Interim Guideline for the First Thinning of Bauxite Rehabilitation Areas Established After 1988 with Native Species in the Wungong Catchment

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Cover photograph: Thinned stand of jarrah in an area that had been mined for bauxite and rehabilitated with jarrah in Wungong catchment
(Taken by Jack Bradshaw)

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1 Introduction

1.1 Background

Bauxite mines in the high rainfall northern jarrah forest have been rehabilitated with native species since 1988. The dense regrowth stands that have resulted are now suitable for thinning to reduce the high water usage of these stands to maintain their health, to increase catchment water yields and to promote the growth of crop trees for timber production. Experimental plots and a small sub-catchment have been thinned by Alcoa but to date there has been no routine thinning program.

The strategies for the sustainable management of areas designated as State forest and timber reserves under the Conservation and Land Management Act are contained in the Forest Management Plan 2004-2013 (FMP).

This Interim Guideline is specifically directed at areas of bauxite rehabilitation that have been established after 1988 with native species and are within the Wungong catchment. The Wungong catchment is the subject of an adaptive management trial of silvicultural practices aimed at increasing water yield along with the other objectives common to State forest. Small catchment studies conducted during the 1980s and 1990s have shown that thinning of native forest results in a substantial increase in water yield but the effect decays after about 5 years and returns to pre-thinning levels after about 12 years as the retained trees, regrowth and coppice, which develops in response to thinning, increase their water use (Bari & Ruprecht 2003). Control of regrowth and coppice development has been shown to prolong the increase in water yield (Stoneman 1993). The Wungong project aims to extend this work to the larger catchment scale and to areas of bauxite rehabilitation to better understand operational factors and the impacts on other forest values (Water Corporation 2005a, b). The principal strategy is that stands suitable for thinning will be thinned, commercially and/or non-commercially. Following thinning, regrowth and coppice will be controlled or regulated until the stand is dense enough to repeat the thinning process or until regeneration is required. Stands unsuitable for thinning will be treated in a manner similar to normal practice.

A comprehensive monitoring program will assess the impact of these practices on the full range of forest values.

Areas of native forest, and areas that have been mined and rehabilitated to non-native species and rehabilitated ‘dieback’ sites are the subject of separate guidelines.

The project and the Interim Guideline will be implemented with the co-operation of several agencies. The Water Corporation is the proponent of the project and is responsible for the funding of operational and research activities that are additional to those normally applied to operations in State forest. The Department of Environment and Conservation (DEC) is the land manager and contractor to the Water Corporation for some aspects of implementation of the project. The Forest Products Commission is responsible for the application of this Interim Guideline where commercial harvesting activities occurs, through the normal DEC approval processes. The working arrangements between the Water Corporation and DEC are contained in a Memorandum of Understanding.

1.2 Scope

This document applies to areas of bauxite rehabilitation that have been established after 1988 with native species, are within the Wungong catchment and occur on State forest, timber reserves managed by the DEC and freehold land held in the name of the CALM Act Chief Executive Officer.

1.3 Custodianship and management of this document

This Interim Guideline has been prepared by the Water Corporation in consultation with DEC. The custodian of this document is the Manager of the Forest Policy and Practices Branch of the Sustainable Forest Management Division in the Department of Environment and Conservation. The document has been issued as an Interim Guideline based on the consultation that the Water Corporation has undertaken on the Wungong proposal. In this form the Interim Guideline is publicly available and will be used to guide operational practice on an initial trial basis. It is intended that the initial trial will be during 2007 and early 2008 and that the review of the Interim Guidelines will form part of the Water Corporation's first stakeholder project review for the overall Wungong project, which is planned to be by the end of 2008. On completion of the trial the Interim Guideline will be prepared as an SFM Guideline using the results of the initial trial and public feedback, submitted to the Conservation Commission for advice and approved by the Minister for the Environment. This process meets the requirements of the FMP for the development of guidelines.

2 Planning

Within the Wungong catchment there are approximately 2,500 ha of rehabilitation in the period 1988 to 2001. These areas have all been rehabilitated with native overstorey species. During that period there have been increasing proportions of native species used in the understorey rehabilitation. There has been 250 ha planted, all of which before 1993. The remainder has been regenerated from seed.

A variety of treatments will be implemented separately in the general thinning program including some variation to thinning intensity, method of thinning, utilisation of thinned stems and in some cases the post thinning treatment of regrowth. The location and minimum size of these treatments will be planned to take into account site representation, the local impact on water yield, landscape aesthetics, fire protection and the requirements of monitoring and research trials.

Annual plans of the location and type of treatment will be jointly prepared by the Water Corporation and DEC.

The thinning will be carried out by contractors to the Water Corporation.

3 Rationale for thinning intensity

In the long term, rehabilitated bauxite mines are required to contribute to all forest values, that is biodiversity, productive capacity, ecosystem health and vitality, soil and water, global carbon cycles, natural and cultural heritage and socio-economic benefits. The thinning regimes in this Interim Guideline are aimed to contribute to these values.

Consideration of the sensitivity of these values to stand density is relevant. Water production is highest under low stand density. Biodiversity is likely to be tolerant of the relatively wide range of density found in native forest. Stand health is most vulnerable at high stand density. Sawlog production is sensitive to individual tree quality, stand density and the timing of thinnings. The thinning regime proposed here is therefore based initially on the requirements for timber production within the constraints of its suitability for other values.

3.1 Present stand condition

The current density (basal area) of 13 year-old rehabilitation regrowth is approximately 25 m^2/ha (about 60% of maximum for the jarrah forest). However, canopy cover is approaching maximum values and LAI is approximately 2.

At age 13, stands have the following characteristics:

- Mean height of the tallest 300 stems per hectare (spha) ≈ 10 m;
- Mean diameter at least height over bark (dbhob) of tallest 300 spha ≈ 15 - 16 cm;
- Mean bole length of tallest 300 spha ≈ 4.5 m; and
- Mean basal area over bark (baob) of tallest 300 spha ≈ 5-6 m^2/ha (Koch & Ward 2005)

The number of good formed (single stemmed) trees is approximately 200 in planted stands (4x2 planting) and 1200 in seeded stands. Planting ceased in 1992. These data are to *a minimum* standard of 2 m bole length. In seeded stands there are about 450 stems with at least a 4 m bole (Koch & Ward 2005).

Field observations suggest that many single stemmed trees in stands older than 12 years have a current bole length of about 8 m with potential to increase further. This is little different to the surrounding native forest regrowth of greater age. The maximum average bole height likely to be achievable is 10 to 11 m.

3.2 Relevant factors in developing thinning regimes

The following factors have been considered in developing the thinning intensities that are included in this Interim Guideline (see Section 4.2):

- Thinning conducted at age 12-14 may result in fixing the bole length of crop trees at their current height, regardless of intensity (this needs to be monitored);
- The dhob of a tree with minimum sawlog specification is approximately 30 cm;
- The maximum density of 30 cm trees that can be supported before stand growth begins to decline is approx. 350 spha (25 m^2/ha);

- Thinning that retains more than 350 spha will require a further non-commercial thinning i.e. few if any stems over 350 spha will ever reach minimum sawlog size;
- The desirable minimum sawlog is 50 cm dbhob i.e. the whole bole then has sawlog potential. A maximum of 150 spha of trees of this size can be supported on the 'plateau' of optimum stand growth (~ 29 m^2/ha);
- 350 spha at dbhob 15 cms ≈ 5.3 x 5.3m spacing ≈ 6.5 m^2/ha;
- 600 spha of dbhob 15 cms ≈ 4.1 x 4.1 m spacing ≈ 10.6 m^2/ha;
- Maximum periodic increment (PMAI) of BAOB is in the order of 1 m^2/ha/ann at age 13 (Grant & Norman 2006) reducing to about 0.4 m^2/ha/ann at age 30 and reducing to 0.3 m2/ha/ann thereafter (Stoneman et al. 1989);
- The maximum diameter increment of trees thinned to about 400 spha is 2.5 to 4 mm /ann (Stoneman et al. 1989); and
- Most of the thinning response is on the fastest growing 300 spha in 12 year old stands of this age (Stoneman et al. 1989).

3.3 Expected stand development

The following stand projection is estimated for two thinning regimes. Diameter is used as the initial growth driver, limited by the predicted maximum basal area growth at different ages. It should be recognised that no actual growth data exists for this growth period for bauxite rehabilitation areas. Predictions are based on current growth data for rehabilitation sites, growth data from native forest at a later age and predicted growth over time based on the normal age/growth trajectory common to all forest stands. Monitoring of thinned stands over the full range of sites is required to provide actual growth data over time.

The tables below provide a prediction of future growth and an indication of their potential impact on timber development and water yield. Differences in these growth predictions relative to actual growth that may occur have no bearing on the thinning regime itself.

Option 1. Thin at age 12 –14 to 350 spha

Period (yrs)	Nominal Stand age (yrs)	spha	Rounded mean dbhob (cm)	BAOB (m^2/ha)
0	12	350	15	6.2
10	22	350	19	9.4
20	32	350	22	13.3
30	42	350	25	16.8
40	52	350	28	21.4
50	62	350	31	26.6
Average for period				15.6

Option 2. Thin at age 12-14 years to 600 spha and 320 spha in 10 years time

Period (yrs)	Nominal Stand age (yrs)	spha	Rounded mean dbhob (cm)	BAOB (m^2/ha)
0	12	600	15	10.6
10	22	320	19	8.6
20	32	320	22	12.2
30	42	320	25	15.7
40	52	320	28	19.8
50	62	320	31	24.6
Average for period				15.3

The following observations are relevant:

- Both regimes result in a similar average basal area over the following 50 years;
- Option 2 is visually more conservative in the short term than Option 1, is more expensive to implement (2 operations), is likely to result in more disturbance to the site (2 operations), produces sawlogs in a similar time but with a slightly lower total thinning volume (fewer stems);
- Both regimes produce the maximum number of potential sawlogs in a similar time;
- Stand density is maintained within the range that occurs naturally and as such should not adversely impact on biodiversity (this is subject to monitoring); and
- The overall health and vigour of the overstorey and the understorey should be improved relative to the unthinned state because stand density is maintained below the threshold at which the stand comes under severe competition for moisture.

These regimes have reduced stand density to a satisfactory level for high water yield, created stand conditions suited to optimum sawlog production and appear to be in the range suitable for maintaining biodiversity and aesthetic values. Since they satisfy the key values no further regimes were considered necessary for broad-scale use at this stage of stand development.

This guideline only applies to the thinnings described in the first decade. These thinnings have not reduced the range of management options available for the future relative to each other or to the unthinned stand.

It is premature for this guideline to detail the range of options that might be tested in future because the stands are not in a suitable condition for testing at this time. Further regimes that might be considered include a further non-commercial thinning before trees reach 30 cm dbh, which would increase water yield, produce a slightly lower total potential sawlog yield but produce 50 cm trees sooner. On the other hand a commercial ‘thinning from above’ would also increase water yield, provide an early return of small sawlogs but delay the time to reach optimum sawlog size.

4 Thinning operations

4.1 Pre thinning advance burn

The aim is that all areas proposed for thinning should be advance burnt, preferably two years before the thinning operation. However, the achievement of this aim will be limited by season, weather and operational constraints. Stands scorched in the burning will need to have thinning delayed till the crown has recovered to ensure that notching is effective. The primary objective is to improve access for treemarking and the manual thinning operation.

Where burnt or unburnt understorey still inhibits access for treemarking and thinning, understorey may need to be scrubrolled sufficient to achieve satisfactory access. Machine access in rehabilitated bauxite mines is difficult due to the presence of the contour mounds resulting from deep ripping. The most suitable machines and technique for scrubrolling will need to be evaluated in trials and will be heavily influenced by considerations of operator safety.

The thinning program and its associated advance burning will be integrated as far as is possible with the fuel reduction burning program of the surrounding area.

4.2 Thinning intensity

Two thinning intensities will be implemented:

- Thin to 600 spha (70% of area) – with the intention of a second thinning 10 years later to 320 spha; and
- Thin to 350 spha (30% of area).

The heavier thinning will generally be applied to the planted stands where there are fewer trees of good form, but thinning of both intensities will be applied to cover the range of site quality that is available. The minimum area of any particular thinning intensity will be sufficient to accommodate any planned monitoring plots or future thinning options. Similarly sufficient areas will remain unthinned to serve as controls, both for scientific purposes and for demonstration. These ratios (70% to 600 spha and 30% to 320 spha) will be reviewed after a period of implementation and following consideration of the impact on tree health, aesthetics, understorey, tree form and future options for treatment.

4.3 Treemarking

Stands will be treemarked prior to thinning by or under the close supervision of a DEC officer trained in treemarking using the following guidelines:

- Preference for retention – dominant and co-dominant trees with good form and a long bole capable of extension (avoid trees with low forks);
- Have regard to spacing at least at the level of 150 spha (8 x 8 m);
- Give preference to jarrah crop trees but 20-30% of the retained trees to be marri or blackbutt where it exists;
- Retain a minimum of 20% of crop trees as jarrah where it exists. Some sub-dominant jarrah may need to be retained to achieve this percentage; and

- Do not retain trees of exotic species, should they occur.

Stands that do not support the nominated thinning intensity will not be thinned.

4.4 Method of thinning

4.4.1 Commercial thinning

Although there is currently no significant market for the products, a harvesting trial will be undertaken where the thinned trees are removed from the site as though it were a commercial operation to develop an understanding of costs and operational issues. Thinning will be carried out using a small harvester. Removal of products from the site will be subject to the normal DEC approval processes.

Harvesting operations will be monitored to ensure that there is minimum damage to crop trees. The objective is to maintain a damage level of < 5% of crop trees.

The use of heavy machinery on rehabilitated bauxite pits will be limited to the Low and Medium risk periods (DEC 2007) as it is noted that rehabilitated bauxite pits are highly disturbed and may be sensitive to further disturbance in terms of the site capacity to support ongoing ecological processes. Soil disturbance will also be monitored using the methods described in the *Interim Manual of Procedures for the Management of Soils Associated With Timber Harvesting in Native Forests* (DEC 2007).

4.4.2 Non-commercial thinning

Notching with herbicide application will be the normal method of thinning and will be carried out consistent with label requirements and DEC prescriptions.

In areas that are important for aesthetic reasons, thinnings will be felled by hand with herbicide applied to the stumps. The 'cut stump' method should be used with caution alongside burn boundaries because of the high ground fuel that will result (note that this is the opposite advice to that applying in native forest where larger trees are present).

Normal thinning procedure avoids the application of herbicide close to marked trees of the same species because of the potential for unintended mortality of the marked trees due to 'flashback'. However in dense stands such as this, such a practice may result in too many unmarked trees (or their coppice) remaining alive, resulting in a higher than intended retained density. In these operations herbicide will be applied to all unmarked stems (except those that are obviously connected) with the object of achieving a 'flashback' rate of <5%. Adjustment to practice will be made to achieve this objective where necessary.

4.4.3 Tops disposal

Where trees are felled for commercial or non-commercial reasons, tops and other residues larger than 7.5 cm diameter are to be removed to at least 1 m from around marked trees to ensure protection from subsequent fire.
Heaps of harvesting debris should be removed from beneath the crowns of retained trees.

5 Post thinning burning

The post thinning burning program will be developed by the Water Corporation and DEC, for approval by DEC. The principal objective is to maintain satisfactory fuel loads for strategic protection purposes. In this respect 'commercial' and 'cut-stump' thinning will have most affect on fuel loads. There is also a need to co-ordinate burning and coppice control in 'commercial' thinning operations.

Post harvest burning will be carried out in spring, under conditions aimed at protecting retained trees from damage and minimising the regeneration of exotic Acacia that exists in some sites.

No burning should be carried out within 12 months of any herbicide application because it may stimulate coppicing.

Some areas will be selected for no pre or immediate post burning as part of the biodiversity monitoring program.

6 Follow-up treatment

6.1 Immediate

6.1.1 Protection of understorey and mid-storey element

The follow-up silvicultural treatment described below involves greater use of herbicides for control of regrowth than is standard practice elsewhere in the jarrah forest. This poses a risk of herbicide impact on non-target species, particularly understorey vegetation. To reduce the risk to non-target species the following practices will be employed:

- Those undertaking herbicide application will receive adequate training so that they can reliably identify target and non-target species and so they use the correct methods of application which minimise the effect of herbicide on non-target species;
- The herbicide application operation will be closely supervised to ensure that practices are being implemented appropriately; and
- All areas subject to regrowth control by herbicide application will be monitored for the effectiveness of the operation on target species and the impact on non-target species.

6.1.2 Weeds

Weed invasion into thinned stands from adjacent pre-1988 rehabilitated bauxite pits will be monitored and controlled by application of herbicide at appropriate intervals.

6.1.3 'Commercial' thinning areas

Trees that are harvested without herbicide treatment will require foliar spraying of coppicing stumps when the coppice is about 0.5 to 1 m high. This will be about one year after thinning. Cull trees remaining after 'commercial' harvesting will be notched or felled (Section 4.4.2).

Foliar spraying has not been commonly practiced on a large scale. Initially the work will be done consistent with label requirements and DEC standard practice for native forests, but modifications to this standard DEC practice will be trialled and implemented where it becomes necessary to do so, whilst still being consistent with label requirements. Particular care is required during foliar spraying to minimise damage to non-target plants. This will be monitored along with any monitoring of spraying success.

6.1.4 Non-commercial thinning areas

Areas treated with herbicide (notching or 'cut-stump') will be monitored for success 12 months after treatment (see below). Areas that do not meet the success criteria, in terms of the mortality of treated trees or stumps or where there is evidence of eucalypt lignotuber release, will be further treated with notching and foliar spray.

6.2 Longer term

Monitoring will be repeated five years after the thinning and the treatment described above will be repeated if necessary.

7 Monitoring

7.1 Operations

7.1.1 Treemarking

The treemarker will monitor marking density at regular intervals using the Tesselated triangle method.

7.1.2 Herbicide application

The correct method of application of herbicide will be regularly monitored by the DEC supervising officer.

7.1.3 Weeds

Where post 1988 rehabilitated bauxite pits that are treated under this Interim Guideline are adjacent to pre 1988 rehabilitated bauxite pits the post 1988 rehabilitated bauxite pits will be monitored for the presence of weeds that establish as a result of the seed source present in pre 1988 rehabilitated bauxite pit.

7.1.4 Monitoring the impact of regrowth control on target and non-target species

Areas that have had follow-up regrowth control will be monitored using systematic strip sampling to determine both the success of regrowth control and the impact on non-target species.

These criteria will be reviewed after a trial period of operational practice.

7.2 Outcomes

7.2.1 Overstorey trees

Following thinning, the stands will be photographed from the air at an appropriate scale and stratified on the basis of surviving stem numbers per hectare.

In the summer following treatment systematically located plots will be established throughout the thinning area to monitor the outcome of silvicultural treatment on overstorey trees.

The following will be recorded at each plot:

- Retained density – spha using the tessellated triangle method, basal area using a 1 factor prism or angle gauge;
- Bole length of the best tree within 4.5 m (~150 spha);
- Diameter of the best tree within 4.5 m (~150 spha);
- Mortality of treated trees;
- Mortality of crop trees;

- Crop trees that have been damaged; and
- Species composition.

Stem numbers and mortality are principally used to monitor operational performance. All parameters are used as a basis for predicting future timber yield. Basal area is used as an indicator of water use.

These procedures will be used in the initial thinning operations but will be reviewed after a sufficient period of application and amended as necessary. Sampling intensity will be determined on the basis of a pilot survey.

7.2.2 Understorey vegetation

A separate project will be initiated by the Water Corporation to monitor the effect on understorey of:

- Thinning intensity;
- Removal of thinnings;
- Burning; and
- Control of regrowth and coppice.

on:

- Understorey species composition (native and exotic); and
- Understorey species density.

This will allow an evaluation of the impacts of treatments on aspects of the completion criteria that Alcoa have rehabilitated the sites to.

7.2.3 Long term tree and stand growth

DEC will monitor tree and stand growth in post 1988 rehabilitated stands as part of the Department's responsibilities for timber inventory and yield regulation. This will be done using existing plots (in association with Alcoa) or with a series of newly established plots.

7.3 Success criteria

The following success criteria will be used:

Thinning operations:

- < 5% of crop trees to be damaged; and
- > 90% of area within a mapped density strata of ± 5 % of target density.

Follow-up operations:

- Target individuals treated to be > 90%;
- Mortality of treated individuals to be > 80%;
- 'Crown area' of non-target vegetation impacted by herbicide treatment to be < 0.5 % of sample area;
- Perennial declared weeds occur at < 50 plants per hectare (see Bauxite mining completion criteria Appendix 1 Section 3.2.1); and
- Non-native overstorey and mid-storey plants occur at <50 plants per hectare within 100 m from pits rehabilitated with non-native species.

Success criteria will be refined in the light of experience and a better understanding of what is feasible.

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