better stems are usually less than this with stands averaging about 6m in height at 2 years, about 9m at 3 years and about 12m at 4 years.

Whilst growth rates of the order described are by no means unusual, average rates in NSW would tend to be somewhat less than are suggested in the quotation.

Planted seedlings, which have some months' nursery growth before being established in the field, have rather faster initial development than germinates from direct seeding or natural seedfall, and as already noted current practice is to seek seedlings at least 60cm tall by the start of winter in order to minimise wallaby attack. Whilst Floyd (1962) at first found no consistent differences in height development between planted and sown regeneration, he later (1969) considered that planting was superior on the sub-optimal sites, such as dry slopes, and should be preferred on such areas for reasons of growth as well as survival.

The dense stocking from direct seeding or the more successful natural regeneration gradually thins itself out. Floyd (1960a) quotes the following figures as an indication of the rate and extent of natural thinning:

Age (years)	**Locality**	**Stocking** (per ha)
0.5	Newry S.F., cpt. 16	30 500
2.5	Newry S.F., cpt. 16	21 300
3.0	Newry S.F., cpt. 8	16 200
5.5	Newry S.F., cpt. 8	13 600
7	Pine Ck. S.F.	2 500
16	Pine Ck. S.F.	2 100

Floyd was able to demonstrate significant responses to early thinning in dense stands of this nature, with the response greater in stands thinned at 6 months than in those thinned at 18 months, when substantial competition was already evident. In an area thinned at age 6 months from about 30 000 stems per hectare to 1 700/ha, the BA of all the potentially saleable stems (370/ha) at age 4.5 years was 55 per cent higher in the thinned than the unthinned plots, and of the potential final crop stems (90/ha), 68 per cent higher. The actual BAs of the selected stems in the thinned plots were 3.4 m^2/ha and 0.9 m^2/ha respectively, equivalent to mean DBHs of 10.8cm and 11.6cm; mean DBHs of the selected stems in the unthinned plots were 8.8 and 8.9cm.

Height also was affected by thinning in these dense young stands. In the first year after thinning top height actually showed a small decrease (of about 20cm) relative to the unthinned plots, but by age 4.5 years it was ahead by about 1.5m. Floyd found that this pattern of initial slowing, and then of faster height growth, was regularly repeated, and he attributed it to early growth in the thinned stands being put into thickening up what were often only small, weak, 'feather duster' crowns. Once the new, stronger crowns were formed, a positive height growth response occurred.

The growth rates of the young Flooded Gum stands, whilst outstanding in comparison with any other regeneration in NSW forests, were still well below these commonly achieved with the same species overseas. This led to various studies examining changes in cultural techniques, including site preparation and the use of fertilisers (Pryor et al., n.d.; Floyd, 1969, Borne, 1980), and culminated in what is known as the 'superculture' experiment established on Wedding Bells S.F. in the summer of 1976-77 (Horne, 1978b; Mackowski et al., 1979-80).

In this experiment site preparation was clearing, either with or without subsequent ploughing. Superimposed on the ploughing treatments were two levels of follow up treatment;

- limited level - where follow up treatment was for only the first twelve months; and,
- continuous - follow up treatment continued for six years.

The types of follow up treatment were:

- Insecticide - mixed contact and systemic insecticide applied as foliar drench for first 18 months, subsequently systemic insecticide as injection first week of December each year;
- Weeding - chemical weeding before planting then hand weeding to two years of age then chemical weeding thereafter; coppice is removed from stumps by hand in thinned treatments in case of translocation by root grafts;
- Fertiliser application at 1.68 kg per seedling of 12:10:8:11 (N:P:K:S) mix in the first year, subsequently fertiliser applied at one kilogram per tree three times a year.

The experiment was fenced during establishment.

The results at age 7 years are as shown in Table 3. As can be seen each treatment alone had a positive effect on growth, but these effects were greatly increased where the treatments were applied together. The most successful treatment (continuous FWI) had produced a conical stem volume of 223 m^3/ha at age 7.

However, whilst the treatments were outstanding in their production of cellulose, the form of the trees was less satisfactory, with some production of heavy, retained branches. This has been a continuing worry with regrowth Flooded Gum, and led to a marked reduction in regeneration treatments for a period after 1964. Whilst Gum is an efficient species for self pruning and occluding branch stubs, in the manner discussed by Jacobs (1955; paras. 53-63), in stems that are growing rapidly the occlusion process may be less successful, leading to large dead branch stubs being grown over and included in the stem wood. These can serve as foci for fungal and insect infection, resulting in further downgrading of the stem wood. It appears to develop as a problem particularly in weed-free sites where early spacing (from planting espacement or very early thinning) is wider than about 3 x 3m (1 100 per ha); wattles and similar plants, whilst reducing growth in the Gum stand, can serve a very useful purpose in restricting branch development and improving stem form in such stands.

Table 3

GROWTH RESPONSE IN "SUPERCULTURE" EXPERIMENT - AGE 7 YEARS

(Unploughed replicates only; growth expressed in terms of volume of the untreated control plots).

Treatment*	Limited Treatment	Continuous Treatment
Control	100	129
I	126	101
W	125	172
V	106	191
WI	127	269
FI	151	306
FW	201	332
FWI	289	386
Volume of Control	58 m^3/ha	
Stocking	1084 trees/ha	1084 trees/ha

* Note: I = insecticide, F = fertiliser, W = weeding

The largest contribution to growth in the "superculture" experiment came from the use of fertiliser. Studies over a lengthy period led to the development of a slow release, sulphur-coated fertiliser pill that has been used with routine plantings since 1917 (see Section 6.5.2). More recent studies (Mackowski, 1979-80a) suggest that the slow release mechanism is not required with Flooded Gum.

7 GROWTH AND YIELD

7.1 Stand Development

Table 4
BIOMASS DEVELOPMENT IN FLOODED GUM PLANTATIONS.
(tonnes per hectare)
(From Bradstock 1981)
Plantation Area Age - years

Biomass Component	2	5	11	12	15	16	27
Tree	18.3	53.2	84.2	196.7	164.7	187.4	394.0
Including -							
Foliage	3.9	4.5	4.0	4.8	3.8	5.7	6.2
Stem Wood	6.3	30.4	60.6	147.2	131.0	137.4	323.8
Understorey	2.7	17.0	13.7	7.1	23.9	11.4	42.1
Including							
Large Shrubs	0	5.5	10.1	4.1	22.5	10.4	41.3
Forest Floor	40.6	21.6	17.7	30.9	30.7	34.3	28.1
Including -							
Sticks & bark	1.2	2.4	4.3	7.2	6.4	7.6	7.1
Eucalypt leaves	1.8	1.9	1.5	1.7	2.3	1.9	1.7
Total Biomass	**61.7**	**91.8**	**115.6**	**234.6**	**219.3**	**233.1**	**464 .1**

The pattern of biomass development with time in Flooded Gum stands has been examined by Bradstock (1981), using a series of Gum plantation areas, aged between 2 and 27 years, in the Coffs Harbour district. A summarised version of Bradstock's results is given in Table 4.

The figures obtained by Bradstock (in a study looking at the potential of plantations as energy-producing units) have a number of features of interest:

- Total and tree biomass were still increasing at age 27 years, but were already among the higher levels recorded in a large range of studies. They were below the biomass of a 50 years old Mountain Ash stand (total tree biomass of 601t/ha), but comparable with the maximum values recorded for lowland tropical rainforest.

- Leaf biomass appeared to be stabilising at about 5 - 7t/ha.

- Annual stem wood productivity appears to have stabilised at about 2t per 1t of foliage after about 10 years of age.

- The increase in the understorey, and particularly in the large shrub component, reflects the continuing development of the rainforest understorey. This contrasts with many other forest communities where the understorey declines as the overstorey develops.

- The fine fuel component (sticks, bark and leaves) appears to have stabilised at about 9 t/ha by age 12 years, with the leaf component showing little variation from the youngest stand studied.

- The values for the forest floor are high in comparison with most other Australian studies. Particularly in the younger stands, but indeed in all ages, they include a large contribution from humus, and this appears to result from prior pastures that had previously covered all except the oldest site.

- One site (not included in Table 4) was a 6 years old stand that had been severely affected by insect attack, to the extent of complete defoliation, during its first 2 years. Its total biomass was only half that of the otherwise generally similar 5 years old stand.

Bradstock notes that the plantations have the potential to yield high-energy storage ecosystems, among the most productive that have been measured in terms of standing biomass in Australia, at young ages. This gives confirmation to what many foresters have long believed.

Although Flooded Gum stands in N.S.W. have been much measured (e.g. Floyd, 1962) and although there is now a fair picture of total biomass development in Flooded Gum stands, N.S.W. still lacks adequate yield tables for wood production in such stands. A very preliminary yield table for thinned stands on the North Coast was produced by the Forestry Commission of N.S.W. (1966), and has been thoughtfully metricated by Borough et al. (1978). The basic growth functions in this early table were modified by Watt & Henry (1972) to estimate plantation production, and Borough and his colleagues also present this modified yield table, as is a table showing the actual growth recorded in an unthinned Flooded Gum plantation near Coffs Harbour from age 5 to age 29 years. These three summaries of N.S.W. growth information are reproduced as Table 5.

Growth recorded from several Queensland Flooded Gum plantations is also given by Borough et al., and is of the same general order as that from N.S.W. Overseas growth experience is summarised by F.A.O. (1979), and for most areas discussed the Australian growth rates are towards the lower end of the range, with the highest overseas rates mentioned being an MAI of 50 m^3/ha for a site in Argentina at age 14 years, and of 45.5 m^3/ha at age 9 for SI II sites in the Transvaal: unthinned stand features for the Transvaal plantations were:

Age	**Mean. Dom. Ht.**	**Mean DBH**	**BA**	**Vol.**
9 years	38.1m	19.8cm	33.1 m^2/ha	409.3 m^3/ha

Even higher rates of volume growth - MAIs of up to 73 m^3/ha - are quoted by Hillis & Brown (1918, citing Rance, 1976, in a reference to the Brazilian Aracruz plantations). By comparison, the growth figures quoted from the "superculture" experiment in Table 3 suggest that the best treatment plot (FWI continuous) would fall into the lower end of the Transvaal SI III range, on a scale of I to VI.

Height data from a large range of plots listed by Floyd (1962) have been plotted by hand and suggest the following range of age/dominant height relationships in N.S.W. (the data probably tend to be weighted towards the better, rather than the poorer, local sites):

Age (yrs)	**Dom. Ht. Range (m)**
10	18-28
20	27-43
30	33-50
40	37-55

Site index curves developed in South Africa by Schönau (1976) define site index as the dominant height at age 10 years, and cover a range of indices from 15 to 40: as can be seen, the NSW stands again fit towards the lower end of the range.

Nonetheless, Flooded Gum is still the native eucalypt that provides the highest general rates of growth in NSW.

Table 5

FLOODED GUM GROWTH AND YIELD ESTIMATES - N.S.W.

(from Borough et al., 1918)

Provisional yield table for thinned stands of E. grandis on the north coast of New South Wales (Anon. 1966)

Age (years) and condition6	**Stocking(stems per hectare)**	**Mean DBH (cm)**	**Basal area (m^2/ ha)**	**Merchantable volumes8 (m^3/ha)**
15 BT	326	25.4	16.6	151.2
15T	59	25.4	2.8	25.2
15AT	267	25.4	13.8	126.0
20 BT	267	31.5	20.9	191.1
20T	267	31.5	4.8	44.1
20AT	190	31.5	16.1	147.0
25BT	190	38.1	21.6	197.4
25T	54	38.1	4.4	39.9
25 AT	136	38.1	17.2	157.5
30BT	136	44.7	21.4	195.3
30 T	32	44.7	3.0	27.3
30 AT	104	44.7	18.4	68.0
35 BT	104	51.1	21.4	195.3
35T	27	51.1	3.0	27.3
35 AT	77	51.1	18.4	168.0
40	77	58.4	20.7	189.0

Total yield 352.8m^3/ha; mean annual increment 8.8 m^3/ha.

6 BT, before thinning; T, thinned; AT, after thinning.

8 Underbark volume to the base of the live crown of those stems greater than 20 cm d.b.h.

YIELD TABLE FOR *E GRANDIS* PLANTATION ON THE NORTH TOAST OF NEW SOUTH WALES, USING A REDUCED BASAL AREA GROWTH TO REFLECT CURRENT UTILIZATION STANDARD. (WATT AND HENRY 1972)

Age (years) and condition	Stocking(stems per hectare)	Mean DBH (cm)	Basal area (m^2/ ha)	Merchantable volume8 (m^3/ha)
12BT	494	24.9	24.1	170.1
12 T	188	23.1	8.0	59.9
12AT	306	25.9	16.1	110.2
20	304	33.0	25.9	257.1

Total yield 317.0 m^3/ha; mean annual increment 15.9 m^3/ha.

8 Underbark volume to the base of the live crown of those stems greater than 20cm DBH

GROWTH OF AN UNTHINNED PLANTATION OF *E. GRANDIS* AT COFFS HARBOUR, NEW SOUTH WALES, REGION 12
(For. Comm. N.S.W. personal communication)

Age(years)	Stocking (stems per hectare)	Mean DBH (cm)	Basal area (m^2/ ha)	Dominant height6 (m)	Merchantable volume8 (m^3/ha)
5	1423	12.2	16.6	na	24
10	1134	16.3	23.8	na	106
16	1097	20.2	35.1	33.9	189
23	917	23.2	38.9	38.6	308
29	799	25.5	40.9	42.5	465

Total yield 465 m^3/ha; mean annual increment 16.0 m^3/ha

6 Mean of the to tallest trees per sample plot irrespective of plot area.
8 Underbark volume to the base of the live crown.

7.2 Tending

Flooded Gum is a highly intolerant species and, as was noted earlier (Section 6.8), dense young regeneration quite rapidly thins itself out and reduces stocking. This process continues in the later life of the stand, and Horne (1978c) has produced figures showing mortality rates of up to 53 per cent (from 1 352 to 636 stems per ha) in unthinned planted stands between ages 6 and 22 years on Whian Whian S.F.; in a comparable trial on Conglomerate S.F. the rate over a similar period was 16 per cent (1 247 to 1 043 stems/ha). In both cases most of the mortality had occurred during the previous 6 years.[6]

Studies on responses to thinning Flooded Gum stands started in NSW with two plots established in 1947 by the Australian Forestry School in a 5½ years old plantation on Pine Creek S.F.: one plot was retained unthinned (initially 1 650 stems/ha), and the other thinned to 810/ha, and then to 400/ha two years later. Floyd (1962) reviewed this study at age 19 years, comparing the growth responses of the best 370 and 86 stems/ha in both plots - the potential saleable and final crop stems. Thinning had provided virtually no benefit to these stems:

BA/ha at age19 yrs (m^2/ha)	Thinned	Unthinned
Best 370/ha	24.5	24.1
Best 86/ha	8.6	8.7

[6] It has been suggested that the different rates of mortality at Whian Whian and Conglomerate reflect the different site qualities of these two sites for Flooded Gum, Whian Whian being a generally poorer Flooded Gum site than Conglomerate.

Following back over the growth records, Floyd found that the dominants at age 19 had also been the dominants at age 5, though at the younger age they may have been only 5mm greater in diameter than their neighbours; only two years later, at the time of the second thinning, they were 2 - 5cm larger. As Floyd states, *"the thinning merely removed the vanquished".* Based on possibly rather arbitrary criteria of active growth, Floyd suggested that between ages 6 and 19 the number of actively growing trees in the unthinned plot had dropped from 550 to 250/ha. Floyd's conclusion that the onset of severe suppression had occurred before age 5 in these planted stands has been echoed by Schönau (1982) in a report on early thinning trials in South Africa.

To check on the Pine Creek findings, replicated trials were established in planted stands at Whian Whian and Conglomerate S.F.s, with the thinned plots reduced from about 1300/ha to 494/ha at age 6. The responses in these plots, to ages 22 and 23 respectively, have been reviewed by Horne (1978c):

- Thinned plots were marginally (0.5 to 1.5m) taller and had larger mean diameters.
- BA increment since thinning was similar in both thinned and unthinned plots, but in the thinned plots was distributed over fewer stems.
- The best 370 stems/ha showed a definite response to thinning, with increases in height, BA, DBH and volume. The volume response was greatest at age 19 at Conglomerate and at 16 at Whian Whian; at these ages the increases in volume of the best 370/ha in the thinned as against the unthinned stands were 26 m^3/ha (11% increase) and 34 m^3/ha (25%) respectively.
- The best 99 stems/ha showed only very slight responses to thinning. These were essentially the dominant stems in the stands, and they tend to grow on largely independently of thinning treatment.
- Greatest response to thinning was in the co-dominant stems, represented by the 100th - 370th largest stems per hectare in the stand.
- The decline in growth advantage, following the peaking of the response to thinning, appears to be associated with the natural mortality in the unthinned stands, thus gradually bringing their stocking towards that of the thinned stands.

Horne concluded that there is little practical advantage to be gained from a single early thinning unless it is possible to utilise the stand when the growth stimulus peaks. In the study, the best 370/ha had mean diameters of 25 - 30cm at peak response time. Alternatively, stands could be thinned at or before peak response time to continue the increased growth response of the larger trees.

If any morals are to be drawn from these studies and from those previously considered in younger stands (Section 6.8), they appear to be that Flooded Gum is very effective in producing dominant stems that, while they retain their dominance, will show only limited response to thinning. However co-dominants will show much greater response. Very early thinning in dense stands, before the dominants are clearly sorted out, will produce a very positive response. Heavy thinning will produce longer lasting effects, but its benefits need to be balanced against the risk of branch retention and wood degrade where young stands are heavily thinned.

Because of the intolerance of Flooded Gum, stems develop shallow crowns as they come into competition with each other, and as the stands mature there appears to be much benefit to be gained from repeated thinnings that maintain deep, actively growing crowns on the retained stems. Crowns that have been affected by competition will usually respond, but the growth response is delayed as the crown gains in size and vigour, and there may be some development of epicormic shoots along the stem.

On purely visual grounds (which nonetheless often will indicate more quantitative truths), a thinning to retain about 150 stems per ha at or shortly after age 20 seems desirable, to be followed by subsequent thinnings to maintain vigorous dominants. The management plan for Urunga (Forestry Commission of NSW, 1984), referring to the development of veneer logs, suggests initial thinning prior to age 20, with a second thinning at age 30 and final felling at age 40; several subsequent thinnings, at rather shorter intervals, might be preferred, but both this matter and the age of first thinning will inevitably be dictated to a large extent by market opportunities and conditions.

7.3 Size and Longevity

The rotation length of 40 years suggested for Flooded Gum in the Urunga management plan, and tacitly accepted on most parts of the North Coast, is based on much experience that, while the stems continue to grow beyond this age, they are likely to show increasing amounts of defect which can effectively reduce their nett merchantable increment. Nonetheless there are many stands of greater age, and with little defect, actively growing on the North Coast. While the 40 years rotation length is useful as an indicative guideline, a flexible approach to rotation age seems desirable wherever market commitments allow, with stands being periodically thinned until diminishing growth or increasing defect suggest that final felling is warranted. In some stands this will be before age 40, in others it may be substantially later.

Flooded Gum can and does reach very much greater sizes than those attained at 40 years, and some of the largest trees known in NSW, including the tallest known tree, are specimens of Flooded Gum. Details of some of these large specimens, growing on State Forests, are given in Table 6, along with a record of a large specimen of Dunn’s White Gum.

The height of “The Grandis” (76m) is unlikely to be significantly exceeded by other trees growing in NSW or Queensland. However a recent report from the eastern Transvaal (South Africa; Anon., 1984a) tells of a “saligna” (almost certainly actually Flooded Gum) with a height of 82.6m and a DBH of 1.14m; the tree was planted in 1905. Specimens of similar size are believed to occur further north in Africa.

Table 6
LARGE TREES IN THE FLOODED GUM TYPE

Species	Location	Height (m)	DBH (m)	Notes
Flooded Gum	Waihou F.R	67	1.29	
	Bruxner Park F.R.	65	2.27	'Vincent Tree' Est. volume 75 m^3
	Bruxner Park F.R.	65	1.80	DBH measured at 2.0m
	Way Way S.F.	60	3.19	
	Middle Brother S.F.	67	2.49	'Big Fella Gum Tree'. Est. volume 110 m^3
	Middle Brother S.F.	64	2.85	
	Bulahdelah S.F.	76	2.73	'The Grandis'*
Dunn’s White Gum	Yabbra S.F.	50	2.49	

* “The Grandis” is currently the tallest known tree in NSW; a record of a slightly taller Roundleaved Gum in the Blue Mountains subsequently was reduced following remeasurement by a surveyor. Trees of comparable height are believed to occur in the Marowin Brook area of Kippara S.F., but have yet to be accurately measured.

The ages of the larger NSW trees are not known.[7] From the limited available growth trends, trees could approach their maximum heights by age 100 years, but the larger diameters suggest ages in the order of 300 years, which could also be fairly close to the longevity of this fast growing tree, though Floyd (1962) suggested that its physical rotation was only about 200 years. C. Mackowski, who has closely studied the growth of large trees (especially Blackbutt) on the North Coast, suggests that the maximum age of Flooded Gum is likely to be about 250 - 300 years, though others, using known rates of diameter growth, believe that some of the larger trees could be as old as 500 years.

8. DAMAGE TO OLDER STANDS

Flooded Gum stands face a range of damage agencies in their establishment phase (see Section 6.7). Some of these continue to cause problems as the stands develop; some diminish or disappear; and some new problems can arise.

The stands seem less affected by **climatic events** than are many eucalypt communities. Their typical site, on deep alluvial soils in a fairly reliable summer rainfall zone, appears to buffer them from the more severe drought effects in the older stands, while frost, a factor in limiting their altitudinal occurrence as seedlings, ceases to be of significance as the stands become taller. However severe winds may occasionally damage young stands, and in at least one case (Pine Creek S.F., about 1954) local gale force winds snapped off trees up to 40cm DBH at heights of 2 - 3m above the ground over a small area. The affected area was at the head of a gully, below a low saddle, in a situation where wind funnelling could, and apparently did, occur. The stand had apparently been recently thinned and some windthrow, both by the snapping of the stems and by blowing out by the roots, is not uncommon in recently thinned stands.

Flooded Gum is among the most susceptible of the NSW eucalypts to **fire** damage. Trees can be readily killed by relatively light fire, and burning under even very mild conditions can cause unacceptable levels of damage. Controlled burning under a 10.5 years old plantation of Gum on Wild Cattle Creek S.F. in August, 1982, with a temperature of 20ºC, no wind, relative humidity of 44 per cent and a fire danger rating of 2, caused sufficient damage that trees over an area of 2 to 3 ha had to be felled and coppiced. As a rule any burning should be avoided within Flooded Gum stands, and protection afforded by appropriate action on adjoining lands.

Even where trees are not killed by fire, their butts are damaged, leading to a high level of internal defect in the most valuable part of the stem; at one site on Bulahdelah S.F. the lower, rough-barked section of the stem tends to coincide closely with the zone of heavy gum veins and pockets, apparently resulting from previous fire damage, and normally has to be discarded. Stands of Flooded Gum type on fire-prone sites (eg close to certain forest boundaries) may be sufficiently damaged and degraded as to be unsuitable for sawlog production, though still suitable for use as pulpwood. However most Gum stands occur on sites where fire is only rarely a serious threat.

Insects are probably the most serious damage agencies of Flooded Gum stands. The leaf-eating scarabs and chrysomelids that can so severely affect young stands (Section 6.7) diminish in significance once a closed forest canopy is formed, but are replaced by other insect pests.

Possibly the most serious of these are the psyllids (lerp insects) which can infest young stands: Section 6.7 refers to the attack experienced at Whian Whian S.F. following the freeing of an 18 months old plantation from wattle and other competition. However the attack can continue in much older stands, and in some sites, typically identified by the presence of Bell-bird colonies, the infestation may be virtually permanent, with heavy mortality of the smaller stems and constant unthriftiness of the larger ones. Whilst normally outbreaks of this type will reach a peak and then

[7] Staff at Coffs Harbour recall the visit, in the late 1970s, of the Chinese Minister for Agriculture. Shown the 'Vincent Tree', he asked its age. A confident Regional Forester replied "300 years". The minister made some comment in Chinese, leading to prolonged Asian laughter. When she had recovered the interpreter, noticing the perplexed and somewhat embarrassed faces of the forestry guides, explained that the Minister had said: "How the hell would they know? They weren't here 300 years ago."

decline as natural predation and other control factors come into play, such a cycle is broken by the establishment of Bell-bird colonies. Although the Bell-birds do feed on the psyllids, they are apparently preferential feeders on some of the psyllid-predators, including certain hover-fly larvae, and their aggressive behaviour excludes other birds that are more effective in reducing the psyllid populations: this pattern was studied by P. Hadlington and K. G. Campbell, of the Commission, in the 1950's, and has more recently been demonstrated in Victoria by Loyn et al. (1983), who found that, after experimental removal of Bell-birds from one psyllid-infested eucalypt stand, some 11 other species of birds moved in and had eradicated the infestation within 4 months.

Unfortunately removal of the Bellbirds is not too easily accomplished, though on Wild Cattle Creek S.F., near Timmsvale, very heavy thinning of an infested Gum stand appeared to upset and greatly reduce the Bell-bird population and allow other birds to move into the stand, at least in the short term. Often clear-felling appears the only answer to a persistent infestation, though this may merely mean that the Bellbirds migrate to a new site nearby: if so, tolerance of the original outbreak may be a more acceptable strategy. More drastic measures to reduce or remove populations of "the silver-voiced Bell-birds, the darlings of day-time" are unlikely to attract much popular support. Probably shouldn't, either.

Floyd (1962) examined the effects on growth of a light and a severe infestation of psyllids on a 14 years old Flooded Gum stand at Boambee S.F. For the first 10 months following the attack, growth was substantially reduced in the more heavily infested area, but with the collapse of the infestation and refoliation of the tree crowns in the following growing season visible evidence of the attack disappeared. The more severely infested trees rapidly made good their loss of increment during and immediately after the attack, leading Floyd to conclude that a single attack of lerp has no lasting effect on volume production.

On its former forest in the Murwillumbah district (see Section 5), the B.G.F. attempted to curb psyllid attack in the 1960s by planting one row of Blackbutt to two rows of Flooded Gum. In these cases the Blackbutt ultimately assumed dominance of the site and most of the Gum died, apparently as a result of competition rather than from lerp attack.

Among other foliage-eaters, the gum-leaf skeletoniser (*Uraba lugens*) has been recorded as damaging Flooded Gum (Carne & Taylor, 1978).

Stem borers, already mentioned in relation to regeneration, continue to cause damage to Flooded Gum at all ages, though apart from the blowing over of young stems due to associated black cockatoo damage (Section 6.7), the damage is to the wood quality, rather than to the growth of the trees themselves. Besides the cossids and other moth larvae, various beetle larvae including longicorns (cerambycids) and scolytids can cause this damage. Carne & Taylor suggest that the weakening of trees by psyllid attack, drought or, in young stands, grass competition may predispose the stems to borer infestation. Heavy branching and subsequent incomplete branch occlusion may also contribute to increased borer attack.

Although attack may occur, particularly on trees growing away from the typical alluvial gully site, Flooded Gum is less prone to damage from termites than most North Coast eucalypts.

Flooded Gum is one of the less durable eucalypts, and is prone to damage from wood-decaying **fungi** that gain entry from bark damaged surfaces. Logging damage, natural damage such as falling branches, fire scars and retained branch stubs can all act as foci for infection which can seriously reduce wood quality.

9. PRESERVATION

The Flooded Gum type in NSW is preserved in a number of North Coast national parks, including Border Ranges, Mt. Warning, Nightcap, Yuragir, Dorrigo and Myall Lakes. It also occurs in national parks in Queensland.

The type is also represented in at least 14 sites specifically preserved by the Forestry Commission as Flora Reserves or Forest Preserves, and Dunn's White Gum type occurs in one of these plus an additional two preserved areas. These areas are listed and briefly described in Appendix 5; most are described in greater detail by the Forestry Commission of NSW (1981). The 16 preserved areas have a total area of over 5 000 ha (12 Flora Reserves, 4 500 ha; 4 Forest Preserves, 700 ha). While in some of them Flooded Gum is only a type of minor importance, most contain significant occurrences, and between them they provide an excellent sampling of the main occurrences of both types as they are represented on State Forests.

Where not already on a formal preserved area, the large trees listed in Table 6 are locally preserved for their natural lives.

10. MANAGEMENT ASPECTS

10.1 Objectives

The Flooded Gum type occurs within the coastal group of forest, the management objectives for which are set out in the NSW indigenous forest policy (Forestry Commission of NSW, 1976) in the following terms:

In general, coastal forests should be managed to perpetuate the indigenous species that have occurred there. There should be only minor silvicultural manipulation to amend species proportions, rather than an attempt to change the species type itself.

The accessible forests of the coastal plain should be managed for sawlog and miscellaneous round timber production and for recreation. This management should aim to maximise sawlog production in the next 30 years, consistent with sustained yield concepts. This will involve the retention of all thrifty stems of merchantable or near merchantable size for further increment. In most cases, this means that some good growing stock will be grown to diameters larger than may have been envisaged in former yield calculations. Where regeneration needs occur, they are to be met by natural means where possible. Where necessary they may be supplemented by artificial techniques such as clearing and jiffy pot planting to obtain a full stocking of the fastest growing commercial species suitable to the site.

The Flooded Gum type occupies a rather anomalous position among native forest types of NSW. In a period when silviculture of the native forests aims generally at extensive practices achieved by little if any treatment other than that provided by logging, the Flooded Gum type stands apart as one that frequently needs, and receives, intensive treatment, even though what might be considered an "adequate" stocking of regeneration can often be obtained by natural seeding after logging.

Most management plans for areas carrying Flooded Gum include the type as one where artificial regeneration treatment is needed, usually with explicit provision for the planting of about 700 stems per hectare where *"natural regeneration to a full stocking of commercial species could not otherwise be expected".* Whilst not in conflict with the Indigenous Forest Policy, the interpretation of the Policy to meet the requirements of Flooded Gum is sometimes rather cloudy, and any future revision or amendment of the Policy might usefully seek to have this clarified.

10.2 Management Problems and Practices

A major problem in the management of the Flooded Gum type appears to be one touched on immediately above: should the forester aim at natural regeneration, which in many cases may give adequate results, or should the aim be to apply more intensive treatments which may well be more suited to the usually very high quality sites, readily accessible locations, and excellent growth responses of Flooded Gum?

There is probably no single or simple answer to this question, but it does seem likely that an economic case exists for intensive management of Flooded Gum more than for any other native species or type in NSW

This basic question aside, the requirements for the management of this type are reasonably well known and understood, and some guidance points outlining these requirements follow in the next section.

However there is one other management issue that can affect the treatment of Flooded Gum stands, and that concerns the application of the Standard Erosion Mitigation Conditions in the Gum type. The conditions were designed to protect soil in the steeper and typically narrow-gullied hinterland forests, and except in relation to the protection of actual creek courses and banks they appear to have little relevance in the broad, alluvial Flooded Gum flats. Whilst the Conditions do not preclude logging or plantation clearing, they can at times increase their difficulty, and again there appears to be a case for closely examining their relevance in relation to some typical Gum stands at any future revision of the Conditions.

10.3 Guidance Points

As in previous Silvicultural Notes, the following guidance points should be interpreted as just those - points to assist and guide the forester. They should not be regarded as immutable instructions or prescriptions, and they should at all times be interpreted in the light of conditions actually existing in the forest.

1. Flooded Gum is a very fast-growing, light-demanding tree that in nature occurs in even-aged stands. These may be extensive or they may be relatively small and localised, but they are a feature of the tree's occurrence and a natural response to its silvicultural characteristics.

2. The tree can be regenerated either naturally or artificially.

3. Natural regeneration is often quite successful. Whilst fire is a cheap, and in most cases is the natural means of preparing a seed bed, success with natural regenerations tends to be more assured where the site has been mechanically cleared or opened up so that it retains its seedbed receptivity for longer and avoids the extremely aggressive weed growth that usually accompanies burning. The retention of at least 4 or 5 well spaced seed trees per hectare seems desirable, at least as insurance; natural regeneration tends to provide a broader genetic base for the regenerated stand; and at least in the short term it is cheaper than artificial regeneration.

4. Artificial regeneration, these days normally accomplished by jiffy pot planting, has a greater surety of success; it allows for the use of genetically improved, or at least superior, stock; and it provides for the application of other treatments, including regular spacing and fertilising, to maximise production from what are among the State's potentially most productive forest sites.

5. The Flooded Gum sites are usually fairly well defined as the alluvial flats and nearby lower slopes of the coastal creeks. Although the tree will grow on higher topographic positions, its growth rate is almost certainly reduced and the risk of establishment failure increased, and in general the temptation to extend the type boundary higher up slopes into other hardwood types should be resisted.

6. Occasionally very low lying sites that have previously carried good quality stands may fail to regenerate after clearing as a result of raised watertables. In such cases consideration should be given to mounding the site and planting on the raised mounds, though stumps from the earlier crop may at times make mounding difficult.

7. Provenance variation in Flooded Gum has been demonstrated. Pending any availability of seed from breeding programmes or from proven provenance sources for the area being planted, artificial regeneration should use seed collected from superior stems growing in the general area where planting is to occur. The selection of superior trees for seed collection not only provides a level of genetic improvement, but also such stems tend to be heavier seed bearers, to provide seed giving better field establishment, and to allow for cheaper collection.

8. In NSW Flooded Gum usually has its major flowering from mid - autumn through winter, possibly to early spring. Whilst viable seed will normally be present in the crown at all times, collection should be delayed for about 5 months after flowering (say till late spring) to obtain good viable seed from the new crop; for viable seed the capsules should be turning (or have turned) from green to brown or purple, and the seed itself should be a fairly dark brown.

9. Whilst a fairly reliable seeder, occasionally Flooded Gum will suffer a poor seed year. Such occurrences should be avoided for planned seed collection, and should be watched if natural regeneration is sought.

10. Natural seedfall is usually delayed till about a year after flowering, though where natural regeneration is being used some seed fall can be expected at other times, and much regeneration is likely to come from seed in the crowns of trees felled during the logging operation unless the site is subsequently burnt.

11. Collected seed should be stored, with an added insecticide, at about 2ºC. Unless required for early local use, collected seed has normally been sent to the Forestry Commission at Coffs Harbour for storage.

12. Seed will normally survive on a dry seedbed until conditions for germination occur. However if dry conditions follow once germination is under way (after about 4 days of moist conditions), heavy mortality is likely; dry conditions after a shorter moist period will induce a degree of dormancy in some of the seed, but germination will subsequently occur.

13. Such dry-moist-dry pulses may promote weed seed germination but not Gum germination. In such cases the subsequent Gum seedlings may be seriously disadvantaged.

14. Some seed is inhibited from germinating if not exposed to light: this appears to provide a reserve in the soil, and the seed may germinate if wash or other movement subsequently redistributes the soil.

15. At the present time the well-established jiffy pot technique should be used to provide seedlings for artificial establishment.

16. Where planting is to occur on grassland or similar sites, the pasture sward should be controlled by herbicide or broken up by scalping and ploughing along planting lines, and every encouragement should be given to the seedlings to grow rapidly and close canopy as soon as possible: this should include the use of large seedlings, fertiliser treatment and, although contrary to current practice, possibly the use of closer spacing. Besides the problem of pasture competition, such sites are very prone to severe insect attack (beetles, psyllids, stem-borers).

17. Mechanical clearing and stacking, with subsequent burning of stacks, is to be preferred where forest sites are to be planted. Burning will promote weed growth, but this is not necessarily bad where seedlings are being planted, while without burning excessive area will be lost under the stacks, fire hazard will be increased for many years, and there will be subsequent extraction problems.

18. Planting should start following the first of the summer rains and once the soil is moist, but should cease if the soil dries out. As far as practicable the site should be planted within 2 to 3 weeks of burning if the seedlings are to avoid excessive weed competition or even suppression. Seedlings should be given a ‘starter’ dose of fertiliser (e.g. the NPS pill in current use), and where wallaby damage is expected the aim should be to have plants up to at least 60 cm high by the end of autumn: this may necessitate the planting of larger seedlings than would otherwise be usual.

19. Planting may also be used for the rehabilitation of log dumps and for the enrichment of larger gaps following logging. Compacted dump sites should be ripped before planting. Planting is also sometimes used as a form of insurance in sites where natural regeneration is expected, though this usually represents unwise use of funds available for silviculture.

20. Flooded Gum coppice receives negligible use in Australia, but could have a place in stands managed for small-wood production. In this event some selection of trees for coppicing ability may be desirable. The production of coppice appears to be influenced by the season of felling, with the one Australian study suggesting that spring-early summer produces the highest proportion of coppicing stumps.

21. Flooded Gum appears at all stages of growth to be highly susceptible to fire damage, and normally efforts should be made to avoid the use or occurrence of fire in Gum stands.

22. Whilst surprisingly resistant to frost, at the higher altitudes some frost-hollow sites may preclude Flooded Gum establishment, and on these sites the substitution of other species, usually Manna Gum, seems warranted. Dunn’s White Gum has also been used in frosty sites, and has received some use as a scattered 'bait' tree in grassland plantings, as a preferred food tree for scarabs: this latter practice appears to have little, if anything, in its favour, though on some grassy sites liable to heavy beetle attack Dunn's White Gum may prove a more satisfactory species to plant than Flooded Gum.

23. Flooded Gum sites are particularly prone to vigorous woody weed growth, especially following the use of fire, though establishment of the Gum seedlings within a few weeks of burning will usually allow them to keep up with or ahead of the weeds. Soldier Vine is probably the most damaging weed, but is rarely a problem on the typical Gum flat; besides its smothering habit, it also tends to attract cattle which browse on it, in the process damaging or destroying Gum seedlings. Wattles, although undoubtedly retarding the growth rates of the Gum seedlings, can have a beneficial effect in reducing branch size and promoting better form. Wattles and Soldier Vine both probably play a valuable role in adding nitrogen to the ecosystem.

24. In addition to seeking tall seedlings by the start of winter, on wallaby-prone sites efforts should be made to establish compact planting blocks and to minimise the length of plantation edge.

25. Insect attack may be severe in young plantations, particularly those established on grassland. Damage is normally of much less significance once the canopy is closed.

26. Thinning at an early stage may facilitate the formation of dominant stems and speed the growth of released co-dominants. However Gum stands are effective in self-thinning, and dominant trees, once clearly formed, appear to gain little benefit from thinning - the benefits mostly accrue as better growth on the other stems in the thinned stand.

27. Under optimum conditions, volume MAIs of over 20 m^3/ha can be obtained with Flooded Gum, but rapidly growing stems established at a wide spacing can suffer from heavy branch development, faulty branch occlusion, and consequent wood defect. Wattle growth helps to eliminate these problems, with a reduction in MAI, but if wattle is not expected there seem good grounds for not exceeding an espacement of 3 x 3m with Gum seedlings, even though this stocking is greater than is otherwise desirable.

28. Thinning practice will be dictated by market opportunities, but under current conditions there is much in favour of the practice of having a first commercial thinning by about 20 years, reducing the stand to about 150 actively growing stems per hectare, and then thinning at intervals of perhaps 6-7 years to maintain healthy crowned dominants for a total rotation of about 40 years. Rotation length can in most cases be lengthened - perhaps by half again - if circumstances favour such a step (eg continued vigorous growth, little heart or other defect, and flexible market conditions).

29. Psyllids can damage older stands of Flooded Gum. Attacks lasting for one season, though setting growth back at the time, appear to have limited long term effects. However permanent infestations, associated with Bellbird colonies, sometimes occur and can severely debilitate the stand. Heavy thinning or clearfelling have broken up Bell-bird colonies, though tolerance of the infestation may help to concentrate the attack and thus be the wiser strategy.

30. Debilitated trees, retained branch stubs and mechanical stem damage are all factors than can lead to high levels of stem defect through borer attack or fungal infection. Avoidance of these factors will greatly improve wood quality.

It might require a coconut, but that is it in a nutshell.

10.4 Further Research

Flooded Gum has been the subject of an unusually extensive and effective research effort in N.S.W., while overseas it has probably produced more research than any other eucalypt, though not all of that is applicable to Australian conditions.

Nonetheless there is scope for further work on the type, and this review has helped to point out some topics that warrant further examination:

- A clearer identification of soil and topographic factors that define the Flooded Gum type, and of the relationship of these factors to ease of establishment and subsequent site quality and dynamics of the developing stand.
- An examination of provenance effects in the important southern Flooded Gum sites (Bulahdelah/Taree); past trials have concentrated on the Coffs Harbour area.
- Further investigation of the development of an open-root planting technique.
- Development of more effective and realistic yield tables for Flooded Gum.
- A more controlled study on the options for dealing with Bell-bird/psyllid infestations.
- Use of herbicides in grassland plantings.
- Assessment of the importance of mature stands of Flooded Gum to mature forest-dependent species of wildlife, and of the value of young stands to wildlife generally.

In the longer run, further work on tree improvement and the development of vegetative propagation techniques would also seem well warranted.

11. ACKNOWLEDGEMENTS

As will be appreciated by anyone who has read through these Notes, much of what is known about the silviculture of the Flooded Gum type has come from a well planned, sustained and imaginative research programme carried out by A.G. Floyd at Coffs Harbour over a period of about 15 years. All Flooded Gum foresters in NSW owe a great debt of gratitude to Alex Floyd. Many other researchers have also contributed, and references to their work are given throughout the Notes. In addition the compilers of these Notes have received great assistance from foresters working with the type in practically every district from Bulahdelah to Murwillumbah, and to all of them are our thanks most warmly given. Special thanks are also due to a number of officers who made valuable comments and suggestions on an earlier draft of these Notes. These include:

I. Barnes	H. Drielsma	C. Mackowski
J. Bruce	H.J. Hanson	M. Potter
R. A. Curtin	G. A. King	C. Stapley

plus a number of unidentified officers at the Wood Technology and Forest Research Division.

12. REFERENCES

Ades, P. & Burgess I.P. (1980). Provenance trials of *Eucalyptus grandis* in northern NSW. Paper to IUFRO Conf. on Fast Growing Tropical Trees, Brazil.

(1982). Improvement in early growth rate achieved by phenotypic selection of *E. grandis*. Aust. For. Res. 12, 169-73.

Anon, (1984a). Record in Saligna? Aust. For. Ind. J. 50(3), April News, p.6.

- (1984b). Brazilian team wins prize for forestry job. World Wood, June, 1984, p.7.

Bamber, R.K., Floyd A.G. & Humphreys F.R. (1969). Wood properties of Flooded Gum. Aust. For. 33(1), 3-12.

Bamber, R.K., Horne R. & Graham-Higgs A. (1982). Effect of fast growth on the wood properties of *E. grandis*. Aust. For. Res. 12, 163-7.

Baur, G.N. (1959). “Raising and planting Flooded Gum.” For. Comm. NSW Res. Note No. 4.

- (1960). “Silviculture in the tropical rainforests of North Queensland.” For. Comm NSW rept., processed, 40 pp.

- (1962). “Forest vegetation in northeastern NSW.” For. Comm. NSW Res. Note No. 8.

Beadle, N.C.W. (1981). “The Vegetation of Australia.” Cambridge Univ. Press, Cambridge, 690 pp.

Bishop, S. (1982). Management of Cabbage Tree Palm for oyster stakes. Aust. For. 45(3), 179-80.

Boland, D.J. (1984). “Australian trees in five overseas countries.” Churchill Fellowship Rept., 199 pp.

Boland, D.J., Brooker M.I.H. & Turnbull J.W. (1980). “Eucalyptus Seed.” CSIRO, Australia, 191 pp.

Bootle, K.R. (1983). “Wood in Australia.” McGraw-Hill Book Co., Sydney, 443 pp.

Borough, C.J., Incoll W.D., May J.R. & Bird T. (1978). Yield statistics, pp. 201-225 in "Eucalypts for Wood Production" (ed's. W.E. Hillis & A.G. Brown), CSIRO, Australia.

Bradstock, R. (1981). Biomass in an age series of *E. grandis* plantations. Aust. For. Res. 11, 111-27.

Burgess, I.P. & Bell J.C. (1983). Comparative morphology and allozyme frequencies of *E. grandis* & *E. saligna*. **Au**st. For. Res. 13, 133-49.

Carne, P.B., Greaves R.T.G. & McInnes R.S. (1974). Insect damage to plantation grown eucalypts in north coastal NSW J. Aust. Ent. Soc. 13, 189-206.

Carne, P.B., & Taylor K.L. (1978). Insect pests, PP. 155-68 in "Eucalypts for Wood Production." (ed's. W.E. Hillis & A.G. Brown), CSIRO, Australia.

Cresswell, R.J. & de Fossard R.A. (1974). Organ culture of *E. grandis*. Aust. For. 37, 55-69.

Cromer, R.N. & Pederick L.A. (1980). Fast Growing Trees. Aust. For. 43, 213-5.

Darrow, W.K. (1983). Provenance-type trials of *E. grandis* and *E. saligna* in South Africa: Eight year results. S. Afr. For. J.-126, 30-38.

F.A.0. (1979). "Eucalypts for planting." 677 pp. FAO Forestry Series No. 11.

Floyd, A.G. (1958). Field identification of seedlings of major tree species in the Blackbutt and Flooded Gum areas. For. Comm. NSW Res. Note No. 1

- (1960a). The regeneration by direct sowing of Flooded Gum. M. Sc. For. Thesis, Univ. of Melbourne.

- 1960b). Investigations into sowing of Flooded Gum. For. Comm. NSW Res. Note No. 2.

- (1961). Some aspects of the silviculture and regeneration in Flooded Gum in NSW, Australia. Paper to 2nd. World Eucalyptus Conf., Sao Paulo, Brazil; FAO, Vol. II, pp. 857-65.

- (1962). Working plan E3 - Flooded Gum type treatment project, 1st. Review. For. Comm. NSW, processed, 62 pp.

- (1965). Raising and planting out of Blackbutt in jiffy pots. For. Comm. NSW Tech. Paper No. 9.

- (1969). Working Plan E3. Flooded Gum type regeneration project, 2nd. Review. For. Comm. NSW, processed, 8 pp.

Forestry Commission of NSW (1965). "Forest types in NSW." For. Comm. NSW Res. Note No. 17.

Forestry Commission of NSW - (1966). "Major plantation species of NSW." For. Comm. NSW Tech. Paper No. 11, pp. 34-40.

- (1971-72). E3 - Flooded Gum forest type; p.42 in Research Report, For. Comm. NSW

- (1972). "Planting Eucalypts in NSW." Aust. Timb. J. 38(6), 5pp.

- (1976). "Indigenous Forest Policy." Processed, 40 pp.

- (1978). "New South Wales - Forest Types." Map at scale 1:4 000 000; Govt. Printer, Sydney.

- (1981). Forest preservation in State Forests of NSW. For. Comm. NSW Res. Note No. 47.

- (1983a). Gains from breeding Flooded Gum. In Research Report, 1981 and 1982; pp. 12-13.

- (1983b). Eucalypt plantation establishment. Ibid, pp. 23-4.

- (1984). Management Plan for Urunga Management Area. Processed, 48pp. appendices.

Franklin, E.C.(1978). “Exotics for hardwood timber production in the Southeastern United States.” Proc. 2nd. Symposium Southeastern Hardwoods, U.S. For. Serv. Southeast. Area S & PF, Atlanta, GA; pp. 171-9.

Fraser, L. & Vickery J.W. (1939). Ecology of the Upper Williams River and Barrington Tops District. Proc. Linn. Soc. NSW 64, 1-33.

Geary, T.F., Meskimen G.F., and Franklin E.C. (1983). “Growing eucalypts in Florida for industrial wood production.” U.S. For. Serv., Southeastern For. Expt. Stn. Gen. Tech. Rept. SE-23.

Hall, N. (1972). “Summary of meteorological data in Australia.” For. and Timb. Bur. leaflet No. 114.

Hall, N., Johnston R.D. and Marryatt R. (1963). “The natural occurrence of the eucalypts.” For. and Timb. Bur. leaflet No. 65 (2nd. ed’n.).

Hayden, E.J. (1971). “Natural plant communities of NSW.” M. Sc. Thesis, A.N.U., Canberra.

Hillis, W.E. & Brown A.G. (1978). The need for improved wood production from eucalypts, pp. 393-402 in “Eucalypts for Wood Production.” (ed's. W.E. Hillis & A.G. Brown), CSIRO, Australia.

Hodgson, L.M.(1975). “Some aspects of reproductive behaviour in E. grandis.” D. Sc. Thesis, Univ. of Pretoria.

(1976a). Some aspects of flowering and reproductive behaviour in *E. grandis* at J.D.M. Keet Forest Research Station. 1. Flowering, controlled pollination methods, pollination and receptivity. S. Afr. For. J. 97, 18-.

Hodgson, L.M.(1975). (1976b). Ibid. 2. The fruit, seed, seedlings, self fertility and inbreeding effects. Ibid, 98, 32- .

Holmes, D.A. & Floyd A.G. (1969). “Nursery techniques for raising eucalypts in jiffy pots on the NSW North Coast.” For. Comm. NSW Res. Note No. 22.

Horne, R.R. (1973-74). “Wallaby control.” For. Comm. NSW Res. Rept., 1973 & 1974, p. 64.

- (1975). Wallaby browsing in eucalypt plantations, pp. 80-101 in Agriculture, Forestry and Wildlife: Conflict or Co-existence?, University of New England, Armidale.

- (1975-76). Open-root planting of E. grandis and E. pilularis. For. Comm. NSW Res. Rept., 1975 and 1976, pp. 61-62.

- (1978a). Eucalypt plantations of the North Coast of NSW - fertilizer growth effects. For. Comm. NSW Rept., processed, 3 + 7 pp.

- (1978b). Superculture report - *E. grandis.* Ibid, 8 + 4 pp.

- (1978c). Flooded Gum thinning report - Conglomerate and Whian Whian *S.F.s*. Ibid, 9 + 9 pp.

- (1979).”Raising eucalypts for plantations on the North Coast of NSW.” For. Comm. NSW Res. Note No. 22 (2nd. ed’n.)

Hoshcke, F.G. (1976). “FORINS - Forest resource inventory of the State, 1971-72.” For. Comm. NSW Tech. Paper No. 28.

Jacobs, M.R. (1955). “Growth Habits of the Eucalypts.” Comm. Gov’t. Printer, Canberra; 262 pp.

Loyn, R.H., Runnalls R.G., Forward G.Y. & Tyers J. (1983). Territorial bell miners and other birds affecting populations of insect prey. Science, 221, 1141-42.

Mackowski, C.M. (1979-80a). Use of starter fertilisers for eucalypt plantation establishment. For. Comm. NSW Res. Rept., 1979 and 1980; pp. 96-97.

- (1979-80 b). Effects of weeds on growth of eucalypt plantations. Ibid, pp. 106-107.

Mackowski, C.M. & Horne, R.R. (1979-80). Frost hollows in E. grandis plantations. Ibid, pp. 129-31.

Mackowski, C.M., Horne R.R. & Lind P. (1979-80). The Flooded Gum ‘Superculture’ experiment. Ibid, pp. 115-116.

Meskimen, G. (1974). “Breaking the size barrier in containerization - ‘washed' Eucalyptus seedlings.” Paper to N. Amer. Containerized Forest Tree Seedling Symposium, Denver, Colo.

Osborn, T.G.B. & Robertson R.N. (1939). Reconnaissance survey of the vegetation of the Myall Lakes. Proc. Linn. Soc. NSW 64, 279-296.

Pidgeon, I.M. (1942). “Ecological Studies in NSW.” D. Sc. Thesis, Univ. of Sydney.

Pryor, L.D. & Clarke B. (1964). Reforestation of former farm sites on the North Coast of NSW. Aust. For. 28, 125-35.

Pryor, L.D. & Johnson L.A.S. (1971). “A Classification of the Eucalypts.” A.N.U., Canberra. 102 pp.

Pryor, L.D., Chandler W.G. & Clarke B. (not dated; about 1967). “The establishment of Eucalyptus plantations for pulpwood production in the Coffs Harbour region of NSW.” A.P.M. Forests Pty. Ltd. Bull. No. 1.

Rance, H.F. (1976). Aracruz: The shape of things to come. Pulp Pap. Can. 77(3), 20-5.

Schönau, A.P.G. (1974). The effect of planting espacement and pruning on growth, yield and timber density of *E. grandis*. S. Afr. For. J. 88, 16-23.

- (1976). Metric site index curves for *E. grandis*. S. Afr. For. J. 98, 12-8.

- (1982). Application of a factorial design to a thinning... in *E. grandis*... S. Afr. For. J. 121, 70-80.

Specht, R.L., Roe E.M. & Boughton V.H. (1974). Conservation of major plant communities in Australia and Papua New Guinea. Aust. J. Bot. Suppl. Series No. 7.

Turnbull, J.W. & Pryor L.D. (1978). Choice of species and seed sources, pp. 6-65 in “Eucalypts for Wood Production.” (ed's. W.E. Hillis and A.G. Brown), CSIRO, Australia.

Turner, J. & M.J. Lambert (1983). Nutrient cycling within a 27-year old *E. grandis* plantation in NSW. For. Ecol. and Mgt. 6, 155-68.

Van Wyk, G. & Roeder K.R. (1979). The status of tree breeding in South Africa. S. Afr. For. J. 107, 54-9.

Van Wyk, G., & Van der Sijde H.A. (1983). The economic benefits of forest tree breeding. S. Afr. For. J. 126, 48-54.

Watt, A.J. & Henry J.L. (1972). Evaluation of reforestation projects - North Coast Flooded Gum Plantations. Paper to 26th. APPITA Conf., Hobart.

Wattle Research Institute (1972). “Handbook of Eucalypt Growing.” W.R.I., Pietermaritzburg.

Appendix 1

PLANT SPECIES MENTIONED IN TEXT

Common Name	Botanical Name
Ash, Mountain	Eucalyptus regnans MAKCA
Bangalay	E. botryoides SECAD
Blackbutt	E. pilularis MAIAA
Booyong	Heritiera spp.
Box, Brush	Lophostemon confertus
Bracken	Pteridium esculentum
Cane, Lawyer	Calamus muelleri
Cedar, Red	Toona australis
Coachwood	Ceratopetalum apetalum
Duboisia	Duboisia myoporoides
Fig	Ficus spp.
Gum, Dunn's White	Eucalyptus dunnii SPIDA
, Flooded	E. grandis SECAB
, Forest Red	E. tereticornis SNEEB
, Manna	E. viminalis SPIKK
, Rose	E. grandis (Standard timber trade name)
, Roundleaved	E. deanei SECAA
, Sydney Blue	E. saligna SECAC
, Timor	E. urophylla SNAAA
Hibiscus	Hibiscus heterophyllus , H. splendens
Hop Bush	Dodonaea triquetra
Inkweed	Phytolacca octandra
Kurrajong, Brush	Commersonia bartrami
Lantana	Lantana spp.
Mahogany, Red	Eucalyptus resinifera SECCC
, Swamp	E. robusta SECAF
, White, Narrowleaved	E. acmenioides MAG:C
Palm, Cabbage Tree	Livistona australis
Soldier Vine	Kennedia rubicunda
Tallowwood	Eucalyptus microcorys SWA:A

Turpentine	Syncarpia glomulifera
Wandering Jew	Commelina cyanea
Wattle	Acacia spp
, Black	A. irrorata, A. oshanesii
, Newry Golden	A. chrysotricha
, Two-veined	A. binervata

Appendix 2

CLIMATIC DETAILS - FLOODED GUM TYPE

TAREE: **Latitude** 31.9ºS **Longitude** 152.4ºE **Altitude** 9m

Rainfall (mm)

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
123	144	144	123	92	98	84	68	65	70	77	105	1192

Lowest Annual: 607 mm Highest Annual: 2409mm

Temperature

Hottest Month: Mean Min : 20.7ºC (Feb) Mean Max: 28.7ºC (Jan)
Coldest Month: Mean Min: 6.OºC (Jul) Mean Max: 18.1ºC (Jul)
Highest recorded: 45.6° Lowest recorded: -3.9°
No. over 32ºC: 23 days Over 38ºC: 3 days
Av. No. Frosts/ year: 0.8 days Ave frost free period: 328

COFFS HARBOUR: **Latitude** 30.3ºS **Longitude** 153.1ºE **Altitude** 21m

Rainfall (mm)

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
33	35	31	26	28	32	144	124	77	70	104	140	1658

Lowest Annual: 685 mm Highest Annual: 376 mm

Temperature

Hottest Month: Mean Min : 19.7° (Feb) Mean Max: 27.0° (Jan)
Coldest Month: Mean Min: 6.5° (Jul) Mean Max: 18.7° (Jul)
Highest recorded: 43.3° Lowest recorded: -3.3°
No. over 32ºC: 14 days Over 38ºC: Less than 1

BROOKLANA: **Latitude** 30° 30'S **Longitude** 152.8°E **Altitude** 565m

Rainfall (mm)

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
209	142	250	161	119	152	113	72	75	91	117	158	1759

Lowest Annual: 932mm Highest Annual: 3294mm

Temperature

Hottest Month: Mean Min : 15.5ºC (Feb) Mean Max: 26.6ºC (Jan)
Coldest Month:Mean Min: 0.6ºC (Jul) Mean Max: 16.5ºC (Jul)
Highest recorded: 38.9ºC Lowest recorded: -8.0ºC
No. over 32ºC: 9 days Over 38ºC: Less than 1
Av. No. Frosts/ year: 62 Ave frost free period: 238 days

URBENVILLE: **Latitude** 28.5ºS **Longitude** 152.5ºE **Altitude** 365 m

Rainfall (mm)

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
152	158	157	67	57	85	57	40	40	74	75	120	1082

Lowest Annual: 635mm Highest Annual: 1649 mm

Temperature

Hottest Month: Mean Min : 26.5ºC (Feb) Mean Max: 29.1ºC (Jan)
Coldest Month: Mean Min: 2.6ºC (Jul) Mean Max: 17.5ºC (Jul)
Highest recorded: 42.8° Lowest recorded: -7.8°
No. over 32ºC: 23 days Over 38ºC: 1 day
Av. No. Frosts/ year: 28 Ave frost free period: 239 days

Appendix 3

PROPERTIES OF MAJOR TIMBER SPECIES: FLOODED GUM TYPE
(Derived from K. R. Bootle: 'Wood in Australia')

Abbreviations: L-S, Lyctid susceptible; G, green; S, seasoned; B, basic (re density)

Common Name	**Box, Brush**	**Gum, Dunn's White**	**Gum, Flooded (Rose Gum)**	**Gum, Sydney Blue**
Botanical Name	Lophostemon confertus	Eucalyptus dunnii	Eucalyptus grandis	Eucalyptus saligna
General Properties	Pinkish brown. Fine interlocked grain common. Dresses well. Very good wearing qualities	Pale brown, sapwood not clearly differentiated. Texture medium, even. Grain straight, gum veins common. Easy to work. Glues well.	Pink to pale red-brown. Straight grain. Rather coarse texture. Easy to work. Gum veins common. Variable in density. Glues well.	Pink to red. Grain straight. Moderately coarse texture. Gum veins common. Easy to work, fix, dress and finish.
Density kg/m³	G: 1160 S: 900 B: 710	G: 1100 S: 800 B: 610	G: 950 S: 620 B: 510	G: 1070 S: 850 B: 650
Durability	3(1-2 for termites). Little Lyctid attack.	4 L-S	3 Seldom Lyctid attack	3 L-S
Strength	S3	S3	S3	S2
Sawlog Group	D	C	B	B
Uses	Flooring, panelling. Cladding, general building. Decking, bearings, industrial flooring, wharfage.	Building framework, joinery	General construction, joinery, plywood, panelling, boat building, flooring. Paper pulp. Very good for fruit cases. Veneer.	General construction, flooring, cladding, panelling.
Other Notes	Slow in drying; some distorts badly. Not suitable for bent work.	Need to dry slowly at first to avoid checks and splits.	Slow drying. Some collapse. Not suitable for bent work. Borer holes may mar appearance.	Dries slowly.

Appendix 3 (cont.)

PROPERTIES OF MAJOR TIMBER SPECIES: FLOODED GUM TYPE

(Derived from K. R. Bootle: 'Wood in Australia')
Abbreviations: L-S, Lyctid susceptible; G, green; S, seasoned; B, basic (re density)

Common Name	Gum, Sydney Blue	Mahogany, Narrowleaved White (White Mahogany)	Turpentine
Botanical Name	Eucalyptus saligna	Eucalyptus acmenioides	Syncarpia glomulifera
General Properties	Pink to red. Grain straight. Moderately coarse texture. Gum veins common. Easy to work, fix, dress and finish.	Light yellow-brown. Fine texture. Grain often interlocked. Not difficult to work.	Red-brown. Fine uniform texture. Interlocked grain. Turns well. Takes high finish. Resistant to wear; does not splinter readily. Dulls cutting tools. Does not readily burn.
Density kg/m³	G: 1070 S: 850 B: 650	G: 1200 S: 1000 B: 780	G: 1130 S: 930 B: 680
Durability	3 L-S	1 Seldom Lyctid attack.	1 Seldom Lyctid attack. Very resistant to marine borers.
Strength	S2	S2	S3
Sawlog Group	B	C	D
Uses	General construction, flooring, cladding, panelling.	Heavy engineering, construction. Poles, sleepers, crossarms. Flooring, cladding.	Marine piling, shipbuilding, wharf decking, flooring bearings, mallets. General building construction.
Other Notes	Dries slowly.	Dries slowly.	Slow drying. Some collapse.

Appendix 4

REPORT ON THE ARACRUZ (BRAZIL) PLANTATION PROJECT
(from Boland, 1984)

Aracruz

Arguably the most progressive eucalypt forest company in the world and the number of international visitors coming to Aracruz lends support to this view. Brandao (pers. comm.) an ex-dentist said that he was involved in F.A.0. forestry propositions and became convinced that forestry and pulp were potentially good investments. With this knowledge he arranged finance in 1966 and then sought suitable land and a port for export. He decided on Aracruz (an old coffee-smuggling port) and bought up available nearby land (lots of land titles were required). The port is 50% government owned, 40% Aracruz and 10% Rio Doce. Aracruz has 9 major shareholders (British Tobacco was mentioned later).

Aracruz covers 80 000 ha of which 60 000 ha have already been planted (45 000 ha near Aracruz and 35 000 ha near Sao Mateus - north of Aracruz). Brandao claims his biggest mistake was not acquiring more land while it was cheap. They now produce 450 000 tons of kraft pulp per year and wish to increase this to 2 million tons year. Aracruz Florestal employs 3 000 people and a further 2 000 in the mill. Only 12% of the total investment is in the forestry sector (Brandao pers. comm.).

The Aracruz area receives abundant, fairly evenly distributed rainfall. The land is mostly flat, the soils sandy, but not good in my opinion. The soil structure is poor and compaction can be bad. The area was formerly rainforest, cleared for agriculture (cattle) and apparently very run down when Aracruz purchased it. Soils are wind blown Tertiary deposits and not alluvium from nearly granitic hills (Campinhos pers. comm.). There are 5 soil types altogether at Aracruz. The top 20cm is 75% silt with silt increasing with depth. They generally get good responses to low levels of phosphorus and there is a suspicion that the soils are deficient in Zn and K.

Their first forestry adviser was Sampaio, nephew of Navarro de Andrade, who advocated Brazil ‘alba’ (perhaps *E. urophylla* x *E. grandis*, my view) initially but more recently Aracruz has been developing a cutting programme for superior individuals in the old plantations but also looking at *E. grandis* from Atherton (because of canker resistance) and *E. urophylla*. The advantage of clones is that paper quality can be strictly controlled and little variation in the pulp is very useful for sales. Also chemicals for pulping can be controlled. Paper pulp is exported to U.S.A. (main market) but also to Germany, France, and Belgium.

Aracruz strongly advocates complete cultivation prior to planting. In some plantations I noticed reverse edge effects where the outside rows were poorer in height growth to those plants inside. This was put down to uncultivated land near the outside row (may be compaction problems).

Aracruz land preparation is as follows. After clearing a site the vegetation is burnt. If the grass is not dry then gramoxone is used to kill the grass before burning. They then wait for regrowth and spray with Roundup. Ant development is checked with baits. The land is then ploughed and rock phosphate (cheap but variable in phosphorus content) dropped at predetermined points at 650 kg per ha. In the one operation old stumps (if second improved crop is being planted) are covered with 20 cm of soil to kill sprouts. Goal is used as a pre-emergence weedicide before or just after planting (goal doesn’t kill seedlings).

At planting a worker carries 144 seedlings weighing only 8 kg thus resulting in huge weight savings. The cuttings are removed from the bullets before the planting (usually women) and thus with only vermiculite are very light.

The old Aracruz plantations were spaced at 3 x 2m at 1666 stems/ha and at 7 years this was down to 900-1 200 producing 34 m3/ha/yr solid volume. The coppicing ability of the stumps was poor (50% to zero) resulting in large losses. Now using 3 x 3m spacings for cutting program (Campinhos).

Trees are felled by chainsaw and the new development is to allow only one stem per stool to develop. This allows better directional felling and also better cultivation between rows. Men wear safety clothes (nylon trousers) and boots. A forwarder is used to collect 6m logs. There is a plan to use road trains to transport logs to the mill. The tops are used for fuel in the pulp mill but this will decrease to some extent if a natural gas pipeline is built in the future. Fire in the plantations is a problem and four fire towers are manned during dry weather.

Visited a fertilization trial with clones and was very impressed on how different clones responded to different fertilizer. This was an excellent and very impressive trial. It enabled one to select soil types and cheapest fertilizers to use with each clone. Brandao expects up to 46% gains in volume production by adding the right fertilizer to the right clones.

There are 10 potentially serious insects pests at Aracruz and over 50 that attack eucalypts. Aracruz have a 4 man team constantly patrolling the forests looking for outbreaks. *Bacillus thuringensis* is sprayed onto diseased sections. Excellent for controlling moths and caterpillars (Campinhos).

To me the secret of Aracruz is intensive management by a well motivated research team (66 workers) headed by E. Campinhos. The research team includes tree breeders, entomologists, soils and nutrient men, with plans for computer mensuration systems in the near future. Research and silvicultural practice is controlled by Campinhos. Brandao, the overall manager, takes an active interest in the research team and gives abundant encouragement. Of course the site, the port and the short distances to transport logs to the mill are very important considerations.

Technique used in establishing Plantations from Cuttings

This company has the most successful cuttings programme in Brazil - an annual planting programme of 10 000 ha/year based solely on cuttings. At present they are using 40 clones and hope to expand this to 100 clones. Standard clonal blocks are 100 ha in size and clones are arranged in mosaics in plantations for protection purposes. The size of the unit blocks is a management decision and clonal sites are selected to some extent on soil types. The cutting programme was started because Aracruz couldn't use the old hybrid seed (policy decision because of performance) and because Campinhos (pers. comm.) was impressed with Burgess's *E. grandis* hedges which he saw at Coffs Harbour. I understand that the bullet container idea came from Campinhos's visit to Hawaii.

Aracruz has teams selecting superior trees in the old *E."alba"* plantations plus they are actively examining trees of pure species such as *E. grandis* and *E. urophylla*. I was told that 14 characters were being examined in the selection e.g. rooting ability, coppicing ability, self pruning, straightness, fast growth, canker resistance, high density, high lignin content, longer fibre lengths etc. Over 5 000 trees have been examined in the old forest. Brandao (pers. comm.) stressed the need to tailor the tree to the needs of the pulp mill to save chemicals, to increase fibre yield per unit volume of wood etc. For instance a 0.1 increase in wood density from 0.4 to 0.5 gives a 20% gain in cellulose yield. Today density is 0.55 (range 0.45-0.6) and Brandao claims a 0.3 gain in density yields $20 million profit. Brandao sets targets for his tree breeders and currently his goal is to increase cellulose content from 54 to 60%. A 3% gain in cellulose gives about $4 million profit. This would adequately pay for the research effort and seems feasible.

The program is basically as follows - select a tree, do clonal tests of 50-100 cuttings and after two years do an evaluation. These are then placed in a clonal multiplication area and managed on a coppice hedge basis. Cuttings are collected 50 days after felling (best time) and 30 days the next crop of cuttings is harvested. At this stage the shoots are about 60 cm high and each stump can produce 100-120 cuttings per harvest. These stems are placed in plastic buckets, full of water, and put in a covered van for transport back to the nursery. Square stems are best for cuttings says Campinhos.

Cuttings are prepared by boys (14-18 years old) who sever the stem into 12 cm lengths (sic) having a pair of leaves and then cut off half of each leaf (outer half). Stems are dipped in Benlate for 15 minutes (400 ppm) and put in rooting hormone (6 g IBA pure (Merck) per 1 kg of talc - talc used to increase volume - 1 kg of mixture is good for 40 000 seedlings.)

The cuttings are placed in plastic bullets in fine grade vermiculite (5:1 vermiculite to water). The slurry is mixed and vibrated into the bullets that are held in a coolite holder (144 seedlings per box). Each bullet needs to be independent to allow sorting of seedling sizes later. No organic matter is used and even dead leaves are removed. Bullets have vertical rills to direct roots and cross roots that develop bind the vermiculite quite tightly.

Cuttings are then placed in a mist tent (50% shade cloth) for 35 days. After 25 days apply fertiliser and after 35 days seedlings are moved outside to harden up. After 45 days seedlings that have rooted are gathered together and the remainder are discarded. Success is 70-90% in rooting. At this stage plants are graded according to size (3 sizes). Cuttings are also rearranged so that all shoots point in the same direction.

Cuttings are trucked to the field. They are also sent to Sao Mateus 120 km distance with only a watering before departure.

Appendix 5

PRESERVED AREAS OF FLOODED GUM TYPE ON STATE FORESTS

Tooloom Scrub Flora Reserve No. 62253. Beaury S.F. 705 ha. Includes several fine occurrences of Dunn's White Gum on basalt plateau areas adjacent to rainforest.

Bruxner Park F.R. No. 73036. Orara East. S.F. 407 ha. Excellent examples of Flooded Gum communities, from young regeneration to giant veteran trees over well developed rainforest. Includes the "Vincent Tree".

Sugar Creek F.R. No. 79958. Wallingat S.F. 85 ha. Extensive stands of Flooded Gum, associated with Cabbage Tree Palm.

O'Sullivans Gap F.R. No. 79966. Bulahdelah and Wang Wauk S.F.s. 320 ha. Highway-fronting reserve with fine examples of Flooded Gum type and associated rainforest.

Woolgoolga Creek F.R. No. 79967. Wedding Bells S.F. 8 ha. Some recent Flooded Gum regeneration adjacent to rainforest.

Mobong Creek F.R. No. 79978. Wild Cattle Creek S.F. 14 ha. Small area of Flooded Gum at altitude of about 700 m.

Madmans Creek F.R. No. 80001. Conglomerate S.F. 92 ha. Flooded Gum included among a range of coastal types.

Bungdoozle F.R. No. 80010. Richmond Range S.F. 145 ha. Includes Flooded Gum stands.

Murray Scrub F.R. No. 80011. Toonumbar S.F. 740 ha. Some areas of Flooded Gum.

Rudders Box F.R. No. 80014. Kiwarrak S.F. 31 ha. Includes Flooded Gum with rainforest understorey along gullies.

Ringwood F.R. No. 80017. Gladstone & Irishman S.F.s. 60 ha. Small area of Flooded Gum included.

Waihou F.R. No. 97523. Conglomerate S.F. 1 900 ha. Some Flooded Gum stands at base of escarpment cliffs.

Mebbin Lagoons Forest Preserve No. 37. Mebbin S.F. 8 ha. Contains large Flooded Gums adjacent to the lagoons, with well-developed rainforest beneath.

Mt. Clunie Forest Preserve No. 41. Koreelah S.F. 375 ha. Stand of Dunn's White Gum present in south of area.

Twelve Sixty Forest Preserve No. 174. Bagawa S.F. 305 ha. Area of very varied vegetation, including some Flooded Gum stands and also an occurrence of Dunn's White Gum close to the species' southern limits.

Newry Golden Wattle Forest Preserve No. 219. Newry S.F. 27 ha. Flooded Gum stands and adjacent areas carrying the rare Newry Golden Wattle (*Acacia chrysotricha*).