Wungong Catchment Trial

The health of the northern jarrah forest 2001–2012

Discussion paper

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WATER CORPORATION

Acknowledgement

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Comment
This report focusses on a local issue and the reader may notice that most of the references quoted are from the so-called 'grey' literature. Although most academics would dismiss any report that is not published in a peer-reviewed journal, the author regards many of these unpublished reports and data as valuable and timely with respect to policy development.

Summary

This report has been prepared for the Wungong Catchment Trial project. It provides an update on monitoring the health of the northern jarrah forest by summarising published and unpublished data available from CSIRO and The Centre of Excellence for Climate Change, Woodland and Forest Health at Murdoch University and The University of WA; data collected by Department of Water, Department of Environment and Conservation, Water Corporation and consultants to Water Corporation; as well as research and observations by the author in the forested catchments over the past decade.

These data show that the health of the higher rainfall forest is already under severe threat with between 5 to 8 per cent of the western jarrah forest collapsing during summer 2011. Because national and regional parks focus on scenic features such as streams, waterfalls, views and hills, the effects of the drought have been disproportionately high on these tenures. As examples, major collapse has occurred in parts of the Darling Range Regional Park, the Monadnocks Conservation Park and the Serpentine National Park.

The pattern observed has been that in the lower rainfall jarrah forest there is longer-term crown decline but with fewer deaths, in contrast to the higher rainfall areas where there is crown stability or increases that are then followed by major collapse. Native forests in lower rainfall areas seem to be better adapted to the drying trends. The forest is shorter, more open and has less crown cover than that in the higher rainfall areas, and appears to be reacting more effectively to lower rainfall by reducing crown cover gradually rather than dying suddenly.

Some of the trees that have died, albeit located on harsh sites with shallow soils, are estimated to be over 200 years old. Have we observed an unusual, one in two hundred, one-off event? Or was 2011 the harbinger of more frequent and severe droughts in these forests?

The latter is the more likely future scenario since we are now witnessing a vicious natural cycle. Rainfall at Jarrahdale in July 2012 was the lowest observed in 128 years of record-keeping, and at the end of winter this year, Perth's rainfall was 38 per cent below average (Bureau of Meteorology). Extensive deaths of trees are also expected from summer 2012 through to autumn 2013.

This recurring pattern of death of trees and crowns, with some recovery, more deaths die-back and then further recovery will begin to stretch the tree's food resources. Eventually the death of trees through starvation rather than by drought is a strong possibility. Similar patterns of crown loss and tree deaths, with some recovery, followed by further deaths have also been observed in some areas that were rehabilitated after bauxite mining.
Will we see the disappearance of some dominant species, like jarrah, as has been observed overseas following severe droughts? This is not likely as jarrah is a very tough species and currently extends into much lower rainfall zones than those of the wetter western catchments.

However we will see a much different forest structure in the future — the overall height will be lower as trees progressively lose their leaves die-back and recover, crown cover will reduce, and many more dead branches will be visible. There may also be a gradual change in the mix and dominance of some species, both in the overstorey and understorey. The forest is also likely to be much less attractive aesthetically.

These data show that immediate and broad-scale silvicultural intervention is necessary, and they also strongly support the Conservation Commission's 'Management option 2' as recommended on page 75 of the Draft Forest Management Plan (2014–2023). The highest priority and most cost-effective location for thinning operations would be the 100000 to 150000 hectares of forest located within the high rainfall areas of the catchments, which

have been most affected by drought, and where the enhancement of biodiversity values as well as the additional water yield would have major environmental and financial benefits.

Introduction

In the decade from 2001 to 2010 there were three very dry years: 2001, 2006 and 2010, with 2010 being the driest year ever recorded in Perth and surrounding areas at that time. To date, 2012's rainfall has also been 38 per cent below average, with July 2012 being the driest month on the 137-year record. This decade followed a much longer drying period of about 25 years which had commenced in the mid-1970s. As an example, the rainfall at Jarrahdale, at the western edge of the northern jarrah forest, averaged 1251 mm between 1911 and 1974; and 16 per cent less (1047mm) between 1975 and 2009. As a result of these longer-term trends, soil moisture content, water tables and streamflow in the forest area have all decreased substantially (Reed et al 2012). Streams that had been perennial, such as Wungong, are now dry for several months each summer, with negative impacts on the aquatic biodiversity (Davies and Storey 2012). The falling water tables are now threatening the health of streamside vegetation and its associated fauna (Batini 2011, Dundas et al 2012).

There are no similar long-term rainfall data for the eastern jarrah forest. Data for York and Beverley (to the east of the forest belt) show that the rainfall averages of 450 mm (1880–1996) and 419 mm (1886–2012) respectively are not much higher than the 430 mm and 418 mm recorded from 1981 to 2010 (Bureau of Meteorology data). The pattern of rain has apparently changed somewhat with York receiving about 13 per cent less rain in winter and about 7.5 per cent more in summer (P Poot, personal communication). Water tables have also fallen by several metres in lower rainfall jarrah forest during the past decades (Batini 2005).

This report will concentrate on the northern jarrah forest from the Murray River to Armadale. It will concentrate on the impacts observed on the dominant tree species — jarrah, marri, bullich, blackbutt, banksia and allocasuarina — as these are key structural components of this forested ecosystem.

Observations

The Wungong catchment is 13000 hectares and is situated approximately 60 km south-east of Perth. In this area, the rainfall recorded at the 'Gardens' pluviometer (which has a 38-year average of 1103 mm) was 747 mm in 2001, 728 mm in 2006 and only 573 mm in 2010. No obvious health concerns were observed or reported during summer 2002 which followed the 2001 dry winter. In summer 2007 some deaths of large, old jarrah up to 80 cm in diameter were observed by the author on two sites within Wungong in native forest situated on shallow soils. In addition, some deaths were also seen in 12-year-old rehabilitated bauxite pits that were seeded to jarrah and marri. In all, these deaths covered less than one hectare. In the period from 2007 to 2010, many of the dead trees partly recovered by re-shooting from epicormic buds located under the bark on the trunk or collar region. New coppice responded favourably to above-average precipitation and, by summer 2011, had grown to between 3 and 4 meters in height.

The 2010 winter rainfall was the lowest ever recorded in the northern forested areas. This was followed by a long, dry, hot summer, including 122 continuous rainless days. By March 2011, major collapse of vegetation was obvious, particularly in the higher rainfall, western jarrah forest (see Figure 1, p. 5). Deaths continued until June/July 2011 and occurred on all tenures including private land, State Forest, national parks and conservation parks.

As a result of these deaths, a number of surveys were commenced by various agencies.

Figure 1 — Extensive death of trees, some over 200 years old, on shallow soils *(taken by K Barrett, summer 2011)*

Data collected by Water Corporation
Initially there was a survey by helicopter of the Wungong catchment area to locate and photograph the extent of the damage. It was roughly estimated by the author that the affected areas covered between 5 and 8 per cent of the survey area. About 150 photographs were taken with GPS coordinates so that areas could be located in the field (see Figure 2 below). A brief report was published in *Wungong Whispers* (Volume 12 May 2011), the newsletter for the Wungong Catchment Trial project.

Figure 2 — Deaths of native and exotic trees, un-thinned (right) and healthy, exotics (left) thinned to 8 m2/ha *(D Birt, Water Corporation, summer 2011)*

Subsequently, a dozen sites were described in the field (Davison 2011) comprising six sites in native forest and five sites in rehabilitated bauxite pits. Two of the sites were those that had partly recovered from the 2007 summer. Trees that were recovering during 2008–2009 had died back or had lost a great deal of crown (Figure 3 below). In addition, the effects were observed over a much larger area than previously. Other interesting observations were that:

- marri appeared more resistant to drought than jarrah
- most dead patches were associated with rock outcrops on steeper slopes
- however some tree deaths were observed on good-quality forest sites with deeper soils
- no recent deaths were seen on sites that had been thinned
- some of the dead trees were over 90 cm in diameter and estimated to be well over 200 years old
- some deaths of bullich and blackbutt were observed in water-gaining sites within streamzones
- the understorey species were mostly healthy, and
- longicorns beetle damage and larvae were observed in the dying trees.

Figure 3 — Site adjacent to Chandler Road which had died in 2007, partly recovered, and then died again in summer 2011 *(taken by F Batini, summer 2011)*

Cobiac catchment

In 2008, an experimental catchment of 340 hectares at Cobiac (a sub-catchment within Wungong) was commercially logged then non-commercially thinned to reduce the basal area from 34 to 18 m2/ha and stem numbers from approximately 400 to 140. For experimental purposes, the designated stream reserve was left un-thinned, as was a 'control' strip 200 meters in width from the streamzone to top of the ridge.

The helicopter survey had suggested that recently thinned areas did not show similar drought effects, so a ground survey was carried out in the Cobiac sub-catchment to quantify this aspect (Batini 2012). The survey compared the crown health in an un-thinned forest with that of thinned areas, some of which were designated as affected by dieback disease (*Phytophthora cinnamomi*) by Department of Environment and Conservation (DEC) and others as dieback free. Data showed that:

- thinning substantially increased the crown health of the remaining trees
- the improvement in crown health was similar in sites-affected or free of *Phytophthora*, and
- in the un-thinned control, many trees had poor crowns and several had recently died (see Figure 4, p. 7).

Figure 4 — Dead and dying jarrah trees within a rehabilitated bauxite pit (left), and on lower slopes of the CSIRO un-thinned control strip (right) *Cobiac research catchment (taken by F Batini, March 2012).*

Remote sensing by Geographic Information Analysis (GIA) has provided several estimates of Leaf Area Index (LAI, a measure of leaf area) derived from Landsat images, some that cover all the major water supply catchments, and other data specifically for the Wungong and 31 Mile Brook catchments. These show that:

- For the period 1988–2011, and for all catchments combined, as average annual rainfall decreases in an east-west transect, leaf area also decreases (700 mm rainfall, mean LAI 0.6; 1300 mm rainfall, mean LAI 1.75). However it is probable that a lower leaf area could be sustained in the drier period than has been experienced since 2001 up to 2012.
- In the Wungong catchment, the highest LAIs are found in the bauxite areas rehabilitated after 1988 (mean 2.20, mode[1] 2.46) and the lowest in the unmined native forest (mean 1.43, mode 1.70). This represents an increase in LAI of about 50 per cent in the areas rehabilitated after mining with native species, which is concerning given the trends in rainfall. Can such high leaf areas be maintained without ill health?
- Bauxite areas rehabilitated before 1988 with exotic species are intermediate in value (mean 1.94, mode 2.02). These areas were mostly planted, whereas post-1988 the areas are mostly sown, resulting in a higher stocking.
- Within rehabilitated areas, at least 5 per cent of the area has LAIs that exceed a value of 3.0.
- In the period 1973–2009, despite the decreasing rainfall, the LAI in the largely undisturbed 31 Mile Brook catchment rose by nearly 50 per cent — from 1.1 to 1.7. In the Wungong catchment, a more highly disturbed catchment, the increase was a more modest 15 per cent. A similar trend of increasing density has been observed for other catchments (J Croton personal communication, Wallace et al 2009). These observations are also of concern, as it appears that the native forest in the higher rainfall zone is not adjusting gradually to a lower rainfall regime. There is no obvious explanation why this should be so and this aspect warrants further investigation.

Spec Terra Services obtained crown cover estimates for Cobiac catchment from remotely sensed imagery at a resolution of 0.5m. The data show that the average canopy cover for native forest in 2005 before treatment was 50 per cent, the cover for rehabilitated areas was 44 per cent and the streamzone was more open at 33 per cent. Following treatment,

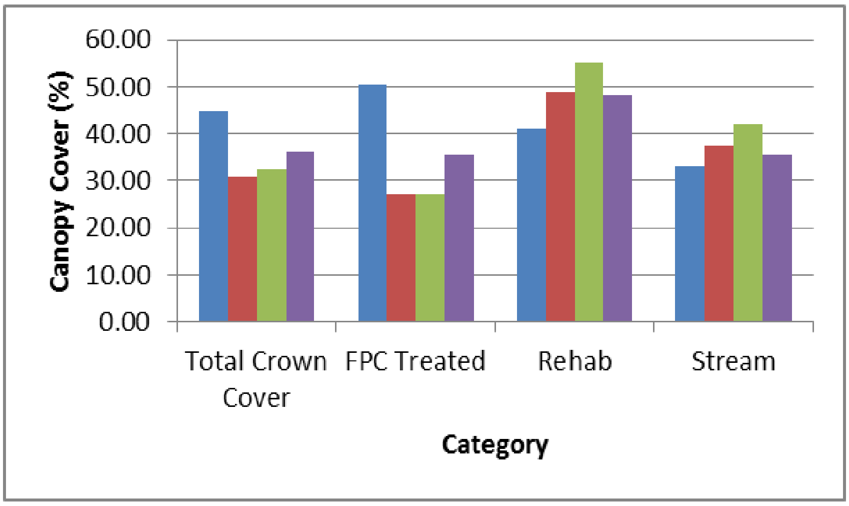
[1] Mode is the most common value

the native forest cover averaged 27 per cent — a reduction of about 46 per cent (Figure 5 below).

The data for canopy area and percentage cover are also available for November 2009 (following an above-average winter rainfall) and for November 2010, which followed the driest winter recorded to date. The pattern of growth varied markedly between treated and untreated areas. In the streamzone and bauxite rehabilitation area, the crown cover increased substantially from 2005 to 2009, by 9 and 14 per cent respectively; but then fell by 7 per cent after the poor 2010 winter. Tree deaths and loss of crown were evident on both sites by summer 2011 (see Figure 4, p. 7).

In contrast, the thinned areas took some time to recover but then expanded by 9 per cent between November 2009 and 2010, despite the poor winter. Tree crowns were healthy and no deaths were observed by summer 2011 (Figure 6 below).

Figure 5 — Canopy cover estimates



2005 = blue
2008 = red
2009 = green
2010 = purple

From remote sensing data collected in November (Spec Terra Services)

Figure 6 — Healthy jarrah forest, thinned in 2007 to 11 m2/ha *(taken by K Barrett, summer 2011)*

Data collected by Centre of Excellence for Climate Change Woodland and Forest Health (Murdoch and UWA Universities)

As a response to these dramatic deaths, Dr G Matusick (post-doctoral fellow at the Centre) arranged for an extensive aerial survey to be conducted over the affected areas, and was accompanied by an experienced DEC staff member. The flight covered about 9 per cent of the western forest area between Mundaring and Dwellingup. One flight line was located above the Darling Scarp, and the other was several kilometres to the east. Along the flight path, the locations of severely affected forest areas were plotted and the area calculated as follows:

- about 1600 hectares were determined to be severely affected, representing 1.6 per cent of the sample area
- in addition, an estimated 5000 hectares (5 per cent of the sample area) was showing severe crown chlorosis and discolouration, and
- the estimate of the proportion of survey area affected (6.6 per cent) is similar to that estimated for the Wungong catchment (5 to 8 per cent).

Doctors Matusick and Ruthrof then established a large number of 'paired' field plots to compare data from within and outside the affected areas (Centre of Excellence Annual Report 2012). Their field survey showed that:

- jarrah was the primary canopy tree observed as dying throughout the forest however, in the most severely affected areas, marri also failed
- in the mid-story, banksia and allocasuarina were also severely affected
- there was very severe infestation by longicorns beetle larvae in recently dead and dying trees
- sampling for *Phytophthora* dieback disease recovered the fungus from some sites but the majority of sites were free from dieback, and
- some months later the sites were revisited to assess the level of recovery from epicormic buds and compare the differences between species, and jarrah and allocasuarina had re-sprouted much more readily than did banksia or marri.

Research at the Centre is continuing at a number of sites on aspects of ecology, eco-hydrology, remote sensing and computer modelling. Recent work by Poot and Veneklaas (in press) shows that:

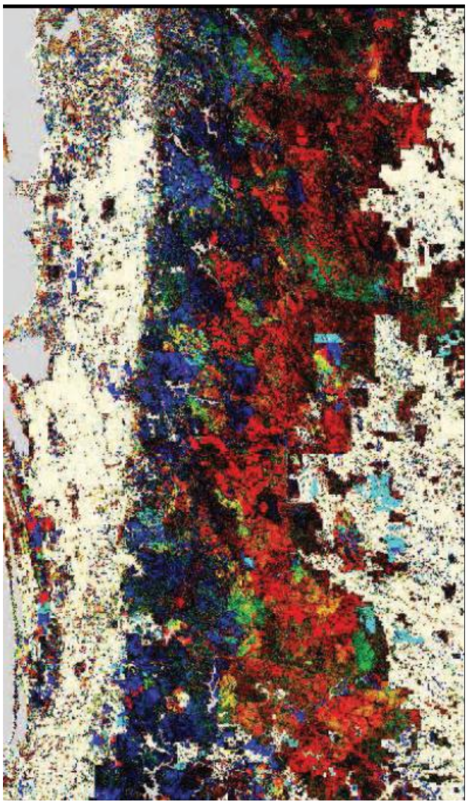
- jarrah and marri have a high vulnerability to cavitation (a type of embolism) in their water conducting tissues, and
- these deep-rooting species that access a large volume of soil have trouble extracting water that is tightly bound.

Data collected by CSIRO

CSIRO scientists at the Leeuwin Centre have monitored forest condition from 1989 to 2007 using canopy cover indices derived from time series Landsat imagery (Wallace et al 2009). The images were taken annually in the summer/autumn period and include the dry years of 2001 and 2006, but not 2010. Broad patterns of change are obvious over these two decades during which rainfall continued to decline (see Figure 7, p. 10), in particular:

- the native forest in the western, higher rainfall zone shows stability or increase in canopy cover, whereas the native forests in the eastern, lower rainfall zone show widespread cover decline
- irrespective of the rainfall zone, rehabilitation post-mining shows increases in canopy cover, and
- plantations of trees on farmland in the eastern, low rainfall zone also show increases in canopy cover.

Figure 7 — Cover trends 1989–2007 for perennial vegetation within northern jarrah forest



Red indicates linear decline, blue is linear increase and black areas are stable.

Green, yellow and cyan show a curvature in the response over time.

(Data extracted from Wallace et al 2009, CSIRO).

CSIRO's Dr C Macfarlane has monitored three sub-catchments (31 Mile Brook, Chandler and Cobiac) for canopy responses to drought, also using time series Landsat imagery but over a shorter period — January 2010 to March 2011 — which includes the very severe drought winter in 2010 and the following long, dry summer. Data for the Cobiac sub-catchment trial are presented in Figure 8 (p. 11) and show:

- severe crown decline was observed within the bauxite rehabilitated pits, the un-thinned control strip and the stream reserve
- tree deaths were recorded within the bauxite rehabilitated pits and the un-thinned control strip (Davison 2011, Batini 2012), and
- crowns within thinned areas show stability or improvement and no drought deaths were observed, irrespective of whether *Phytophthora* dieback was present or not (Batini 2012).

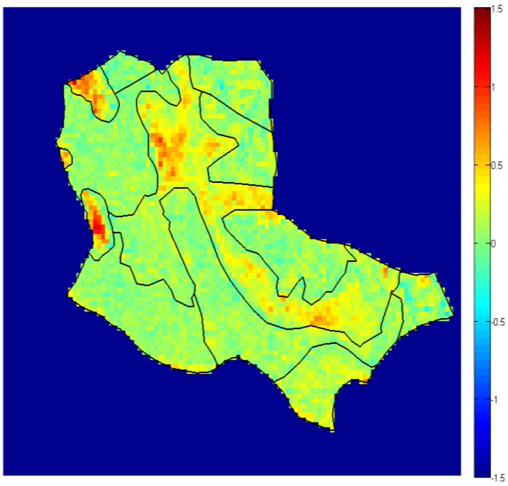
Data collected by Department of Environment and Conservation
In autumn 2011, Department of Environment and Conservation (DEC) also conducted aerial surveys and flew three strip lines parallel to the Darling Scarp, from Collie to Mundaring, to observe the pattern of tree deaths. Most dead patches were located in the western, higher rainfall area, with only occasional deaths observed in areas of lower rainfall (Lorkiewicz personal communication). These observations were confirmed by two ground surveys conducted by the author, from Mundaring to York and from Beverley to Roleystone.

The Department of Environment and Conservation has a comprehensive set of growth plots in the northern jarrah forest. Analyses of growth data over the period from the 1970s to 2012 have not shown any decrease in the already low growth rates of jarrah (Rayner personal communication). These data may not have enough sensitivity to detect small changes in growth rate.

Rainfall and stand density data were collated by rainfall zone for 1128 plots established up to 1960 in virgin forest. Rainfall isohyets and corresponding basal areas were: 1300mm, 36 m2/ha; 900mm, 28 m2/ha; 700 mm, 25m2/ha; 600 mm, 17m2/ha (J Bradshaw, personal communication 2007). Data clearly show that as rainfall decreases, the basal area also decreases. The forest in lower rainfall areas has clearly adapted to the historical rainfall conditions.

Rainfall and crown cover data derived from Aerial Photo Mapping in the 1960s over an area of 707000 hectares show crown density of virgin jarrah forest by rainfall. The weighted crown densities were as follows: > 900 mm, 63 per cent; 700–900 mm, 55 per cent; < 700 mm, 46 per cent (J Bradshaw, personal communication 2007). The forest has adapted to the historically lower rainfall by reducing its crown cover. As soil-water stores continue to be depleted, further adjustment in crown cover is likely.

Figure 8 — Estimate of changes in leaf area index (LAI), Cobiac sub-catchment trial area, January 2010 to March 2011



Red and yellow = decline
Green and blue = improvement

(Data provided by Dr C Macfarlane, CSIRO)

Discussion

The forests that form a backdrop to Perth are valuable for conservation of biodiversity, water supply, minerals, recreational activities and timber production. All of these values are threatened by major collapse of the dominant overstorey and mid-storey species which form the main structural elements of the northern jarrah forest.

The data and observations summarised above are consistent between observers. The long period of below-average rainfall, the reduction in streamflow and groundwater, the very low winter rainfall in 2010 followed by a record dry summer, the pattern of deaths and recovery, the healthy understorey and the timing of the collapse, all point to sudden and severe drought stress as the primary driver.

Trees that are stressed are more likely to succumb to a fungal or an insect attack. There has been noticeable frost damage to seedling and tree crowns, especially in valleys, during recent winters which may be due to a more frequent incidence of clear skies and less rain. The mean daily minimum temperature in July 2012 was also the lowest on record. In addition, the fuel loads will be higher, the average tree crown height will now be lower and the crowns are more likely to be scorched, even by a milder prescribed burn. Dead and dying trees then provide food sources for a build-up of insect populations and fungi. Major infestations of the native longicorn beetle have been observed in dead and dying trees.

The observed increase in crown cover in plantations and areas rehabilitated after mining, even in lower rainfall zones, also warrants a comment. There are two probable explanations: (a) these trees are using an excess of stored soil water resulting from clearing for agriculture or mining; and (b) the younger trees have not yet fully occupied the site and are currently not under water stress.

However the situation is changing. These trees are growing vigorously and, as they age, they will fully occupy the site and use all of the excess stored water. These stands will then become increasingly under stress. Stocking rates on many rehabilitated areas that were seeded can be well above 2000 stems per hectare, and estimates of leaf area that average at least 50 per cent more than that for native forest have been measured in the Wungong catchment.

Patterns of crown loss and tree deaths, with some recovery, followed by further loss of crowns die-back have now been observed in some of the areas that were rehabilitated after bauxite mining. Can these stands survive in a healthy condition and maintain their high leaf areas without intervention to reduce the competition between the trees? Based on what has been observed to date, this is unlikely.

There are two million hectares of high forest in the South West of Western Australia. Are there any silvicultural practices that can alleviate or delay these changes? The obvious answers are: thinning to reduce competition for water within the overstorey (Stoneman et al 1996, Batini 2012); more appropriate prescribed burning regimes to reduce damage to biodiversity, forest and catchment values through wildfire (Batini and Barrett 2007); and to create mosaics that favour diversity in understorey species (Burrows 2008).

A possible target for prescribed burning could be 250000 to 300000 hectares per annum, but silvicultural operations are more limited in scale and may at best only cover 20000–25000 hectares annually — about three times the current level of Forest Product Commission's operations. The highest priority and most cost-effective location for operations would be the 100000 to 150000 hectares of forest located within the high rainfall areas of the catchments which have been most affected by drought, and where the additional water yield (Reed et al 2012), as well as enhancement of biodiversity values (Batini 2011, Dundas 2012) would have major financial and environmental benefits.

However this will account, at best, for only 5–8 per cent of the two million hectares of forest area. An increase in the level of thinning in catchments is also supported by the independent *Review of Silviculture in Forests of South-west Western Australia* (Burrows et al 2011).

Even such a small proposal for thinning will be strongly opposed by minority but influential pressure groups. The one million hectares of high forest (about 50 per cent) that are designated as national parks or various other reserves will be left to cope with drought with minimal or no intervention. The Conservation Council also opposes any form of silviculture in the remaining one million hectares of State Forest, their target being to stop all logging and to close the timber industry in Western Australia.

Given the climate projections for these areas of forest, it is now time to reconsider attitudes to silvicultural intervention in order to reduce the likelihood of future collapse in parts of the northern jarrah forest.

It is important to note that such a silvicultural option — *Management option 2* — is contained on page 75 of the Draft Forest Management Plan (2014–2023) issued for public comment in August 2012 by the Conservation Commission of Western Australia and the Department of Environment and Conservation. This option deserves broad-scale support.

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