AUSTRALIAN CONSERVATION FOUNDATION

WOODCHIPPING OUR WATER

Victoria's Goulburn Broken Catchment

A case for reassessing the use of the catchment's wet montane forests. **May 2009**

WOODCHIPPING OUR WATER

A case for reassessing the use of Victoria's Goulburn Catchment's wet montane forests

May 2009

Acheron Valley near Black Spur looking east toward Mt Ritchie (C.Taylor 2008)

Australian Conservation Foundation
Floor 1, 60 Leicester St, CARLTON VIC 3053
Ph 03 9345 1109 Fax 03 9345 1166

The Australian Conservation Foundation is committed to inspiring people to achieve a healthy environment for all Australians. For over 40 years we have been a strong voice for the environment, promoting solutions through research, consultation, education and partnerships. We work with the community, business and government to protect, restore and sustain our environment.

Contents

Appendices

1 Introduction

This report, *Woodchipping Our Water*, assesses how the logging of mature forests in the Goulburn River catchment threatens the enormous water production and carbon sequestration potential of the region.

The Goulburn River is one of Australia's most important and degraded river systems. It supplies water to many regional towns and cities, including Shepparton, Bendigo and Ballarat. The Goulburn also supports Victoria's major irrigation industries and its flows are vital to the health of the Murray River system.

The report finds that if logging in the study area stopped tomorrow, an additional water yield of 3,807 gigalitres would be delivered into the Goulburn River over the next 100 years. This is more than six times Melbourne's annual average water use and around 165 times the amount of water the City of Bendigo uses in a single year. The economic value of this water would be $1.68 billion.

In addition, the carbon sequestration gains – the ability of mature forests to draw down carbon dioxide from the atmosphere – are immense. Stopping logging operations would enable 21,150 additional tonnes of carbon to be stored in the Goulburn's forests each year. That's the equivalent of taking 4,700[1] cars off our roads. This stored carbon could be worth $6.15 billion over the next 100 years.

The Australian Conservation Foundation (ACF) estimates that the financial assistance needed to support the ending of logging operations would be approximately $12 million.

Clearly, the Goulburn Broken Catchment offers far greater economic and environmental opportunities to Victoria than those that come from current timber extraction practices. In addition, the implementation of proactive management practices and a return to the forests' ecological maturity would restore ecosystem health, build resilience to climate change, strengthen the forests' potential to survive wildfire events and provide vital flows to the Goulburn River.

1 Average vehicle = 4.5 tonnes per year; http://www.environment.gov.au/settlements/challenge/members/greenhousetips.html

2 Geography

2.1 Victoria's eastern Central Highlands

Victoria's eastern Central Highlands extend to Seymour and Lake Eildon in the north, the Hume Freeway in the west and Baw Baw National Park and Moe in the east. The Great Dividing Range is the dominant feature, running east-west and dividing the north of the region from the south. The defining image of the Central Highlands forested catchments is the tall Mountain Ash, the tallest flowering plant in the world.

2.2 The study area – Goulburn Broken Catchment

The Goulburn Broken Catchment lies between the Murray and the forested catchments on the northern face of the Great Dividing Range. The catchment's state-owned public native forests are located within the sub catchments of the:

- Upper Goulburn River
- Snobs Creek
- Royston and Rubicon Rivers
- Acheron River
- Yea River

A rain-shadow effect[2] has created drier environments on the higher ridges of the divide, making mixed species forests and woodlands more common. However, there are ash-type forests within the upper riparian corridors and the highest rainfall zones, characterised by an over story canopy dominated by Mountain Ash (E. regnans), Alpine Ash (E. delegatensis) and Shining Gum (E. nitens).

View of Goulburn Valley looking north from Mt Torbreck C.Taylor 2008

[2] When mountains block the passage of clouds, and therefore rain, casting a 'shadow' of dryness

3 Goulburn Broken Catchment – the study area

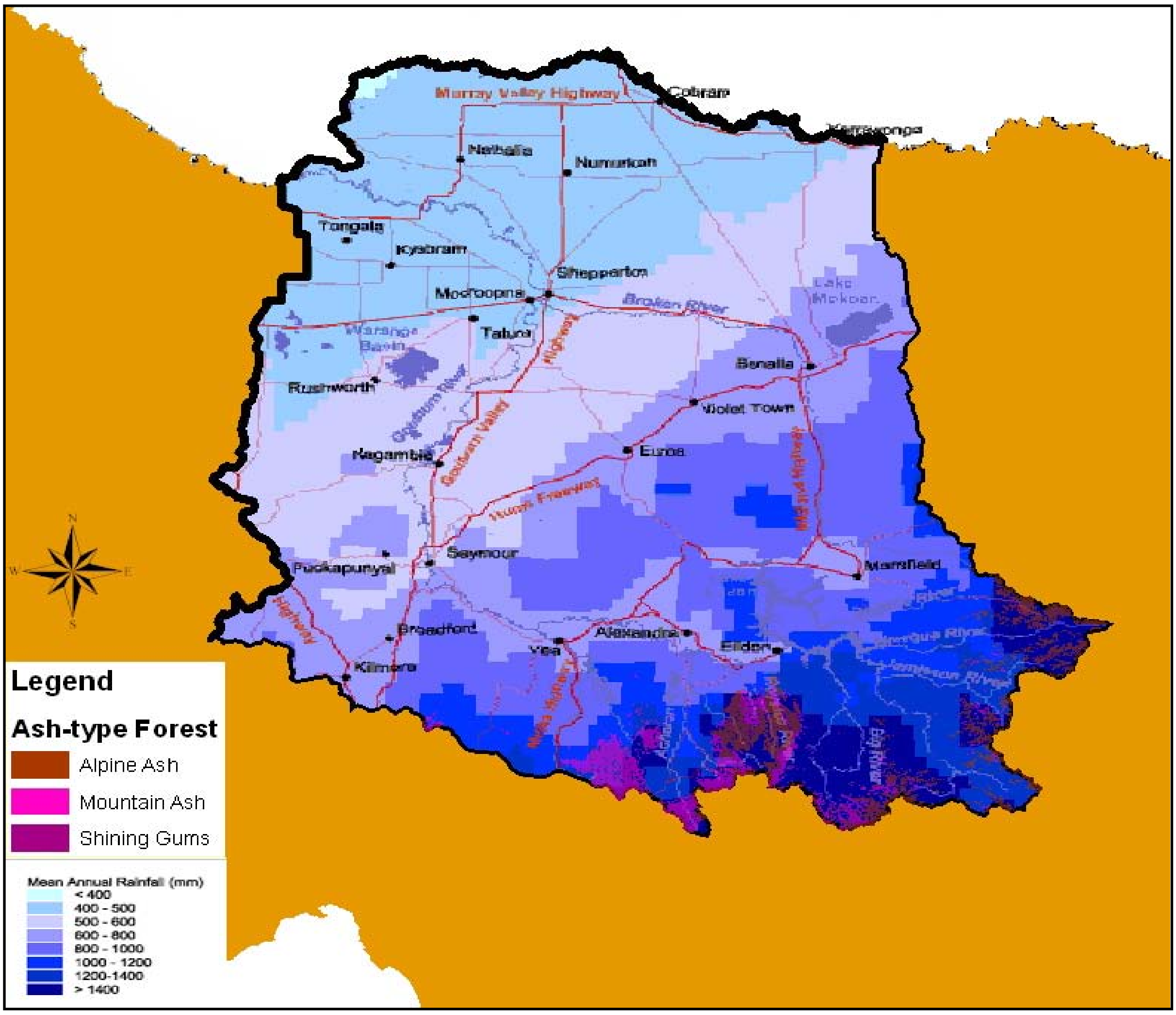


Fig 1: Goulburn Broken Catchment Management Area (GBCMA) Source: Victorian Resources online

Ash-type forests are considered to be ecologically mature when the eucalypt overstorey reaches an age of around 120 to 150 years. These trees form the major part of a multi-aged canopy that sits high above an understory composed of cool temperate rainforest species. Mature wet eucalypt forests may contain individual trees that reach 500 years of age before they decline and decompose, often assisted by fire.

4 Timber extraction

Timber is currently logged from public forests within the Goulburn Broken Catchment by the State government business enterprise, Vicforests. This logging is conducted under a Timber Allocation Order created by the Department of Sustainability & Environment and approved by the Minister.

Ash-type forests are logged using the 'clearfelling' technique, which sees virtually all standing trees removed from the area in the form of sawlogs and residual logs.

This logging is planned on an 80-year rotational basis, which allows for around 500 hectares of forest to be cut every year from an area of approximately 40,000 hectares. After clearfelling the vast quantity of wooden debris and other vegetation left behind, known as 'slash', is formed into rows which are allowed to dry through the ensuing summer. The following autumn the slash is burnt in intensely hot 'regeneration burns' in order to convert the remaining organic material into an ash bed. This creates optimum conditions for eucalypt seed germination following aerial distribution of the seeds.

Employing an 80-year growth cycle means the regrowth forests in the area don't achieve ecological maturity. Instead, they become more like plantations, which are converted into even aged monocultures with a simplified understory. Thinning operations currently proposed in the area's regenerated forests, similar to those conducted in plantations, will also add to this conversion and ecosystem impoverishment.

This practice results in the average forest age class being maintained at a point of maximum water demand, and denies the forest the opportunity to reach its full carbon sequestration potential.

4.1 Current extraction

Each year the Goulburn catchment's state forests produce approximately 50,000m^3 of sawlogs, sold to sawmills in the region, and approximately 135,000m^3 of residual logs. These are sent to Australian Paper in Gippsland or to Geelong to be wood chipped for export to the Japanese paper industry.

4.2 Alternative resource

Vast amounts of alternative hardwood timber are becoming available in Victoria due to the extensive expansion of the hardwood plantation industry. There is an enormous opportunity now for the wood product industry to make the transition from a reliance on hardwood native forest toward this emergent plantation base. Indeed given the global financial crisis and reduced Japanese demand for Australian woodchip, this may become necessary to underpin the security of the highly capitalised Victorian private plantation sector.

5 Impact of logging on water production

Victoria is currently in a water supply crisis, and on top of the current situation, three major factors threaten the future supply of our most precious resource:

- Increasing public demand in both rural and city regions,
- climate change, and
- land clearing and logging in water catchments.

Given these challenges, Victoria must improve its water conservation and efficiency. Alongside other measures, this means reviewing logging practices in the rain-soaked upper catchments that supply water to Melbourne and to the stressed catchments of the upper Murray. This report shows that mature forests return cleaner and larger volumes of water to river systems – around 12 megalitres per hectare per year – than re-growth[3] forests, therefore creating additional water for public use.

5.1 Ash forests water yield analysis

ACF commissioned consultants Practical Ecology to investigate and profile the hydrological performance of the wet mountain ash forests of the Upper Goulburn Broken catchments. Using Fred Watson's hydrology model, known as the 'Water Balance' model (Watson et al 1999), the study assessed water production yields for two scenarios in the catchment from the present day to 2150.

- Status quo – the projected water production from continued logging.
- Management change – the projected water production with no logging.

It is important to note that this report does not model projected decreases in rainfall caused by the impacts of global warming on Victoria's climate.

The study found that due to the regrowth effects of 1939 bushfire regeneration, water production will continue to increase in the catchment in the absence of extensive bushfire and regardless of management changes, by an additional 80,000 ML/year by 2035.

However, an immediate end to logging would see water yields increase even further beyond 2035. To be specific, an immediate end to logging would mean:

- 20,000 ML/year of additional water by 2050
- 36,000 ML/year of additional water by 2060
- 52,000 ML/year of additional water by 2070
- 67,000 ML/year of additional water by 2080
- 81,000 ML/year of additional water by 2090
- 94,000 ML/year of additional water by 2100
- 163,000 ML/year of additional water by 2150 [4]

3 Vertessy R, Watson F, O'Sullivan S, Davis S, Campbell R, Benyon R, Haydon S (1998), 'Predicting Water Yield from Mountain Ash Forest Catchments', Cooperative Research Centre for Catchment Hydrology

4 See Appendix A – Water yield analysis of ash forests – Goulburn Broken Catchment (Practical Ecology 2008)

6 Timber extraction vs water production

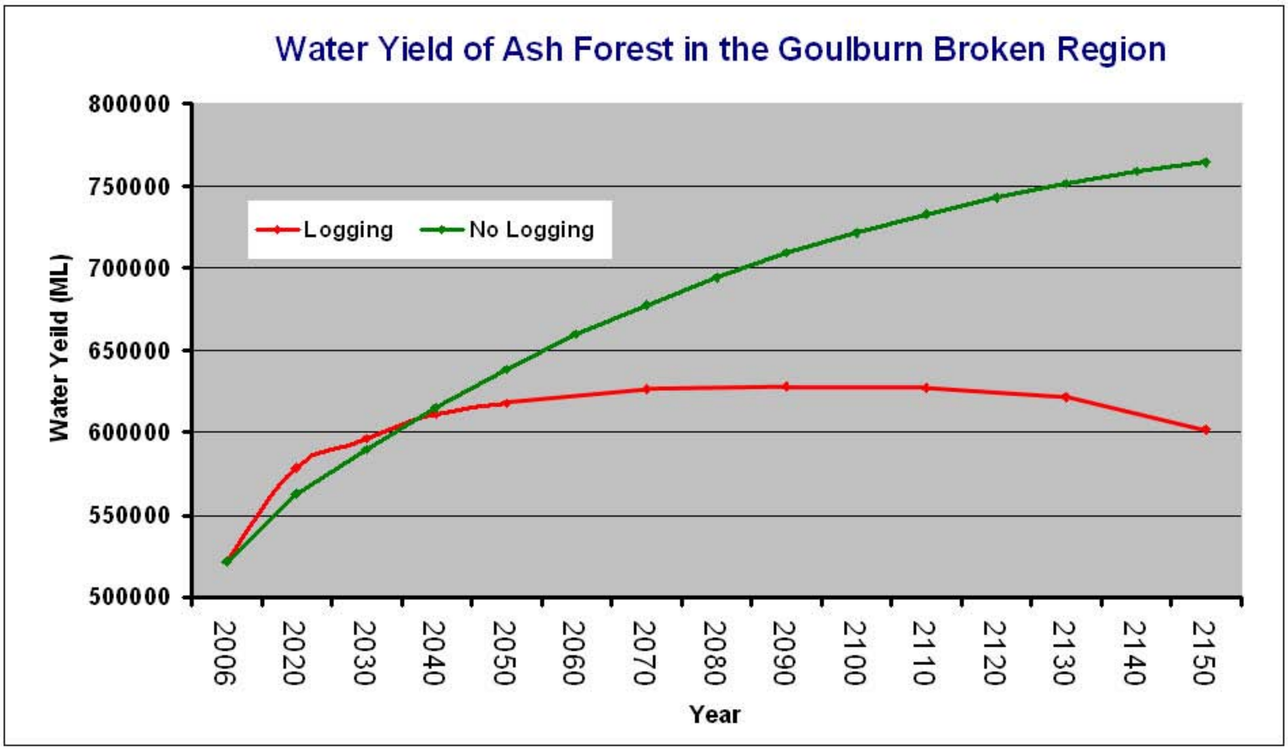


Fig 2: Water yield of ash forest in the Goulburn Broken region

The NPV analysis on water (based on data from the previous section) shows that the economic value of water saved by stopping logging is clearly greater than the economic value of timber logged.

While an immediate end to logging in the catchment will lead to decreased water yields in the short to medium term, it will have huge medium to long term water yield benefits. This makes it a sound investment, particularly in light of decreasing rainfall projections due to the effects of climate change.

As the forests regrow, eventually establishing a mature age profile (150+ years), water yields will increase drastically when compared to a continued logging regime (as shown in the previous section).

Modelling shows that if logging in the wet montane catchments ceased altogether, there would be an additional water yield of 3,807 GL delivered over the next 100 year period, with the gain rate continuing to increase beyond that time.

That's more than six times Melbourne's annual average water use.

Net present value analysis shows that the additional water yield delivered over the next 100 year period has a value of $1.68 billion.

In order to calculate the NPV of water over 100 years, a low discount rate of 2 per cent has been applied. This follows the example set by the world's most significant recent climate change modelling reports – Lord Nicholas Stern, author of the UK's Stern Review and Professor Garnaut, in Australia's Garnaut Review. In both of those reviews, a discount rate of close to zero was considered appropriate for the long term environmental impact of climate change (0.05 per cent in Garnaut the Review).[5]

This was due to both authors arguing that when considering long term impacts, the welfare of future generations should not be considered less valuable than those of us alive today. The impact of water availability and carbon emissions are of equal importance to all humans, whether today or in 50 years time. Due to the applicability of this theory to water yields over a century, we have followed the precedent of Stern and Garnaut in choosing a low discount rate. However, in order to remain conservative, we have chosen a slightly higher two per cent discount rate.

The potential to create more than one and a half billion dollars worth of additional water over the next 100 years clearly demonstrates the significant value of stopping logging in the wet catchments. When fully calculated to include the multiplier impacts across environmental flows and agricultural enterprises, this is likely to create additional tens of billions of dollars, as well as healthy and productive downstream riverine ecosystems.

In comparison, the NPV of timber harvested in the catchment over the same 100 year period is overwhelmed by the value of water (at the same discount rate).

The value of saw logs and residual timber extracted from the catchment over a 100 year cycle has a net present value of $811 million.[6]

This figure represents revenues from the sale of timber (stumpage), without any costs of harvesting or transport, and as such, well overstates the profit that can be derived from these forests. VicForest's recent annual reports would indicate that actual profit from these extraction activities is minimal. Furthermore, the appropriate discount rate for an investment by a government business enterprise to extract timber would be more appropriately upwards from 8 per cent. For comparison, we have used the same rate as the water NPV in this report.

It is clear the economic benefits derived from additional water yields, due to stopping logging in this catchment, are a significantly greater contribution to the economy than continued logging activity.[7]

---

5 Garnaut, R. (2008), Garnaut Climate Change Review Final Report page 18.

6 Based on extraction of 50,000m3 of saw logs per annum at $100/m3, and 135,000m3 of residue at $10m3, and includes a 2.5% CPI per annum on timber values.

7 See Appendix B – Water vs Wood Net Present Value Analysis (ACF)

7 Carbon and wet eucalypt forests

In August 2008 the Australian National University (ANU) released a report, *Green Carbon,* [8] which profiled long term research into the levels of carbon stored within Australian native eucalypt forests. The ANU describes the research and its application as:

> *"Green Carbon is the carbon stored in the plants and soil of natural ecosystems and is a vital part of the global carbon cycle. The report is the first in a series that examines the role of natural forests in the storage of carbon, the impacts of human land use activities, and the implications for climate change policy nationally and internationally. REDD ("reducing emissions from deforestation and degradation") is now part of the agenda for the "Bali Action Plan" being debated in the lead-up to the Copenhagen climate change conference in 2009."*
>
> *Currently, international rules are blind to the colour of carbon so that the green carbon in natural forests is not recognized, resulting in perverse outcomes including ongoing deforestation and forest degradation, and the conversion of extensive areas of land to industrial plantations. This report examines REDD policy from a green carbon scientific perspective."*[9]

In addition to increased water yields, ending logging in the area will provide further external benefits, including additional carbon sequestration and ecosystem services, such as habitat for insect eating animals and pollinators that benefit local farmers and water filtration. Most critical though, and potentially the most economically attractive, is carbon sequestration.

In *Green Carbon* the ANU estimates South-East Australian eucalypt forests can store a mean value of 640 tonnes of carbon per hectare. (It is worth noting that the report indicates this may be a conservative figure for the Goulburn Broken Catchment, where the highest carbon stocks were found – up to 1,500 tonnes of carbon per hectare in the ash forests of the Central Highlands.)

Much research now shows that older mature forests, particularly of mountain ash, have significant carbon storage capabilities which are well above that of young forests actively managed for logging.

---

8 Brendan G. Mackey, Heather Keith, Sandra L. Berry and David B. Lindenmayer (2008). Green Carbon. The role of natural forests in carbon storage. Part 1. A green carbon account of Australia's south-eastern Eucalypt forests, and policy implications. http://epress.anu.edu.au/green_carbon_citation.html
9 ibid

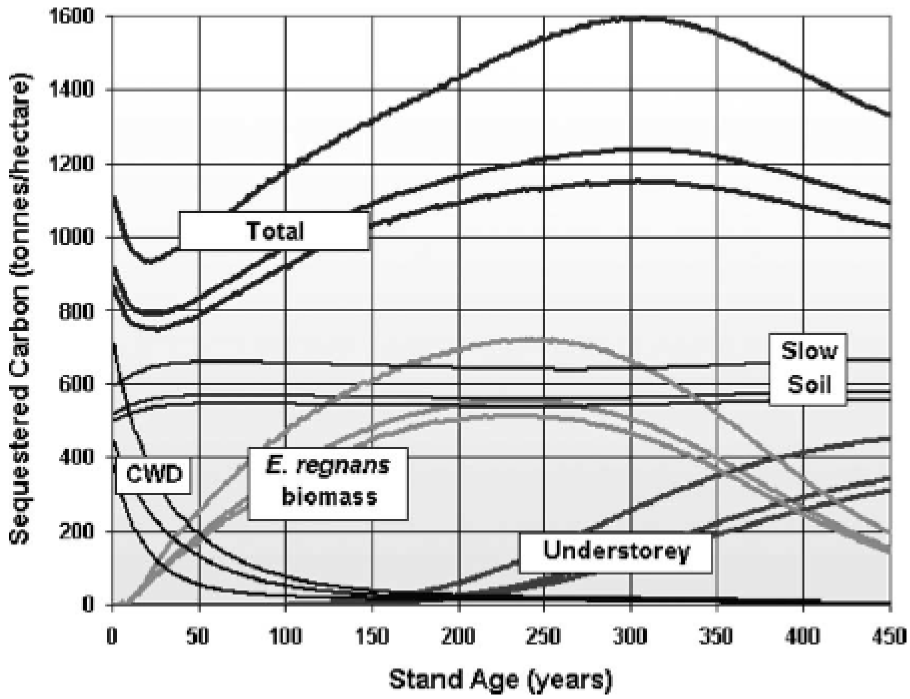


Fig 3: Forecasting landscape-level carbon sequestration using gridded spatially adjusted tree growth, from Dean, Roxburgh and Mackey (2004) *Forecasting landscape-level carbon sequestration using gridded spatially adjusted tree growth* in Forest Ecology and Management 194:109-129

This carbon stock does not reflect the annual sequestering ability of a forest, rather the total stock of carbon held in the timber and soil of the forest. A direct conversion to estimate the value of the carbon sequestering ability of these forests can be difficult to make. As a result, accurate calculations of carbon held and sequestered in native forests and subsequent values are too often ignored.

A great deal of research on this topic supports a strong position to protect the carbon storage capacity of these forests in light of the urgent need to reduce carbon emissions. Currently, there is no policy mechanism that allows for the trading of carbon in Australia's native forests and therefore no way of realising the potential value of carbon sequestered in the Goulburn Broken Catchment.

Nevertheless, as a proxy value for this carbon asset, an estimate of the value of these carbon stores is an absolute priority. These values may, under future policy scenarios, be realisable values, and despite their economic value, are critical for Australia's efforts to manage greenhouse gas emissions.

Based on data from the same research conducted for the ANU report (by Brendan Mackey), with an estimate of carbon sequestration of 12 tonnes of carbon per hectare per year (or, when converted to carbon dioxide, 43.2 tonnes of carbon dioxide equivalent per hectare per year), an NPV can be undertaken using shadow carbon prices as estimated by Federal Treasury modelling.[10]

Under a scenario where logging ceases in the Goulburn Broken Catchment, it is estimated, based on current logging patterns, that 500 hectares of logging would be avoided per annum.

10 Treasury (2008), Australia's Low Pollution Future, based on data under the low CPRS-5 scenario (5 per cent cuts by 2020)

In order to remain consistent with the water calculations in the previous section, there would be an additional carbon sequestration benefit from avoiding this logging upon which we can place a value. This is carbon sequestered above business as usual logging and needs to be valued and treated as an asset that it is.

Modelling shows that if logging stopped altogether in the wet mountain ash catchments the additional carbon yield delivered over the next 100 years would be valued at $6.15 billion.[11]

It is important to recognise that this value is merely the additional carbon sequestered above business as usual logging. It is critical that policymakers begin to account comprehensively for the carbon stocks and yields across the entire catchment. In this way, the significant value of carbon sequestered annually across the entire catchment could be recognised for the state asset that it is, and more accurately reflect the critical role of forests in greenhouse gas reductions.

8 Resilience to bushfire

Ecologically Mature Ash forest

Regrowth Ash forest (C.Taylor)

8.1 Mature wet ash forests compared with regrowth

Ecologically mature wet forests have a greater ability to tolerate and survive severe bushfire events when compared with their re-growth form, which are more easily destroyed by a 'crowning fire.' The great height of mature wet forests, coupled with wet understory and midstory species and low level of fine fuels, have been shown to reduce and lessen bushfire intensity once it has entered their domain. In *Australia Burning* (2003), ANU forest ecologist David Lindenmayer refers to the submission by ANU forestry lecturer Ross Florence, who

[11] See Appendix C - Analysis of the Value of Carbon sequestration potential (ACF)

made the following observations on fuel loads and forest disturbance in a submission to the New South Wales Bushfire Inquiry in 1994.

On fuel loads in pre-settlement forests

"The amount of litter which accumulates on the floor of the old growth forest may be appreciably less than that which accumulates at earlier growth stages. Where regrowth develops following a severe perturbation, the forest floor biomass builds up rapidly to a point of peak fuel energy storage during the forest's rapid early growth stage. This point may be as soon as 35 years in stands of fast growing species. Beyond this point there will be a progressive reduction in the forest floor biomass as wood volume production and the rate of crown expansion and litter fall decline, as the shrubby understorey breaks up, and as the litter accumulated at the point of peak energy storage is incorporated into the soil organic matter.

It may be this natural successional process - as much as burning by Aborigines - which limited the build up of forest floor fuels before European settlement, and hence the frequency of more intense and damaging crown fires. [12]

Further to the above statement on pre-settlement forests, Florence also comments on the effect that burning within protected forests has on fuel loads:

As the uncontrolled fires of the post-settlement period damaged the forest ecosystems, the deeply fire-scarred old-growth trees could no longer exert strong site control. Eucalypt regrowth developed in either small patches or more extensively throughout the forests, generating an increase in litter production and hence fuel loads. Fire-stimulated shrubs were now more persistent, contributing a further significant source of potential flame energy.[13]

8.2 'Thinning' in wet forest regrowth

The proposal to conduct 'thinning' operations in regrowth wet eucalypt forests in Victoria's Central highlands, including in the Goulburn Broken Catchments, will also increase the risk destruction by bushfire.

The intention of thinning is to use mechanical harvesters to extract around 50 per cent of the regenerating stand for pulp wood, and then enable the retained trees to take up the available water to achieve rapid growth. The practice of leaving the tree heads, or 'slash', in the regrowth stand increases the level of fine woody debris and thus increasing the risk of intense bushfire behaviour.

It appears Victorian State forest managers have no published code of practice for this activity nor does it seem any research has been conducted into the environmental impact on ecosystem processes. It appears the intention of this intensive industrial logging program is more focused on converting the natural forest ecosystem into something more akin to a plantation development.

---

[12] Florence, R.G. 1994, The Ecological Basis of Forest Fire Management in New South Wales, submission to NSW Cabinet Bushfire Review, Sydney

[13] ibid

Ecologically mature wet eucalypt forest(E.denticulata)

Thinned wet eucalypt forest regrowth (E.denticulata) (Errinundra Plat. Vic)

Forestry Tasmania conducts 'thinning' operations in wet native eucalypt forest regrowth in a climatic zone with considerably less fire risk than that in Victoria's forests. Yet the increased fire risk created by these Tasmanian operations has required prescriptions for these operations.

Forestry Tasmania's Technical Report no. 13 (2001) indicates the increased risk of wildfire destroying a regrowth forest stand due to the increase fuel load from these operations.

> *"One of the major planning constraints associated with thinning is the higher level of fuel present after the operations. It is not considered feasible in Tasmania to carry out fuel reduction burns in thinned coupes because of the high fuel loads and the sensitivity of the retained trees to fire. The location of thinned coupes amongst conventionally logged coupes is problematic, as it is not recommended that any regeneration burn take place within two kilometres of areas with high levels of flash fuel within two years of harvest (Cheney 1988)."*
>
> *"Tree crowns (heads), bark, and other harvest residue make up the fuel load. The climate on the floor of the forest is altered by thinning, with higher wind speeds and temperature, lower humidity, and lower moisture content in the fuel itself. Understorey vegetation characteristics change because of these changes to the microclimate, especially increased light. Bracken ferns and cutting grass may grow vigorously, each having a far higher flammability than the replaced woody species (Cheney and Gould 1991).*[14]

9 Biodiversity protection and ecosystem resilience

There is a significant number of old growth or ecologically mature forest stands scattered throughout the Central Highlands region. Many of these remain as dead, or 'stag', trees and are noted for their importance as nesting sites for a wide range of fauna, including the state's faunal emblem, the Leadbeater Possum (Gymnobelideus leadbeateri). A large number of other threatened species can be found in the highlands and in many cases there is a strong connection between threatened fauna and threatened vegetation communities.

[14] Forestry Tasmania (2001), Thinning Regrowth Eucalypts – Native Forest Silviculture Technical Bulletin No. 13 Second Edition

By systematically removing trees less than 100 years old, logging causes a major loss of tree hollows (it normally takes this long for hollows to begin forming in eucalypt species), which are critical for shelter and breeding by 98 per cent of Victoria's animal species.[15]

> *Logging radically alters the structure of the forest – the number of big old trees with hollows, the number of fallen logs, the density of the understorey and the canopy vegetation. It also alters the floristic structure of the forest – the number, type and density in the forest. Logging can also create conditions which promote the spread of pest animals and weeds and increase the probability, frequency and severity of fire. Consequently, many plants and animals are now absent from the forest.* [16]

The removal of suitable habitat trees will move many species closer to extinction.[17] While extinction is often associated as an end point, where a species is no longer found on the planet, this is not wholly the case. There is a scale along which a species moves towards this point, and we have the ability to avert this slide.[18]

10 Transition and structural adjustment package

Transitioning away from timber extraction in the Goulburn Broken's wet mountain catchments can be achieved under a Forest Industry Structural Adjustment Package, similar to that produced by the Victorian Government for *Our Forests Our Future* in 2002.[19]

In 2002, the Victorian government was required to reduce the level of logging in Victoria's state native forests in an attempt to maintain a 'sustainable yield' of future sawlog supply. The program was quite successful, with native hardwood yields reducing over the last ten years from 921,000m^3 to 567,500m^3/year.[20] Current sawlog extraction from state forests in eastern Victoria is in the order of 450,000m^3/year.

As stated earlier in this report, 1, 50,000m^3 of sawlogs and 135,000m^3 of residual logs are extracted annually from the Goulburn's ash forest catchments.

The Victorian government could phase out logging in these catchments and reap the greater economic benefits provided by increased water yields by implementing a structural adjustment package on the same principle as that applied to *Our Forests Our Future* in 2002.

---

[15] Lindenmayer D, Cunningham R, Tanton M, Smith A, Nix H (1991), 'Charactaristics of hollow bearing trees occupied by arboreal marsupials in the montane ash forests of the Central Highlands of Victoria, south-east Australia', Forest Ecology and Management, pp289-308

[16] Traill,B. (1995) Woodchips or Wildlife – the case against logging our native forests. Environment papers, Vol 1 Victorian National Parks Association

[17] Possingham H, Lindemayer D, Norton T, Davies I (1994), 'Metapopulation Viability Analysis of the Greater Glider Petauroides volans in a Wood Production Area', Biological Conservation pp227-236

[18] Appendix D - Old-growth forest, water and climate change - some scientific understandings. (Choosing a Future for Victoria's forests. Victorian Forest Alliance 2006)

[19] Our Forests, Our Future - Balancing Communities, Jobs and the Environment http://www.dse.vic.gov.au/dse/nrenfor.nsf/FID/-22A28C77A72588894A256B67000E0B85?OpenDocument

[20] ibid

10.1 Voluntary licence reduction program

Under the 2002 *Our Forests Our Future* program, the Victorian government purchased timber allocation licences back from the industry with up to five years remaining; meaning that after that time all licences would expire and not be renewed. All allocation of timber extraction beyond this time was made at the commercial discretion of the state owned government business enterprise, Vicforests. By 8 July 2003, the government had bought back a total of 268,360m^3 of licensed sawlog volume, achieved at a cost of $31.2 million.[21]

Given Vicforests engages in short to medium term sales contracts of up to five years, it is reasonable to assume that the same rules could apply today. Such contracts would be of similar nature to that of the pre-existing licences given that they also had approximately five years to expiry. The adjustment package requires that 50,000 m^3/year sawlog commitment be retired. So 18 per cent of the *Our Forests Our Future* volume reduction would equate to $5.81 million.

Many Vicforests customers may wish to reconsider their contractual arrangements given the onset of the global financial crisis in mid 2008, ending the obligation and also seek compensation.

10.2 Worker assistance program

Through the 2002 *Our Forests Our Future* Worker Assistance Program, the Department of Victorian Communities helped forest industry workers undertake training, relocate, secure new jobs or retire, if that is what they wanted to do.[22]

10.3 Contractor assistance program

When applications opened for the Contractor Assistance Program in November 2002, the program objective was "… easing the transition for contractors directly affected as a result of the implementation of the Voluntary Licence Reduction Program".

The guidelines established that eligible contractor businesses were those that:

- directly participated in the forest industry or were directly dependent on the industry; and
- were adversely affected by the licence buy-back.[23]

---

[21] http://archive.audit.vic.gov.au/reports_par/Forests_Part%203.pdf
[22] ibid
[23] ibid

Proposed Goulburn Forest Industry Structural Adjustment Package (FISAP)

Structural Adjustment Package Components	Item	Our Forests Our Future 2002 [24] Funds allocated	Goulburn Transition Proposed FISAP Package (16% Our Forests Our Future) Funds required
Voluntary Licence Reduction Program	Licence Volume reduction (Our Forests Our Future 2002) or current VicForests contractual obligations	268,360m3 $M 31.2.	50,000m3 $M 5.8
Worker Assistance Program	Job search assistance, relocation, training etc. Industry restructure payments	$10.9M (40%) $16.7m (60%)	$1.74M $2.67M
Contractor Assistance Program	Payments for plant and equipment	$7m (54%)	$1.3M
	Job search assistance, relocation, training etc.	$2.3m (18%)	$0.43M
	Industry restructure payments	$3.4m (27%)	$0.63M
	Statutory redundancy payments	$0.16m (1%) $12.86 (100%)	$0.03M
Total		**$71.66M**	**$12.6M**

Note: 2002 $ values

Transition and reform will provide additional water yields for the Goulburn River, at no additional infrastructure cost.

Future regional forest managers should include water production and carbon sequestration as key commercial components of their revenue stream, and utilise the skills of foresters and the equipment of timber production contractors for the essential forest management tasks of:

- maintaining road access, upgrades and maintenance
- drainage and water infrastructure maintenance
- ecologically and structurally focused forest restoration
- wildfire mitigation measures in re-growth forests
- ecologically planned prescribed burning
- appropriate fire break construction
- providing a larger dedicated fire fighting service

[24] http://archive.audit.vic.gov.au/reports_par/Forests_Part%203.pdf

11 Conclusion

This report shows there is a great opportunity available to the Victorian Government to capitalise on the natural advantages present in this key public asset.

Changing the focus of natural resource exploitation in the study area – from timber extraction to water and carbon sequestration – would deliver major net present value gains, indicative of the strong rates of return that can then be reinvested into the region.

Key findings of the report reveal:

- Modelling shows that if logging stopped altogether in the wet mountain ash catchments there would be an additional water yield of 3,807 GL delivered over the next 100 years, with the gain rate continuing to increase beyond that time.
- Net present value analysis shows the additional water yield delivered over the next 100 years has a value of $1.68 billion.
- Modelling shows that if logging stopped altogether in the wet mountain ash catchments the additional carbon yield delivered over the next 100 years would be valued at $6.15 billion.
- Water are carbon values far outweigh that of saw logs and residual timber extracted from the catchment over a 100 year cycle, which has a net present value of $811 million.[25]
- Old growth or ecologically mature forests have a much greater resilience to bushfire.
- Stopping logging in the catchment provides a greater economic opportunity, with increased forest related employment, with an affordable transition package that has little impact on the wood product industry sector.

There are greater economic and environmental benefits for Victorians than current timber extraction practices in the catchment's wet mountain forests. The implementation of proactive management to return the forests to ecological maturity will restore ecosystem health, build resilience to climate change, strengthen the forests' potential to survive bushfire events and provide vital flows to the Goulburn River.

[25] Based on extraction of 50,000m³ of saw logs per annum at $100/m³, and 135,000m³ of residue at $10m³, and includes a 2.5 per cent CPI per annum on timber values

Practical Ecology Pty Ltd
Contracting and Consulting in Ecological
Restoration and Environmental Planning
ABN 88 082 911 377

Goulburn Broken Water Yield Analysis of Ash Forests

Goulburn Broken Catchment

December 2008

Lorna Pettifer – BA/BSc (Honours) MEnv

Phone: 9484 1555 , Fax: 9484 9133
Email: enquiries@practicalecology.com.au
Address: PO Box 228 Preston 3072 Office: 2B Stott Street Preston

Goulburn Broken Water Yield Analysis of Ash Forests

Goulburn Broken Catchment

Re-released December 2008
Original released November - December 2006

PRACTICAL ECOLOGY Pty Ltd

ACN: 082 911 377 ABN: 88 082 911 377
PO Box 228 Preston VIC 3072
(2B Stott Street Preston Vic 3072)
P: 9484 1555 F: 9484 9133
www.practicalecology.com.au

Report by Lorna Pettifer.
Report prepared by Practical Ecology Pty Ltd on behalf of Australian Conservation Foundation
Review and auditing of this report for quality control was conducted by Patrick Lane and Lincoln Kern

Acknowledgments:

Patrick Lane	Senior Research Fellow, Forest Hydrology School of Forest and Ecosystem Science The University of Melbourne
Chris Taylor	PhD candidate in Forestry Certification, RMIT University.
George Kuzcera	Phone communication – advice on existing Models
DSE	GIS Data suppliers
Bureau of Meteorology	Rainfall Data suppliers

Contents

1. INTRODUCTION

Practical Ecology Pty Ltd was commissioned by Australian Conservation Foundation (ACF) to analyse the effect of disturbance on water yield in ash-type forests (*Eucalyptus regnans, Eucalyptus delegatensis and Eucalyptus nitens)* within the Goulburn Broken Catchment. The project involved modelling the effects of forest disturbance on water yield using Fred Watson's Water Balance Model (Watson *et.al.* 1999), an updated version of the Kuzcera Bushfire Model (1985). The forest disturbance that was assessed within the analysis was considered an absolute regeneration event such as clearfelling, seed tree retention and wildfire.

The analysis projected the effect of no-logging versus continued logging in the Goulburn Broken Catchment on water yield from the present, 2006, to 2150. This report is a brief of the data, methods and limitations involved in the analysis.

1.1 Aims

This report aims to:

- Present all findings of the water yield analysis and provide background of the methodology.
- Present future projections of logging versus no logging from 2006 until 2150.

1.2 Study Area

The study area is located within the Goulburn Broken Catchment Area. The analysis looked at the public water supply areas and other catchment areas within the southern region of Goulburn Broken catchment. The catchment areas where selected on the basis of the presence of ash-type forest, percentage of ash-type forest that was affected by the 1939 wildfire, direction of streamflow and annual rainfall.

The study area falls within the Victorian Alps and Highlands Northern Fall Bioregions (DSE 2005[online]).

1. METHODS

1.1 Catchment Areas

The catchment areas where selected on the basis of the presence of ash-type forest, percentage of ash-type forest that was affected by the 1939 wildfire, direction of streamflow and annual rainfall. The catchment areas that fulfilled these criteria and analysed within this project were the Upper Goulburn Public Water Supply Area, the Royston/Rubicon, the Acheron, Yea River and Snob's Creek.

1.2 Forest Type and Disturbance

Within this analysis the dominant eucalypt species that were defined as ash-type forest were Mountain Ash *Eucalyptus regnans,* Alpine Ash *Eucalyptus delegatensis* and Shining Gums *Eucalyptus nitens* as defined in previous studies (Reid and Sturgess 1994; Kuzcera 1985). It was assumed where no future forest disturbance data exists that the area clearfelled each year would be a function of area of ash-type forest considering an 80 year rotation. Where these figures did not correlate with previous forest harvesting practises future projections were modified to represent an average of recent clearfelling events.

1.2.1 Existing Information

The most accurate existing records of dominant ash-type species in forest management areas can be sourced from SFRI (State Forest Resource Inventory) data and maps. This data source gives both information on dominant eucalypt groups and previous disturbance history. SFRI maps can be accessed from the DSE website and digitised in ArcView 9.1. and data from DSE.

1.2.2 New Information

The methodology of forest data collection was originally based on gaining information for future harvesting purposes. The SFRI information is based on what resources are available and it is now being applied to analyses that focus on water yield and climate change. The method of forest data collection in the future will most likely be more easily applied to the current forest investigation topics and methods.

1.2.3 Limitations

The SFRI forest data is an incomplete dataset and, as mentioned above, this information is being applied to analyses that were not intended by the data collection and collation method. However, it is currently the most complete and accurate dataset to be applied to this project.

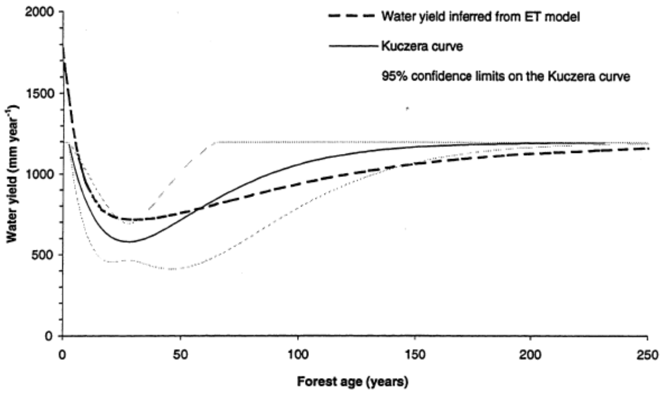
1.3 Modelling

The modelling method chosen for this project was based on the best available data and timeframe of the analysis. The Watson's Water Balance Curve (Watson *et.al.* 1999) is a modification of the frequently quoted and exercised Kuzcera Curve. The Watson Curve defines the initial response of an ash-type forest to disturbance more accurately (Patrick Lane *pers, comm.*; Watson *et.al.*1999). When an ash forest is clearfelled or burnt by wildfire there will be an initial increase in water yield.

1.3.1 Existing Information

Previous studies including Read Sturgess (1994), Peel *et.al.* (2002), Peel *et.al.* (2000), Hughes (2003), Watson *et.al.* (1999), Zhang *et.al* (1999) and Sinclair Knight Merz (2000) were reviewed. These studies explored static and dynamic modelling approaches to analyse the effect of forest disturbance on water yield. Commonly used models are the Macaque Model involving process-based catchment modelling developed by Dr. Fred Watson. Previous to process-based modelling, water yield in ash-type forests was predicted by an empirical based model, the Kuczera Curve, developed by George Kuczera (1985). The 'Kuczera Curve' shows the relationship of water yield to forest stand age of an ash-type forest (Peel *et.al.* 2000). The curve implies that there is an initial decrease in water yield after disturbance, reaching a minimum at 20-30 years and then gradually increases and re-stabilises at around 100 years (Peel *et.al.* 2000; Watson *et.al.* 1999). The decline in water yield has been correlated to the leaf area index (LAI), which relates to younger ash-type species having a greater leaf area and foliage, therefore a higher evapotranspiration rate. Watson adapted this curve to the Water Balance Curve (1999) to incorporate the initial increase in water yield after forest disturbance; a comparison of the two curves is shown in Figure. 1 below. The parameters used in the Macaque model are based on the Water Balance Curve.

Figure 1. Comparison of Water Balance and Kuczera Curve (Figure 26. Watson *et.al.* 1999)



The Watson curve is derived from on the equation below (Watson *et.al* 1999).

$$
\begin{aligned}
ET = \quad & (ET_P - ET_C - ET_D) \quad \frac{e}{\tau_P} AGE\, e^{\left(\frac{-AGE}{\tau_P}\right)} \qquad (21) \\
+ \quad & (ET_C + ET_D - ET_M) \left(\frac{2}{1 + e^{\left(\frac{-AGE}{\tau_C}\right)}} - 1 \right) \\
+ \quad & ET_D \left(e^{\left(\frac{-AGE}{\tau_D}\right)} - 1 \right) \\
+ \quad & ET_M
\end{aligned}
$$

As the above models were developed within the Maroondah and Thomson Catchments the annual rainfall assumption of 1800-2000mm was inaccurate for application of the curve to the Goulburn Broken Catchments. The Model parameters were re-calibrated based on rainfall overlays indicating 1600+mm annual rainfall in areas of ash-type forest (Figure 2.) and a study completed by Zhang *et.al.* (1999). Zhang *et.al.* (1999) looked at water yield as a function of evapotranspiration (ET) versus annual rainfall for approximately 250 different forest areas and grasslands (Figure 3.). The ET used in this analysis was scaled proportionally to the change in ET from 2000mm-1600 mm given by Zhang *et.al.* (1999).

Figure 2. Annual Rainfall Overlays on Ash-type Forest

a. Victorian Resources on line **b. Bureau of Meterology**

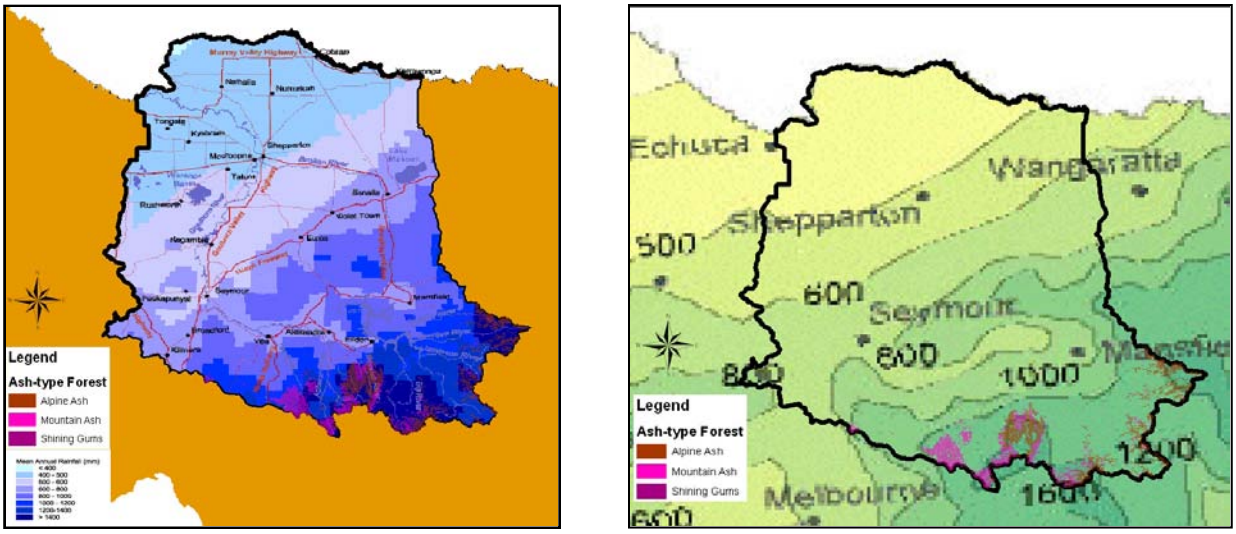


Figure 3. Water yield as a function of ET versus annual rainfall (Zhang *et.al.* 1999)

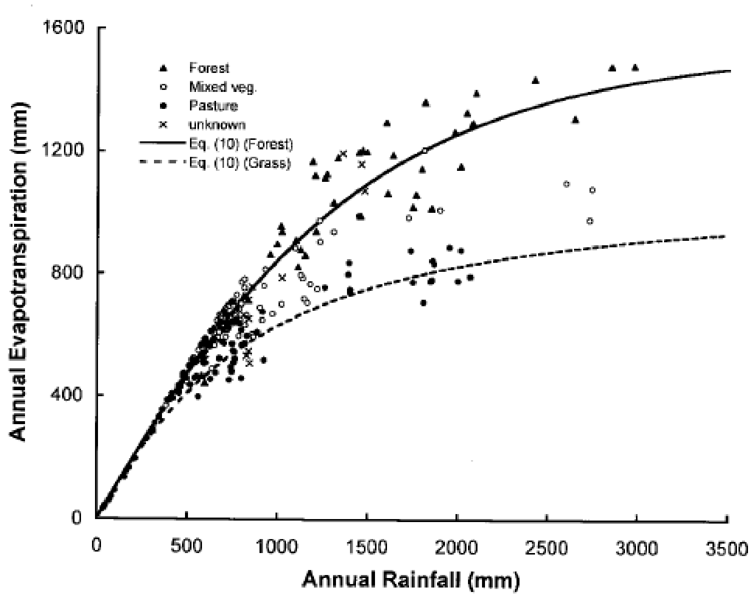


Fig. 10. Relationship between annual evapotranspiration and rainfall for different vegetation types

1.3.2 Limitations

The Water Balance Curve was applied to this analysis considering the available data in the Goulburn Broken Region and the timeframe of the project. Like the Kuzcera curve the Water Balance Curve is an average of various conditions over space and time. Many variables effect water yield such as soil type and depth, climate, geology, understorey and overstorey biomass, rainfall distribution and topography. These variables would not be constant over all the areas looked at in this analysis therefore this empirical model must be viewed in light of these assumptions.

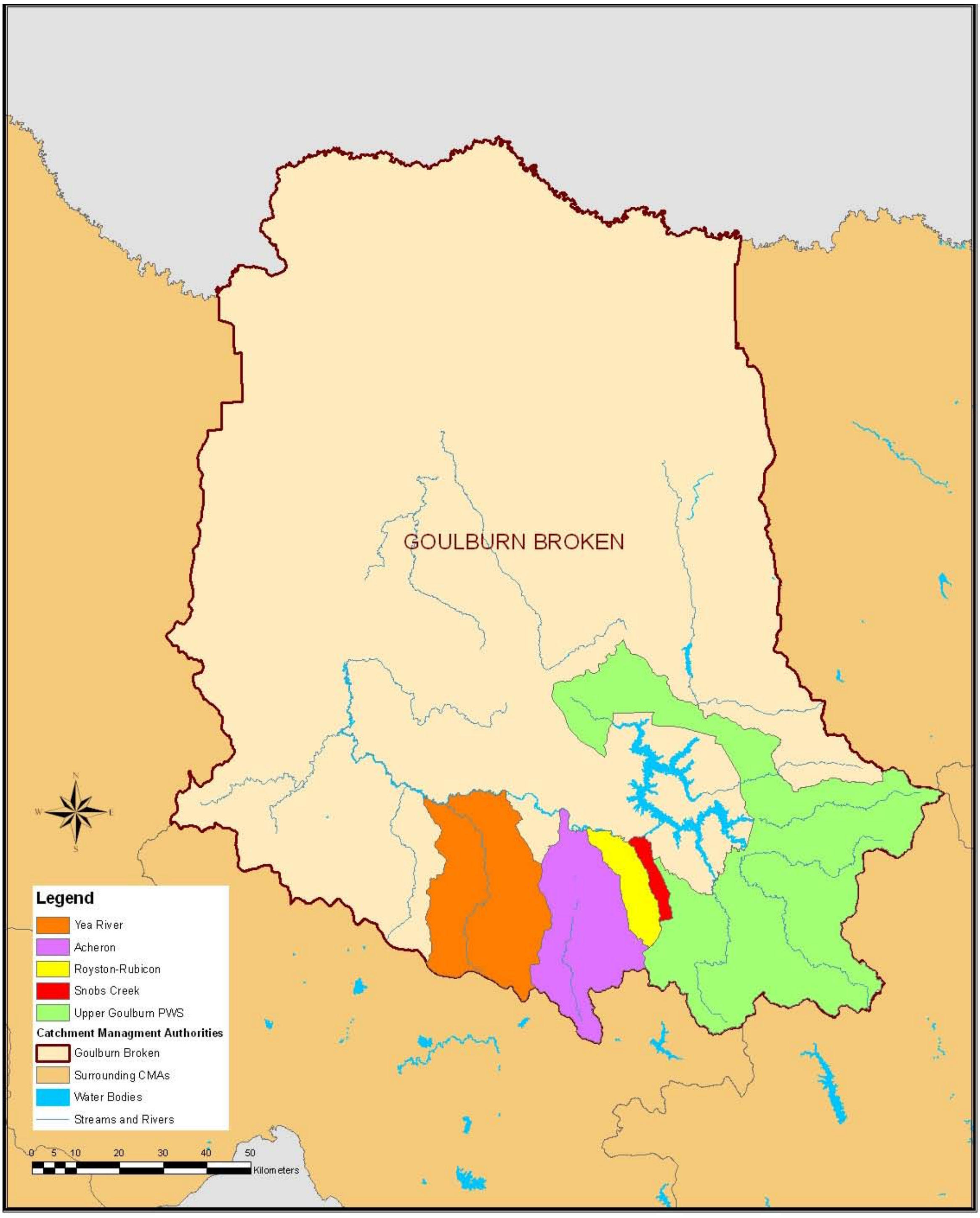
The model did not consider future rotations in terms of forest location, each area cleared was considered to be at the age defined by the last recorded disturbance. In reality areas would be re-logged which would re-start the water use “clock”, resulting in a different water yield sequence for those areas. This would include the initial post-disturbance yield increase.

2. RESULTS

2.1 Catchment Areas

The areas used in this analysis are presented in Figure 4. below.

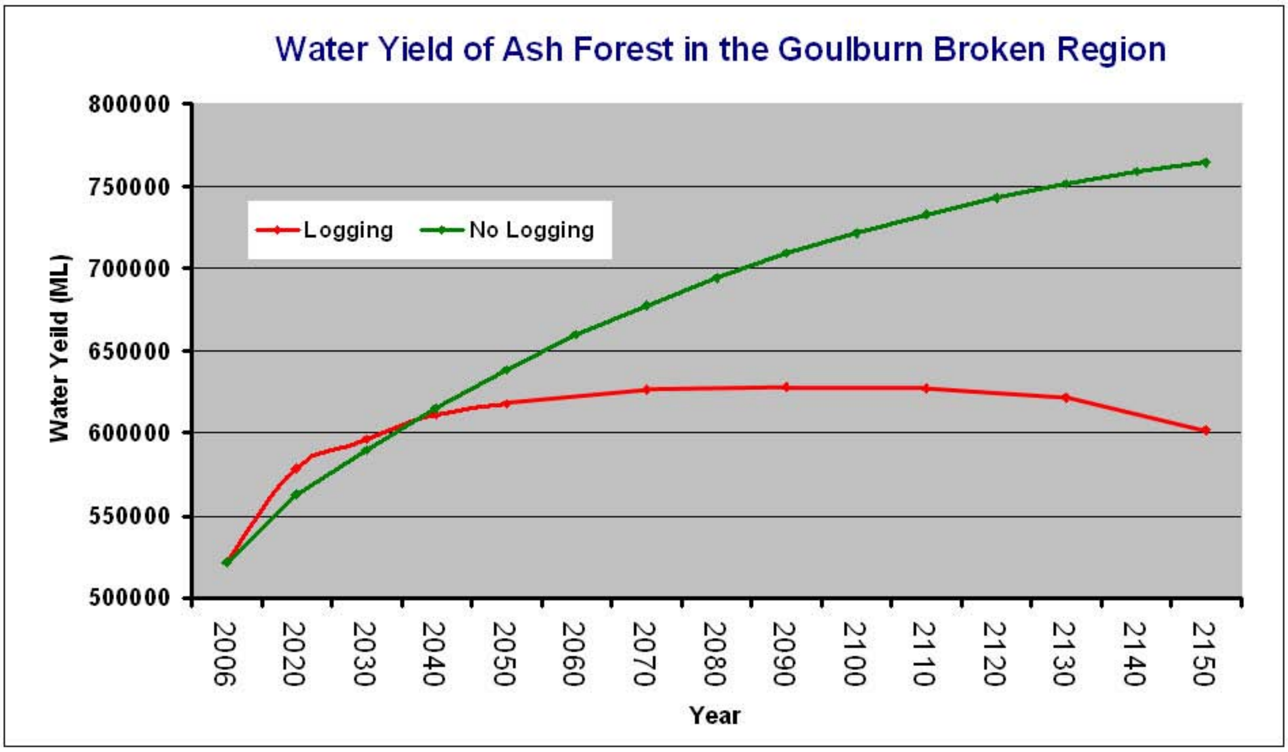
Figure 4. Catchment Areas in Goulburn Broken CMA used in the Analysis



2.2 Modelling

The results of modelling of effect of forest disturbance is summarised in Figure 5. below. Appendix 1. represents a more detailed summary of the all the results below.

Figure 5. Water Yield of Ash-type forest in the Goulburn Broken Region depicting logging versus no logging scenarios 2006-2150



3. DISCUSSION

3.1 Results of Modelling

The Results as predicted indicate that if logging within the ash-type forest continued into the future it would decrease the water yield of these catchment areas. Due to the nature of the Water Balance Curve there is an initial increase in water yield and it is not until 2035 that the no future logging scenario shows a greater water yield. The results are only considering water yield in areas that ash-type forest reportedly exists.

4. CONCLUSION

Current clearfelling logging practices in ash-type forests and bushfires have shown to decrease water yield in catchments. The available modelling methods, such as the Kuczera Curve, the Water balance curve and the Macaque have also proven this with best available data. As methodologies consider more real life parameters and variability the closer we will be to predicting how forest disturbance events will effect of public water supplies and catchments. This current study explored the effect of disturbance on water yield in ash-type forest in the Goulburn Broken catchment which unlike its neighbouring catchments has not been extensively analysed. The models mentioned above were all developed within the Maroondah and Thomson catchments and if they were applied in a different state, country and to different species the results would be questionable. However the Goulburn Broken catchment borders these catchments and using these existing models in this area would provide a plausible estimation of how water yield would be affected by forest disturbance in ash-type forest, subject to the stated assumptions and model uncertainty.

The results presented here do not consider any other future disturbance such as wildfire or the effect of climate change, both of which have the potential to impact profoundly on forest water yield. There is also no consideration of alternative silvicultural techniques to clearfelling, particularly thinning, which may have a different hydrologic outcome.

5. REFERENCES

Hughes, R. (1999). The impact of logging on water yield and Victorian water supplies. Doctors for Forests Report.

Kuczera G. 1987, Prediction of water yield reductions following a bushfire in ash-mixed species eucalypt forest. Journal of Hydrology, 94:215-236.

Peel M.C, Vertessy R.A and Watson F.G.R.(2002) Generating water yield curves for forest stands in the Thomson catchment for inclusion in the Integrated Forest Planning System. Cooperative Research Centre for Catchment Hydrology.

Peel M.C, Watson F.G.R, Vertessy R.A, Lau A, Watson I, Sutton M and Rhodes B. (2000) Predicting The Water Yield Impacts Of Forest Disturbance In The Maroondah And Thomson Catchments Using The Macaque Model. Cooperative Research Centre for Catchment Hydrology. Technical Report 00/14.

Sinclair Knight Merz (2000) Otway Forest Hydrology Project - Impact of Logging Practises on Water Yield and Quality in the Otway Forests. Report for the Department of Natural Resources and Environment.

Watson F.G.R., Vertessy R.A., McMahon T.A., Rhodes B.G. & Watson I.S. 1999a, The hydrologic impacts of forestry on the Maroondah catchments. Cooperative research Centre for Catchment Hydrology, Melbourne, Technical Report 99/1, 80pp.

Zhang L, Dawes W.R and Walker G.R. (1999) Predicting the effect of vegetation changes on catchment average water balance. Technical Report 99/12. Cooperative Research Centre for Catchment Hydrology. CSIRO Land and Water.

APPENDIX 1. Summary of Results

Year	Yield of whole catchment (ML) AREA = 476772.37ha	Yield of ash forest (ML)	Cumulative yield of ash forest (ML)	Yield Cumulative difference (ML)	% Yield Cumulative difference	Yield difference due to logging (snapshot) (ML)	Yield of ash forest (ML)	Yield in year (snapshot) (ML)	Increase or decrease	%
2006	2480123.67737033000	521859.59069614300	521859.59069614300				521859.59069614300	521859.59069614300		
2007	2496219.66127604000	524770.61622056900	1046630.20691671000				524770.61622056900			
2008	2512323.08995000000	527682.98816224400	1574313.19507896000				527682.98816224400			
2009	2528425.52162354000	530595.17979225500	2104908.37487121000				530595.17979225500			
2010	2544518.91010756000	533505.73592389000	2638414.11079510000				533505.73592389000			
2011	2560595.59044583000	536413.27031798900	3174827.38111309000				536413.27031798900			
2012	2576648.26506358000	539316.46317785500	3714143.84429095000				539316.46317785500			
2013	2592669.99038909000	542214.05872970700	4256357.90302065000				542214.05872970700			
2014	2608654.16392782000	545104.86288499700	4801462.76590565000				545104.86288499700			
2015	2624594.51177138000	547987.74098133700	5349450.50688699000				547987.74098133700			
2016	2640485.07652416000	550861.61559899500	5900312.12248598000				550861.61559899500			
2017	2656320.20563259000	553725.46445018900	6454037.58693617000				553725.46445018900			
2018	2672094.54010248000	556578.31833856800	7010615.90527474000				556578.31833856800			
2019	2687803.00359101000	559419.25918645100	7570035.16446119000				559419.25918645100			
2020	2703440.79186057000	562247.41812752100	8132282.58258871000			16458.78160	562247.41812752100	578,706.20	increase	2.92732
2021	2719003.36258260000	565061.97366279500	8697344.55625151000				565061.97366279500			
2022	2734486.42547960000	567862.14987777400	9265206.70612928000				567862.14987777400			
2023	2749885.93279469000	570647.21471881600	9835853.92084810000				570647.21471881600			
2024	2765198.07007779000	573416.47832679100	10409270.39917490000				573416.47832679100			
2025	2780419.24727869000	576169.29142620500	10985439.69060110000				576169.29142620500			
2026	2795546.09013684000	578905.04376803200	11564344.73436910000				578905.04376803200			
2027	2810575.43185891000	581623.16262454500	12145967.89699370000				581623.16262454500			
2028	2825504.30507456000	584323.11133449900	12730291.00832820000				584323.11133449900			
2029	2840329.93406210000	587004.38789710100	13317295.39622530000				587004.38789710100			
2030	2855049.72723522000	589666.52361320400	13906961.91983850000	331861.9361	2.386300746	6722.720967	589666.52361320400	596,389.24	increase	1.140089
2031	2869661.26988274000	592309.08177226500	14499271.00161070000				592309.08177226500			
2032	2884162.31715340000	594931.65638361300	15094202.65799440000				594931.65638361300			
2033	2898550.78727799000	597533.87095064300	15691736.52894500000				597533.87095064300			
2034	2912824.75502135000	600115.37728658100	16291851.90623160000				600115.37728658100			
2035	2926982.44535701000	602675.85437051900	16894527.76060210000				602675.85437051900			
2036	2941022.22735746000	605215.00724244500	17499742.76784450000				605215.00724244500			
2037	2954942.60829329000	607732.56593604900	18107475.33378060000				607732.56593604900			
2038	2968742.22793459000	610228.28444810200	18717703.61822870000				610228.28444810200			
2039	2982419.85304818000	612701.93974326300	19330405.55797200000				612701.93974326300			
2040	2995974.37208459000	615153.33079319400	19945558.88876510000			-4018.88656	615153.33079319400	611,134.44	decrease	-0.65331
2041	3009404.79004864000	617582.27764888500	20563141.16641400000				617582.27764888500			
2042	3022710.22354791000	619988.62054515200	21183129.78695920000				619988.62054515200			
2043	3035889.89601348000	622372.21903627700	21805502.00599550000				622372.21903627700			
2044	3048943.13308727000	624732.95116180400	22430234.95715730000				624732.95116180400			
2045	3061869.35817093000	627070.71264152600	23057305.66979880000				627070.71264152600			
2046	3074668.08813094000	629385.41609874100	23686691.08589750000				629385.41609874100			
2047	3087338.92915500000	631676.99031085800	24318368.07620840000				631676.99031085800			
2048	3099881.57275489000	633945.37948650100	24952313.45569490000				633945.37948650100			
2049	3112295.79191102000	636190.54256823700	25588503.99826310000				636190.54256823700			
2050	3124581.43735428000	638412.45256012400	26226916.45082330000	190779.0223	0.727416899	-20611.59155	638412.45256012400	617,800.86	decrease	-3.22857
2051	3136738.43398052000	640611.09587926800	26867527.54670250000				640611.09587926800			

2052	3148766.77739372000	642786.47173062900	27510314.01843310000				642786.47173062900			
2053	3160666.53057334000	644938.59150430400	28155252.60993750000				644938.59150430400			
2054	3172437.82066211000	647067.47819458400	28802320.08813200000				647067.47819458400			
2055	3184080.83587025000	649173.16584006800	29451493.25397210000				649173.16584006800			
2056	3195595.82249227000	651255.69898414100	30102748.95295620000				651255.69898414100			
2057	3206983.08203283000	653315.13215517500	30756064.08511140000				653315.13215517500			
2058	3218242.96843805000	655351.52936579100	31411415.61447720000				655351.52936579100			
2059	3229375.88542870000	657364.96363056900	32068780.57810780000				657364.96363056900			
2060	3240382.28393218000	659355.51650160400	32728136.09460940000				659355.51650160400			
2061	3251262.65960986000	661323.27762130800	33389459.37223070000				661323.27762130800			
2062	3262017.55047665000	663268.34429191600	34052727.71652260000				663268.34429191600			
2063	3272647.53460993000	665190.82106112000	34717918.53758370000				665190.82106112000			
2064	3283153.22794468000	667090.81932332000	35385009.35690700000				667090.81932332000			
2065	3293535.28215211000	668968.45693595800	36053977.81384300000				668968.45693595800			
2066	3303794.38259891000	670823.85785044900	36724801.67169340000				670823.85785044900			
2067	3313931.24638458000	672657.15175721300	37397458.82345070000				672657.15175721300			
2068	3323946.62045410000	674468.47374435000	38071927.29719500000				674468.47374435000			
2069	3333841.27978345000	676257.96396948900	38748185.26116450000				676257.96396948900			
2070	3343616.02563571000	678025.76734437800	39426211.02850890000	-553220.4258	-1.403179284	-51949.00130	678025.76734437800	626,076.77	decrease	-7.6618
2071	3353271.68388504000	679772.03323179300	40105983.06174070000				679772.03323179300			
2072	3362809.10340664000	681496.91515433800	40787479.97689500000				681496.91515433800			
2073	3372229.15453018000	683200.57051474700	41470680.54740980000				683200.57051474700			
2074	3381532.72755466000	684883.16032729100	42155563.70773700000				684883.16032729100			
2075	3390720.73132267000	686544.84895992500	42842108.55669700000				686544.84895992500			
2076	3399794.09185188000	688185.80388679200	43530294.36058380000				688185.80388679200			
2077	3408753.75102204000	689806.19545075400	44220100.55603450000				689806.19545075400			
2078	3417600.66531532000	691406.19663558400	44911506.75267010000				691406.19663558400			
2079	3426335.80460841000	692985.98284750800	45604492.73551760000				692985.98284750800			
2080	3434960.15101445000	694545.73170576700	46299038.46722340000				694545.73170576700			
2081	3443474.69777313000	696085.62284187900	46995124.09006530000				696085.62284187900			
2082	3451880.44818727000	697605.83770732900	47692729.92777260000				697605.83770732900			
2083	3460178.41460430000	699106.55938935400	48391836.48716190000				699106.55938935400			
2084	3468369.61744111000	700587.97243458200	49092424.45959650000				700587.97243458200			
2085	3476455.08425062000	702050.26268022600	49794474.72227670000				702050.26268022600			
2086	3484435.84882875000	703493.61709257200	50497968.33936930000				703493.61709257200			
2087	3492312.95036038000	704918.22361252100	51202886.56298180000				704918.22361252100			
2088	3500087.43260279000	706324.27100791000	51909210.83398970000				706324.27100791000			
2089	3507760.34310540000	707711.94873240000	52616922.78272210000				707711.94873240000			
2090	3515332.73246442000	709081.44679068200	53326004.22951280000			-81239.31503	709081.44679068200	627,842.13	decrease	-11.457
2091	3522805.65361129000	710432.95560977500	54036437.18512260000				710432.95560977500			
2092	3530180.16113353000	711766.66591621300	54748203.85103880000				711766.66591621300			
2093	3537457.31062702000	713082.76861889400	55461286.61965770000				713082.76861889400			
2094	3544638.15807847000	714381.45469739800	56175668.07435510000				714381.45469739800			
2095	3551723.75927702000	715662.91509557600	56891330.98945070000				715662.91509557600			
2096	3558715.16925391000	716927.34062020900	57608258.33007090000				716927.34062020900			
2097	3565613.44174924000	718174.92184456800	58326433.25191550000				718174.92184456800			
2098	3572419.62870476000	719405.84901668500	59045839.10093210000				719405.84901668500			
2099	3579134.77978176000	720620.31197216700	59766459.41290430000				720620.31197216700			
2100	3585759.94190324000	721818.50005138400	60488277.91295570000	-3454976.033	-5.711810871		721818.50005138400			
2101		723000.60202087200					723000.60202087200			

2102	724166.80599878900		724166.80599878900			
2103	725317.29938428400		725317.29938428400			
2104	726452.26879062000		726452.26879062000			
2105	727571.89998191400		727571.89998191400			
2106	728676.37781336400		728676.37781336400			
2107	729765.88617482400		729765.88617482400			
2108	730840.60793759600		730840.60793759600			
2109	731900.72490432400		731900.72490432400			
2110	732946.41776186900	-106247.19933	732946.41776186900	626,699.22	decrease	-14.4959
2111	733977.86603704500		733977.86603704500			
2112	734995.24805510100		734995.24805510100			
2113	735998.74090086100		735998.74090086100			
2114	736988.52038238900		736988.52038238900			
2115	737964.76099710300		737964.76099710300			
2116	738927.63590022800		738927.63590022800			
2117	739877.31687549900		739877.31687549900			
2118	740813.97430801400		740813.97430801400			
2119	741737.77715917300		741737.77715917300			
2120	742648.89294358200		742648.89294358200			
2121	743547.48770787800		743547.48770787800			
2122	744433.72601136800		744433.72601136800			
2123	745307.77090842000		745307.77090842000			
2124	746169.78393253300		746169.78393253300			
2125	747019.92508200200		747019.92508200200			
2126	747858.35280712700		747858.35280712700			
2127	748685.22399888800		748685.22399888800			
2128	749500.69397902400		749500.69397902400			
2129	750304.91649146000		750304.91649146000			
2130	751098.04369501700	-129588.5086	751098.04369501700	621,509.54	decrease	-17.2532
2131	751880.22615734600		751880.22615734600			
2132	752651.61285004300		752651.61285004300			
2133	753412.35114487100		753412.35114487100			
2134	754162.58681106100		754162.58681106100			
2135	754902.46401362600		754902.46401362600			
2136	755632.12531264200		755632.12531264200			
2137	756351.71166346100		756351.71166346100			
2138	757061.36241779800		757061.36241779800			
2139	757761.21532566000		757761.21532566000			
2140	758451.40653806400		758451.40653806400			
2141	759132.07061052200		759132.07061052200			
2142	759803.34050723600		759803.34050723600			
2143	760465.34760597600		760465.34760597600			
2144	761118.22170360900		761118.22170360900			
2145	761762.09102223500		761762.09102223500			
2146	762397.08221590400		762397.08221590400			
2147	763023.32037788200		763023.32037788200			
2148	763640.92904843500		763640.92904843500			
2149	764250.03022309800		764250.03022309800			
2150	764850.74436140600	-163023.35378	764850.74436140600	601,827.39	decrease	-21.3144

Appendix B – Water vs Wood. Net Present Value Analysis (ACF)

Value of water yields from the Goulburn Broken Catchment under a 'no logging' scenario:

Value of water in 2009 ($/ML):	$2253 per ML[1]
Value of water beyond 2009 – increase based on Consumer Price Index:	2.5% increase per annum
Water yield volumes:	Taken from Practical Ecology report – Appendix A
Total water yield from study area over 100 year period with no logging:	65,462 GL
NPV of total water yield from catchment under a 'no logging' scenario over 100 year period (2% discount rate):	$188,902,391,295 ($188.9 billion)
Total *additional* water yield from study area over 100 year period with no logging:	3,807 GL
NPV of total *additional* water yield compared to business as usual logging under a 'no logging' scenario over 100 year period (2% discount rate):	$1,683,023,978 ($1.68 billion)

NPV of total *additional* water yield above business as usual logging under a 'no logging' scenario over 80 year period – decade by decade breakdown (2% discount rate):	**Years:**	**Net Present Value:**
	2010-2019	-$200,556,107
	2020-2029	-$245,747,928
	2030-2039	-$38,266,764
	2040-2049	$230,763,011
	2050-2059	$568,445,526
	2060-2069	$888,446,335
	2070-2079	$1,191,998,596
	2080-2089	$1,490,751,111

In order to calculate the NPV of water and carbon over a long time frame (100 years), we undertaken research to choose an appropriate rate of discount. Analysis for this report has applied a low discount rate of 2% in keeping with precedent set by leading global reports on costs of climate change – both the UK Stern Review and Australia's Garnaut Review.

[1] Based on a $2253/ML price as reported in the GHD report to the Department of Environment, Water, Heritage and the Arts - *Murray-Darling Basin Water Entitlements summary of market prices (approved transfers).* Price is for Victorian Goulburn high reliability entitlement, at an average price for the first half of 2008/09.

In both of those reviews, a discount rate of close to zero was considered appropriate for the long term environmental impact of climate change (0.05% in Garnaut Review)[2]. Both authors argued that when considering long term impacts, the welfare of future generations should not be considered less valuable to those of us alive today. The impact of water availability and carbon emissions both have an equal importance to all humans whether today or in 50 years time. Due to the applicability of this theory to water and carbon over a century, we have followed the precedent of Stern and Garnaut in choosing a low discount rate, however, in order to remain conservative, we have chosen a 2% discount rate, rather than 0.05% to reflect the natural human tendancy to value today above tomorrow.

For consistency in our analysis, we have applied the same low discount rate to timber values. This presents a different probelsm, however, in that timber is being extracted by a government business enterprise charged with making a profit from Victoria's natural resources. In reality then, VicForests should be undertaking their business decisions based on a discount rate closer to 6+% (it could be argued up to 10%). However, to make the three assets of water, carbon and timber comparable, we have applied the same low discount rate for all three assets.

Value of timber harvested in Goulburn Broken Catchment under a business as usual logging scenario:

Hectares harvested per annum:	500 hectares
Sawlogs harvested per annum:[3]	50,000 m3
Residual timber harvested per annum:	135,000m3
Average cost sawlog:[4]	$100/m3
Average cost residual:	$10/m3
Value of timber beyond 2009 – increase based on Consumer Price Index:	2.5% increase per annum
NPV of timber harvested over 100 years at 500 hectares per annum (at 2% discount rate):	$811,118,345

2 Garnaut, R. (2008), Garnaut Climate Change Review Final Report page 18.

3 Timber volumes taken from internal ACF research based on VicForests own publicly disclosed information

4 Timber prices taken from publicly available timber auction results – sawlogs average auction results 2006; residual average prices paid by Midway

Appendix C - Analysis of the Value of Carbon sequestration potential (ACF)

Additional value of carbon in the Goulburn Broken Catchment above business as usual under a 'no logging' scenario:

Total carbon per hectare:	640 tonnes
Total carbon sequestered per hectare per annum:	12 tonnes
Total CO2-equivalent sequestered per hectare per annum:	43.2 tonnes
Total forest logged per annum:	500 hectares
Total tonnes CO2-equivalent sequestered in year 1 under 'no logging' scenario:	21,150 tonnes (per 500 hectares per annum)
Price of carbon – 2010 – 2050[1] - Based on Treasury modeling – low carbon reductions scenario of -5% by 2020:	\$20 - \$115
Price of carbon post-2050 – indexed to Consumer Price Index	2.5% per annum
NPV of total additional carbon sequestered by forests under a 'no logging' scenario over 100 year period (at 2% discount rate):	\$6,152,322,601 (\$6.15 billion)

Summary of value of carbon using indicative 10 year values (modeling has been undertaken annually):

Year:	**Carbon price, based on Treasury modeling figures (\$ per tonne)**	**Value of carbon sequestered per annum:**
2010:	\$20	\$0.85 million
2020:	\$35	\$8.88 million
2030:	\$62	\$28.85 million
2040:	\$89	\$60.24 million
2050:	\$115	\$102.15 million
2060:	\$147	\$161.90 million
2070:	\$188	\$247.10 million
2080:	\$247	\$381.74 million
2090:	\$309	\$535.52 million
2100:	\$395	\$769.11 million

[1] T reasury (2008), Australia's Low Pollution Future, based on data under the low CPRS-5 scenario (5% reduction by 2020)

Appendix D

Old-growth forest, water and climate change -

Some scientific understandings.

Old-growth

Old-growth forests are an important part of Victoria's natural heritage. They contain many of Australia's endemic plant and animal species and, as such, contain unique communities found nowhere else in the state. However, they have been systematically destroyed by logging and clearing over the past century. Since European settlement, 65% of Victoria's forest cover has been cleared and much of that has been old-growth forest.[1]

Logging began during the gold rush days of the 1840's and from this time up to the 1950's most logging was selective, with individual trees felled and removed. The modern method of clearfelling entire forest stands started in the 1960s this process removes nearly all of the trees from a selected area.

The logging of old growth forests directly leads to the destruction and the direct removal of habitat needed for the survival of old-growth forest dependent species. The destruction of habitat through activities like logging has been identified as the main past (and present) cause of biotic endangerment and extinction in all vegetated countries on Earth. [2] [3] [4] [5] [6]

Logging does not simply destroy habitat - it leads to the fragmentation of continuous species' population into a series of small residual populations. Research has shown that these isolated pockets of populations are far more susceptible to extinction through processes associated with genetic inbreeding and increasing vulnerability to the effects of fire and disease. [7] [8]

In Victoria, the permanent loss of old-growth forest habitat has led to a serious decline in both the abundance and distribution of many plant and animal species.[9] It has been found that many plants and animals simply do not come back after logging operations have taken place.[10] Many of these species are supposedly protected by state and federal law, including the Leadbeaters possum, Long footed potoroo and Spotted-tailed quoll.

The present reserve system, that attempts to protect species against processes that drive extinction has been criticised extensively by the scientific community. [11] [12] Currently, in Victoria, 15% of each forest type is set aside to ensure biodiversity is maintained. This level of reservation is insufficient for securing the conservation of Victoria's biodiversity for a number of reasons:

- A large number of species simply do not occur in a protected forest and therefore have no protection status.

- Even the largest old-growth forests in Victoria are too small and vulnerable to broad area disturbance. The long-term survival of populations of threatened species within the present Victorian National park is now limited as a consequence of the fire.

- The relative isolation of many old-growth forest reserves to its neighbours is another significant limitation. The exchange of individuals of threatened species within the reserve system is necessary to overcome problems associated with genetic inbreeding, yet many reserves are too isolated for this gene flow to occur. The small size and isolation of reserves do not leave much scope for plants and animals to adapt to long-term climate change, either through dispersal or by evolution.

These issues mean that a complete reassessment is necessary if the species inhabiting old-growth forests are to persist in the future. This is not the only reason such a reassessment is required. Fire is an ever present issue for wildlife and humans inhabiting Victoria and the processes of logging of old-growth forests contribute to an increase in the frequency and intensity of fires. This is because logging reduces the resistance of these forests to fire. The process changes the very nature of the forest's microclimate, resulting in a change in plant composition and structure. An old-growth forest goes from a fire resistant 'wet' forest to a much 'drier', fire-prone ecosystem. [13]

The present conservation strategy for Victoria makes little or no attempt to synthesize the parts of each threatened ecosystem into a working whole. It is not valid to assume that just because certain elements are included in a reserve system, the entire ecosystem is protected and that biodiversity and ecological processes that the forest provides will somehow be preserved in the long term. Perhaps more importantly, the current reserve system does not take into account climate change at all. It is now believed that accelerated anthropogenic global climate change will be the major driver of biodiversity change and species extinctions in the near future [14] [15] [16] [17] [18] [19] [20] and that the process has already contributed to species extinctions [21] [22] [23] [24] [25] [26]. Species are expected to respond to the changing climate by migrating to track the environmental conditions to which they are adapted. [27] [28] [29] [30] [31] [32]

This means that the only way species will survive the influence of climate change in Victoria is to ensure that connectivity within the landscape is maintained. There must therefore be suitable habitat sufficiently connected to enable threatened animals to move between isolated pockets of old-growth. If species are unable to track their distribution among old-growth forest remnants when local changes in the climate occur, then local extinction will be the only outcome.

The current system of island like parks in Victoria cannot meet the needs of many species, or enable the dispersal and re-establishment of wildlife following events associated with climate change. The protection of biodiversity within old-growth forest ecosystems is a complex problem and requires detailed analysis. Protected areas need to ensure that viable populations of individual species occur across their entire range, and that adequate contact between these populations is maintained to allow genetic interchange and to overcome inbreeding while allowing evolutionary processes to continue. [33] Enough suitable habitat must therefore be maintained, in the right locations, in adequate amounts and in a connected manner to allow this to occur.

In Eastern Victoria according to the most recent data available only 668,396 ha (DSE Modeled Old-growth coverage) of old-growth forest remains this is only about 10% of the land area. The vast majority of this area was forest and woodland at the time of European settlement.

As a result of logging a major loss is that of the number of trees containing hollows. It normally takes around 100 years for hollows to begin to form in eucalypt species[34] and logging is systematically removing this age class from the public native forests. Tree hollows are needed by 98% of Victoria's animal species for shelter and breeding. [35] The resulting decrease in the number of available hollows will move species closer to extinction. [36] We often think of extinction as an end point where a species is no longer found on the planet. This is however not the case. There is a scale along which a species moves towards this particular point.

Logging radically alters the structure of the forest – the number of big old trees with hollows, the number of fallen logs, the density of the understorey and the canopy vegetation. It also alters the floristic structure of the forest – the number, type and density in the forest. Logging can also create conditions which promote the spread of pest animals and weeds and increase the probability, frequency and severity of fire. Consequently, many plants and animals are now absent from the forest. [35]

Research by botanists Keely Ough and Murphy from the Victorian Department of Conservation and Environment (now Department of Sustainability and Environment), found that four common shrub and tree species never returned after logging. Tree ferns are also mostly eliminated by logging. These tree ferns play a vital role in maintaining the moisture of the forest floor and providing protection for the growth of other forest plants. [37]

These magnificent old-growth forests which pre-date the arrival of the first European ships will not regenerate to their original state for between 1,500 and 2,500 years. [38]

There is now a need to expand the definition of old-growth forest to include the class "late mature", as many of the last remaining stands of old-growth forests have been removed from the Victorian landscape over the last decade. If species are to survive the onset of climate change in our changed landscape it has become evident that the preceding age class to 'old growth' must be included in the old-growth definition.

This preference has also been advocated by forests managers. The technical report by Natural Resources and Environment in 2000 A *Study of the Old-growth Forests of East Gippsland* stated that the preference should be extended beyond old-growth forest to negligibly-disturbed younger forests and forest with a mature growth stage which have the potential to become the old-growth forests of the near future. The long term conservation of old-growth forests must therefore include a wider class range. There are many natural processes constantly shaping and re-shaping the extent and characteristics of these forests. New areas will be recruited as trees reach their older growth stages or as the effects of past disturbance become negligible. [39]

Water

Water is Australia's most precious and scarce resource. The Wilderness Society considers that three major factors will potentially have dire effects on water supply. Namely, increasing public demand in both rural and city regions, climate change and continuing land clearing and logging in water catchments.

Victoria is in a water shortage crisis, and old-growth forests produce far cleaner and high volumes (around 12 megalitres of water per hectare per year) than regrowth[40] forests. Logging is extensive in the rain-soaked upper catchments of the rivers that supply water to Melbourne, to the irrigation districts of West Gippsland and to the stressed rivers of the upper Murray.

A key challenge facing Victoria is the management of water resources to ensure that we have sufficient clean clear water in the future. To do this sustainably we need to look beyond old solutions, such as the building of dams and continually extracting more water from river systems.

As our demand for water continues to increase and with the added pressure recent drought years have placed on available supply, concerns within the general community are growing.

If Melbourne's water consumption continues to grow at present rates, it is projected we will be using all available water by the year 2012.[41] Stream flow reductions due to logging will compound other changes to the reliability of stream flow expected as a result of climate change. [42] [43]

In order to achieve long-term water sustainability we need not only to focus on demand management, but more importantly, on resource management in order to achieve maximum resource yield and quality for all end users.

Protecting water catchments has shown to be economically beneficial to the community. For example, The New York Department of Environment and Conservation estimates that the expenditure of US $1.5 billion in catchment management has allowed the City of New York to cancel proposed water treatment plants with an estimated cost of US $6.7 billion. [44]

Water for consumptive use in Victoria is taken from reservoirs, streams and aquifers under entitlements issued by the Victorian Government and authorised under the *Water Act 1989*.

Generally, water for consumptive use is allocated to either water authorities, who are granted bulk entitlements, or to individuals who are issued a license. Exceptions to this include private power generating companies in the Latrobe Valley, which hold bulk entitlements, as does Southern Hydro, and the Minister for Environment.

Water authorities also have licenses to extract surface water and groundwater to supply urban areas. There are also many situations in which private individuals have the right to take water for domestic and stock use without a license (e.g. from a farm dam or a groundwater bore).

Table 3-1 Water allocated for consumptive use in Victoria (State Water Report 2003-2004: a statement of Victorian water resources DSE June 2005)

Entitlement Total (ML)

Surface Water

Bulk entitlements (1)	4,619,970
Licenses (2)	233,300
Private right (farm dams) (3)	512,670

Groundwater Licenses	804,065
Total water entitlements	6,170,005

The supply of clean water is emerging as one of the biggest, possibly the biggest issue the world has to face over the next 50 years.[45]

Research has conclusively shown that logging adversely affects water yield. [46] In the Thomson catchment logging operations have already, and will have in the future, considerable implications for the supply of water to Melbourne. If logging were phased out of the Thomson catchment by 2020, this would result in a saving of 20,000 ML per annum by the year 2050 [47] .

As water becomes scarcer in future years, it will become increasingly important to protect this resource. Water is far more valuable to the community than native forest wood, for which there are existing plantation alternatives. [48] [49]

It is generally agreed that, Australia-wide, insufficient long-term funds are being committed to Integrated Catchment Management (ICM). [50] It is estimated that potential agricultural production foregone due to land and water degradation could be as high as $0.6 Billion a year in Victoria [51].

Government bodies or water authorities could either buy out the sawlog licenses, compensating saw millers, employees and contractors, or procure wood requirement from plantations should they be available. The protection of water catchments would not only result in increased water yield but would also have environmental gains.

A cessation of logging in water catchments would increase water yield to rural communities. Catchments need to be protected to prevent changes in water quality, volume, salinity and nutrient levels. Maintaining intact healthy catchments will assist rural communities in their attempt to buffer themselves against drought.

The Victorian Infrastructure Planning Council discussed a couple of principles that could be applied nationally to catchments. Managers should have a duty of care to not damage the resource, but where damage occurs the responsible party, if identifiable, should pay. It was also recommended that improvements should be paid for by government. Assisting a transition out of headwater catchments and into lowland plantations would not only improve catchment health, it would result in increased water yields to all.

Management of Water Resource

A recent Strategic Water Review undertaken in Melbourne found that if catchments were logged, a decrease in water yield would result.[41]

Principles governing the implementation of catchment management in Chapter 5 on Water in the Victorian Infrastructure Planning Council document of 2002 [52] state that

- A duty of care not to damage the natural resource base (remedying any damage incurred) by users and managers of the natural resource;
- Beneficiary pays, where it is not possible to identify the cause of damage; and
- Government contributions, where activities generate public benefits for both existing and future users. The Government has undertaken to meet the cost of statewide planning, resource; monitoring and assessment, research and investigation where they are crucial to sustainable resource management.

The logging taking place in many of Victoria's water catchments is leading to severe damage to catchments in Victoria and substantial reductions in water supply. [53] Instead of responding in the traditional way by harvesting more water or building more dams, we could extract more water from catchments simply by ending logging in these areas.

Research on water yield in Alpine Ash/ Mountain Ash/ Mixed Species Forests

Several studies undertaken across Australia have investigated the effect logging has on water yield, determined by forest type, soil, rainfall and soil depth. [54] The most comprehensive study was undertaken by Kuczera (1985) after the 1939 wildfire in the Central Highlands. This study found that burnt or logged areas experience a reduction in water yield.

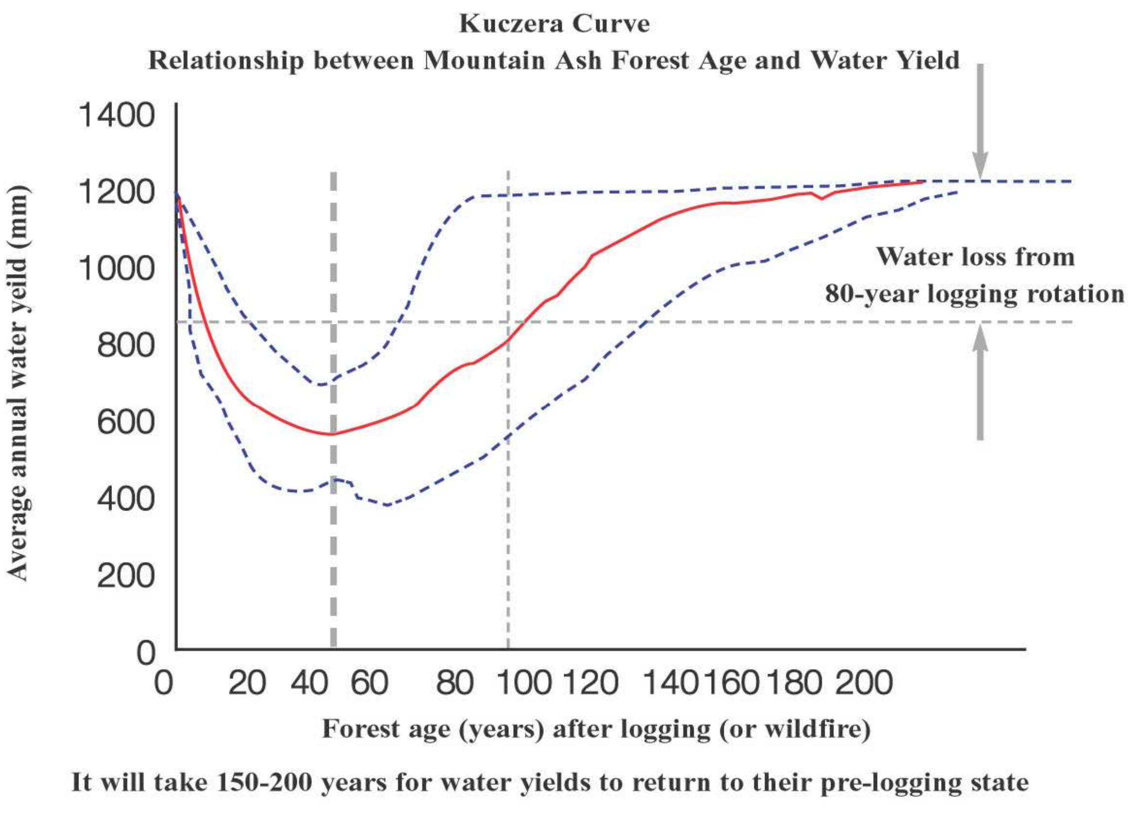


Figure 1: Correlation of annual water yield and forest age

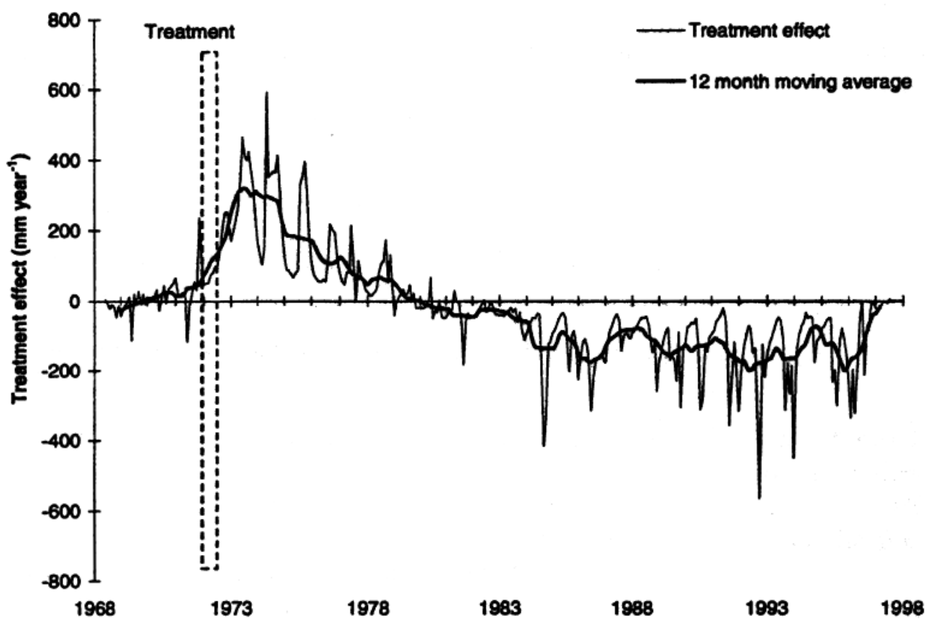


Figure 2. Treatment Effects on monthly stream flow at Picaninny [55] .

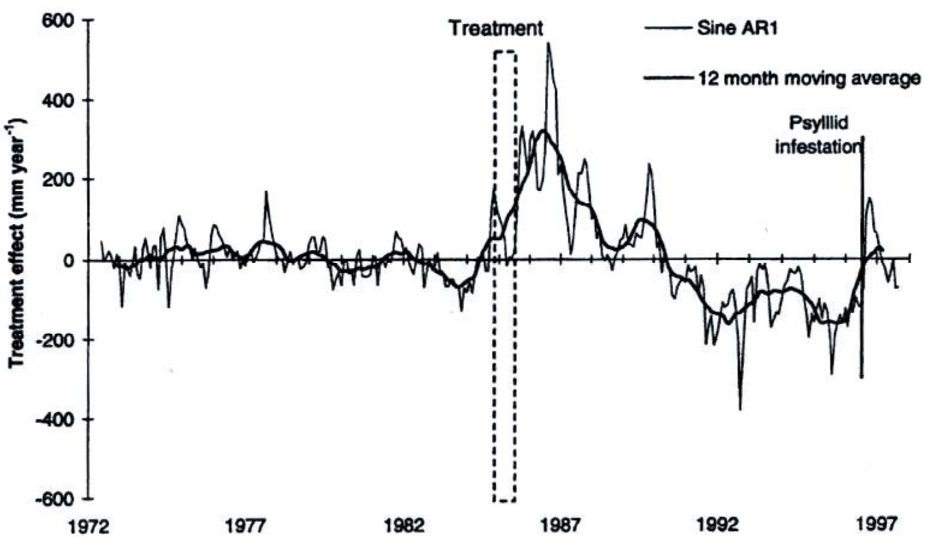


Figure 3. Treatment effect on monthly stream flow at Myrtle 2 [56]

Once logging takes place and the area is burnt, there is an initial increase in water yield as rain falling runs straight off the cleared areas and into adjacent streams. However, after 5-10 years water yield drops drastically as young forests begin to grow. These young forests have high evapotranspiration rates (they consume large volumes of water during their growing phase). It takes approximately 150 years for water levels to return to those experienced prior logging.

Further studies comparing the effect logging has on water yield have corroborated this early research. [40] The length of the logging rotation has a particular effect on the water yield of a catchment. In ash type forests, a rotation length of 50 years produces the maximum reduction in water yield. In the Thomson and Yarra Tributary catchments the logging rotation is 60 years or less [56] , not 80 to 120 years as recommended in the Comprehensive Regional Assessment. [57]

Historically, not much is known about the correlation between forest age and water yield in mixed species forests. However, recent research in the Tantawanglao Creek Catchment in New South Wales has shown that logging has a detrimental effect on water yield. [58]

There are several research studies undertaken throughout Victoria and NSW which highlight the detrimental effect logging has on water yield [Coranderrk];[59] [60] [61] West Kiewa Study [62] Delegate River Study [63] and a study on aquatic plants to measure stream flow decline, the Otways Moran Study]. [54]

Further Research on water quality

The Victorian Infrastructure Planning Council [64] states that water quality is intrinsically linked to the health of Waterways and Catchment Management. Sediment sources were then identified as the primary cause of the water quality decline.[65] The researchers identified the two main sources of sediment likely to be contributing to the water quality decline as agriculture and logging. [66] Decreased water quality, such as increased sedimentation and turbidity (suspended sediment) are known to reduce the effectiveness of filtration and disinfection – requiring higher level treatment at greater cost. Although several practices are employed by the Department of Sustainability and Environment to ameliorate these impacts, the attempt to evaluate the effectiveness of these measures is minimal.

Many streams that flow for less than 90% of the year are termed non-permanent, as a result these streams do not have filter strips [67], logging therefore takes place right up to the edge of the stream, resulting in an increase in temperature as well as sediment load. Solar radiation, responsible for stream temperature, will increase in these exposed streams, with a detrimental effect on the breeding cycle of many temperature sensitive species. [68]

Forestry practices contribute significantly to the sedimentation of streams and lakes. Sediment production rates of 90 tonnes/ha/annum have been measured from roads in the Maroondah catchment in the Central Highlands.[69] Erosion rates of120 tonnes/ha/annum have been measured from log landings in the Cuttagee catchment in NSW. [70] These enormous movements of sediment are a clear risk to water quality.

Regeneration burns further compound the decline in water quality. When regeneration burns occur the soil is dramatically heated. The heating of the soil causes the soil to become less permeable to water resulting in increased runoff. Eucalypt forests appear particularly prone to this phenomenon. [40]

The Financial Cost of logging water catchments

The logging industry does not pay for the loss of water; it is paid for by the Victorian community. The logging industry has therefore gained subsidized access to water because the overall decline in supply is not factored into the price of logs removed. This means that alternative sources, such as plantations and farm forestry, must unfairly compete with catchment wood resource.

Water lost due to logging has an economic value. A study of future options for harvesting logging and harvesting water from the Thomson catchment [48] (largest of Melbourne's catchments) revealed that the value of water from catchment outweighs that of the wood in the forest. Extending the current harvest rotation from 80 to 200 years increases the catchments net present value by $81 million, while shorter 20-year rotations would decrease it by $525 million and requires the building of a $250 million water treatment works (Prime Ministers Science, Engineering, and Innovation Council, 2002 this is from a 1994 report cited in this document). Present logging rotations are 60 years or less, according to the Department of Primary Industries Wood Utilization Plans.

Forests as carbon stores

It is becoming increasingly clear that logging of old growth forests is not a 'greenhouse neutral' process. Old growth forests have been found to play an extremely important role in acting as a carbon sink at regional and continental spatial scales, and hence, their conservation would be an important step in ameliorating the impacts of climate change.[71] In a seminal study of the impacts of logging on old growth forests conducted, the authors showed that logging of forests in the Styx Valley (an old growth forest in Tasmania) would produce approximately a thousand tonnes of greenhouse gases per hectare.[71] In simpler terms, clearing 1000 hectares of Styx old growth forest would produce greenhouse gas pollution equivalent to all the cars in Tasmania in a year. The authors also found that undisturbed old growth forest can store up to 1500 tonnes of carbon per hectare. [71] Logging greatly reduces the carbon stored in the forest to levels much lower than levels estimated after severe wildfire. Stand replacement wildfires left between 1000 and 1100 tonnes of carbon stored per hectare. After successive logging scenarios, it was found that carbon stored in a regenerating forest could be reduced to around a total of 485 tonnes per hectare.

These results reflect a review of the global literature[72], which found the amount of Carbon stored in the forest ecosystem to be related to the age class of the forest. There are a number of associated reasons why logged forests contain far less carbon than old growth forests:

(i) logged forests have relatively more frequent fires that emit gaseous carbon,
(ii) when a forest is logged, wood products are not returned to the soil,
(iii) logged forests often contain a vegetation understorey that is under-developed when compared to old growth forests and
(iv) trees in logged forests often only grow to around 60% of the size they would in an old-growth forest.
(v) forest soils can also lose carbon due to logging because of:
(a) a loss of nutrients,

(b) changes in the physical properties of the soil due to disturbance by logging machinery,
(c) changes to the microclimate as a result of the loss of forest canopy.

Protecting our old-growth forests will make a significant contribution to keeping carbon sequestered rather than volatilized to the atmosphere as smoke and methane.

References

---

[1] Woodgate P and Black P 1988, 'Forest Cover Changes in Victoria 1869-1987', Department of Conservation, Forests and Lands. Victoria

[2] Czech, B and Krausman P R 1997, 'Distribution and causation of species endangerment in the United States', *Science* vol 277 pp.1116-1117.

[3] Dobson A P, Rodriguez J P, W. M. Roberts, and D. S. Wilcove. 1997. Geographic distribution of endangered species in the United States. Science 275:550-553.

[4] Pimm, S. L., and P. Raven. 2000. Biodiversity - Extinction by numbers. Nature 403:843-845

[5] Sala, O. E., F. S. Chapin, III, J. J. Armesto, E. Berlow, J. Bloomfield, R. Dirzo, E. Huber-Sanwald, L. F. Huenneke, R. B. Jackson, A. Kinzig, R. Leemans, D. M. Lodge, H. A. Mooney, M. Oesterheld, iacute, N. L. Poff, M. T. Sykes, B. H. Walker, M. Walker, and D. H. Wall. 2000. Global Biodiversity Scenarios for the Year 2100. Science 287:1770-1774.

[6] Green, R. E., S. J. Cornell, J. P. W. Scharlemann, and A. Balmford. 2005. Farming and the fate of wild nature. Science 307:550-555.

[7] Watson, James, Freudenberger, David & Paull, David (2001) An Assessment of the Focal-Species Approach for Conserving Birds in Variegated Landscapes in Southeastern Australia. *Conservation Biology* 15 (5), 1364-1373.

[8] Watson, J. E. M., R. J. Whittaker, and T. P. Dawson. 2004. Habitat structure and proximity to forest edge affect the abundance and distribution of forest-dependent birds in tropical coastal forests of southeastern Madagascar. Biological Conservation 120:311-327.

[9] DSE (2003) *Advisory List of Threatened Vertebrate Fauna in Victoria 2003.* Department of Sustainability and Environment, Victoria.

[10] Ough K (2001), 'Regeneration of Wet Forest Flora a decade after clearfelling or wildfire – is there a difference', (Australian Journal of Botany, 2001, Vol 49, pp 645-664)

[11] Soule ME, Mackey BG, Recher HF, Williams JE, Woinarski JCZ, Driscoll D, Dennison WG and Jones ME (2004), 'The role of connectivity in Australian Conservation', Pacific Conservation Biology, 10: 266-79

[12] Recher et al., in press.

[13] Griffiths, R.C. and Muir, A.M. (1991) Comparisons between the floristic composition of some regrowth and mature forest. Management of Eucalypt Regrowth in East Gippsland Technical Report No 17, DCE and CSIRO.

[14] Peterson, A. T., L. G. Ball, and K. P. Cohoon. 2002a. Predicting distributions of Mexican birds using ecological niche modelling methods. Ibis 144:E27-E32.

[15] Peterson, A. T., and D. A. Kluza. 2003. New distributional modelling approaches for gap analysis. Animal Conservation 6:47-54.

[16] Thomas, C. D. 2004. Extinction risk from climate change. Nature 427:145-148.

[17] Shoo, L. P., S. E. Williams, and J. Hero. 2005. Climate warming and the rainforest birds of the Australian wet tropics: using abundance data as a sensitive predictor of change in total population size. Biological Conservation 125:335-343.

[18] Thuiller, W., S. Lavorel, and M. B. Araujo. 2005a. Niche properties and geographical extent as predictors of species sensitivity to climate change. Global Ecology and Biogeography 14:347-357.

[19] Thuiller, W., S. Lavorel, M. B. Araujo, M. T. Sykes, and I. C. Prentice. 2005b. Climate change threats to plant diversity in Europe. Proceedings Of The National Academy Of Sciences Of The United States Of America 102:8245-8250.

[20] Thuiller, W., S. Lavorel, M. T. Sykes, and M. B. Araujo. 2006. Using niche-based modelling to assess the impact of climate change on tree functional diversity in Europe. Diversity and Distributions 12:49-60.

[21] Walther, G. R., E. Post, P. Convey, A. Menzel, C. Parmesan, T. J. C. Beebee, J. M. Fromentin, O. Hoegh-Guldberg, and F. Bairlein. 2002b. Ecological responses to recent climate change. Nature 416:389-395.

[22] Parmesan, C., and G. Yohe. 2003. A globally coherent fingerprint of climate change impacts across natural systems. Nature 421:37-42. community structure. American Zoologist 40:597-630.

[23] Root, T.L., J.T. Price, K.R. Hall, S.H. Schneider, C. Rosenzweig, and J.A. Pounds 2003. Fingerprints of global warming on wild animals and plants. *Nature* 421, 57-60

[24] Hickling, R., D. B. Roy, J. K. Hill, and C. D. Thomas. 2005. A northward shift of range margins in British Odonata. Global Change Biology 11:502-506.

[25] Pounds, A. J., M. R. Bustamante, L. A. Coloma, J. A. Consuegra, M. P. L. Fogden, P. N. Foster, E. La Marca, K. L. Masters, A. Merino-Viteri, R. Puschendorf, S. R. Ron, G. A. Sanchez-Azofeifa, C. J. Still, and B. E. Young. 2006. Widespread amphibian extinctions from epidemic disease driven by global warming. Nature 439:161.

[26] Thuiller, W., M. B. Araujo, R. G. Pearson, R. J. Whittaker, L. Brotons, and S. Lavorel. 2004. Uncertainty in predictions of extinction risk. Nature 430.

[27] Hill, J. K., C. D. Thomas, R. Fox, M. G. Telfer, S. G. Willis, J. Asher, and B. Huntley. 2002. Responses of butterflies to twentieth century climate warming: implications for future ranges. Proceedings of the Royal Society B-Biological Sciences 269:2163-2171.

[28] Midgley, G. F., L. Hannah, D. Millar, M. C. Rutherford, and L. W. Powrie. 2002. Assessing the vulnerability of species richness to anthropogenic climate change in a biodiversity hotspot. Global Ecology and Biogeography 11:445-451.

[29] Williams, S. E., E. E. Bolitho, and S. Fox. 2003. Climate change in Australian tropical rainforests: an impending environmental catastrophe. Proceedings of the Royal Society of London Series B-Biological Sciences 270:1887-1892.

[30] Thomas, C. D., S. E. Williams, A. Cameron, R. E. Green, M. Bakkenes, L. J. Beaumont, Y. C. Collingham, B. F. N. Erasmus, M. F. de Siqueira, A. Grainger, L. Hannah, L. Hughes, B. Huntley, A. S. van Jaarsveld, G. F. Midgley, L. Miles, M. A. Ortega-Huerta, A. T. Peterson, and O. L. Phillips. 2004. Biodiversity conservation - Uncertainty in predictions of extinction risk - Effects of changes in climate and land use - Climate change and extinction risk - Reply. Nature 430.

[31] Midgley, G. F., and W. Thuiller. 2005. Global environmental change and the uncertain fate of biodiversity. New Phytologist 167:638-641.

[32] Walther, G. R. 2004. Plants in a warmer world. Perspectives in Plant Ecology Evolution and Systematics 6:169-185.

[33] Williams J, Read C, Norton T, Dovers S, Burgman M, Proctor W, Anderson H (2001), 'Biodiversity – State of the Environment Australia 2001 Report', (Commonwealth of Australia)

[34] Lindenmayer D, Cunningham R, Tanton M, Smith A, Nix H (1991), 'Charactaristics of hollow bearing trees occupied by arboreal marsupials in the montane ash forests of the Central Highlands of Victoria, south-east Australia', Forest Ecology and Management 40, pp289-308

[35] Traill,B. (1995) Woodchips or Wildlife – the case against logging our native forests. Environment papers, Vol:1. Victorian National Parks Association.

[36] Possingham H, Lindemayer D, Norton T, Davies I (1994), 'Metapopulation Viability Analysis of the Greater Glider Petauroides volans in a Wood Production Area', Biological Conservation 70 pp227-236

[37] Ough K, Murphy A (2004), 'Decline in tree fern abundance after clearfell harvesting', Forest Ecology and Management 199, pp153-163

[38] Norton T (1996), 'Conserving biological diversity in Australia's temperate eucalypt forests', Forest Ecological and Management 85, pp21-33

[39] DNRE (2000) Gippsland Old Growth. Technical Report. Victoria

[40] Vertessy R, Watson F, O'Sullivan S, Davis S, Campbell R, Benyon R, Haydon S (1998), 'Predicting Water Yield from Mountain Ash Forest Catchments', Cooperative Research Centre for Catchment Hydrology

[41] WRSCMA (2001) Discussion starter: Stage 1 in developing a water resources strategy for the Greater Melbourne area. Water Resource Strategy Committee for the Melbourne Area.

[42] Howe C, Jones R, Maheepala S, Rhodes B (2005), *Implications of Potential Climate Change for Melbourne's Water Resources,* (CSIRO)

[43] Hennessy K, Lucas C, Nicholl N, Bathols J, Suppiah R, Ricketts J (2005), *Climate Change Impacts on fire weather in South-East Australia,* (CSIRO)

[44] BREC (199) BREC proposes 120 million dollar catchment protection revenue bond for SEQ. Brisbane region environment council media release 7 Dec 1998. http://brec.ozecol.org/news/current/catchmentbond.html

[45] Harris G (2002) Ensuring sustainability – paradigm shifts and big hairy goals. Speech by Dr Graeme Harris, CSIRO Enviro2002, Melbourne 8 April 2002.

[46] Watson FGR (1999) Large scale, long term, physically based modelling of the effects of land cover change. PhD dissertation. Department of Civil and Environmental Engineering, University of Melbourne, Victoria, Australia

[47] WRSCMA (2002) Strategy directions report: stage 2 in developing a water resources strategy for the greater Melbourne area. Water resource strategy committee for the Melbourne area. 52

[48] Read Sturgess Associates,. RG Mein and Associates, consultants in hydrology and water supply management resource and Environmental Economics Group, LaTrobe University, Arthur Webb and Associates, forestry consultants, (1992). *Evaluation of the economic values of wood and water for the Thomson catchment.*

[49] ABARE 2005 Australian Forest and Wood Products Statistic Australian Bureau of Agricultural and Resource Economics Canberra

[50] See Parliament of the Commonwealth of Australia, House of Representatives Standing Committee on Environment and Heritage (2000). *Co-ordinating Catchment Management: Report of the Inquiry into Catchment Management,* December.

[51] DNRE Land and Water Management in See Parliament of the Commonwealth of Australia, House of Representatives Standing Committee on Environment and Heritage (2000). *Co-ordinating Catchment Management: Report of the Inquiry into Catchment Management,* December.

[52] http://www.dpc.vic.gov.au/CA256D800027B102/Lookup/IPC-B-Water/$file/WATER.pdf

[53] Vertessy R, Watson F, O'Sullivan S, Davis S, Campbell R, Benyon R, Haydon S (1998) Predicting water yield from mountain ash forest catchments. Cooperative research centre for catchment hydrology. Industry report 98/4

[54] Sinclair Knight Merz (2000) Otway Forest Hydrology Project - Impact of logging practices on water yield and quality in the Otway forests. A report for the Department of Natural Resources and Environment.

[55] Watson F, Vertessy R, McMahon T, Rhodes B and Watson I (1999) The hydrologic impacts of forestry on the Maroondah catchments. Cooperative research centre for catchment hydrology. Report 99/1

[56] NRE (2002, 2000, 1999) Wood Utilisation Plans. Victoria.

[57] VicRFASC (1998) Comprehensive Regional Assessment North East Victoria. Commonwealth and Victorian Regional Forest Agreement Steering Committee, Canberra.

[58] Lane an Mackey (2001) Streamflow response of mixed species eucalypt forest to patch cutting and thinning treatments. Forest ecology and management 143: 131-142

[59] O'Shaughnessy PJ & Jayasuriya MDA (1991) Water supply catchment hydrology research – status report 1991. Melbourne Water

[60] O'Shaughnessy P, Fletcher T, Bren L (1995) A report on the effects of forest harvesting on water yield and quality in the Lerderderg catchment. Forest service technical report 95-1. Department of Sustainability and Environment.

[61] Doeg TJ and Koehn JD (1990) *A review of Australian studies on the effects of forestry practices on aquatic values.* Victorian Department of Conservation and Environment. SSP Technical Report No. 5.

[62] Lawrence R (1990) The interaction between the environment, land use and hydrology of the Bogong High Plains area from 1850 to 1985. PhD. Thesis, GeoFigurey Department, University of Melbourne. NRE (2000) A study of the Old- growth forest of Gippsland. Forest Services technical reports 00-2 page 35.

[63] Wilby, R.L. & Gell, P.A. (1994). *The impact of forest harvesting on water yield: modelling hydrological changes detected by pollen analysis*. Hydrological Sciences – Journal 39.5 Oct 1994 pp 471 –485).

[64] http://www.dpc.vic.gv.au/CA256D800027B102/Lookup/IPC-B-Water/$file/WATER.pdf

[65] Hairsine P (1997) Controlling sediment and nutrient movement within catchments. Cooperative research centre for catchment hydrology. Industry report 97/9

[66] Hairsine P (1997) Controlling sediment and nutrient movement within catchments. Cooperative reseach centre for catchment hydrology. Industry report 97/9

[67] Department of Natural Resources and Environment (1996), *Code of Forest Practices for Timber Production – Revision No.2*

[68] Doeg TJ and Koehn JD (1990) *A review of Australian studies on the effects of forestry practices on aquatic values.* Victorian Department of Conservation and Environment. SSP Technical Report No. 5.

[69] Grayson, R.B.; Haydon, S.R.; Jayasuriya, M.D.A.; Finlayson, B.L. (1993). *Water quality in mountain ash forests - separating the impacts of roads from those of logging operations*. Journal of Hydrology 150: 459-48

[70] Croke J, Wallbrink P, Fogarty P, Hairsine P, Mockler S, McCormack B, Brophy J (1999) Managing sediment sources and movement in forests: The forest industry and water quality. Cooperative Research Centre for Catchment Hydrology. Industry Report 99/11

[71] Dean C, Roxburgh S, Mackay B (2003), 'Growth Modelling of *Eucalyptus regnans* for Carbon Accounting at the Landscape Scale', in 'Modelling Forest Systems', eds Amaro, Reed D, Soares P (CAB International)

[72] Pregitzer, K and E. Euskirchen, 2004, Carbon cycling and storage in world forests: biome patterns related to forest age, Global Change Biology 10, 1–26,