ESTIMATED EFFECTS OF POTENTIAL FORESTRY OPERATIONS ON WATER QUANTITY, KOONYA DISTRICT

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APPROACH

Effects of forestry activities on water yield have been measured in many countries, but the studies most relevant to the Koonya district are those conducted in the *Eucalyptus regnans* forests of the Melbourne Water/ CRC for Catchment Hydrology experimental catchments of the Central Highlands of Victoria and summarised by Vertessy (1999) and Vertessy et al. (2001). These catchments have been producing results since the 1960s and a large amount of information has been gathered on treatment effects, plant physiology and water behaviour in soils and vegetation. As a result there has been a progression from collecting measurements to process modelling. In theory the modelling approach will allow the effect of forestry activities to be predicted at any site, provided key information such as rainfall, temperature, humidity, leaf area index, soil depth and stand age is known. In practice this information is seldom available, even for experimental catchments. The information available for the Koonya uplands falls short of that required for inputting into a process model, and suitable models for small catchments are not available but are still being developed (R. Vertesssy, personal communication). The approach taken in this brief review has therefore been to extrapolate from the Victorian studies, making use of those studies which most closely match the Koonya situation.

WATER YIELD IN MANAGED FORESTS

The general trend of water yield after forest harvest or after fires is shown by the Kuczera curve (Figure 1) which has been much quoted in the literature and shows that annual streamflows after harvest and regeneration of *E. regnans* forest reach approximately half their original values about 25–30 years after harvest (Figure 1), and then recover.

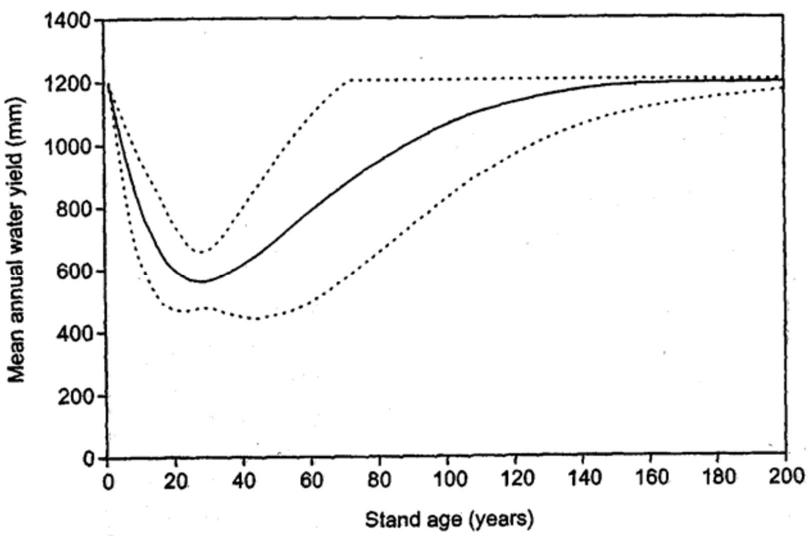

Figure 1. The generalised Kuczera curve for water yield of *Eucalyptus regnans* stands following fires in old-growth forest in Victoria. After Vertessy et al. (2001, figure 2).

It is important to note the limitations of the Kuczera curve: (1) it is an average curve, based on information from a variety of catchments with differing geology, soils, stand age, understorey vegetation and streamflows; (2) as an average, it represents catchments with a mean annual rainfall of about 1800 mm, which is considerably higher than in most commercial forestry areas in eastern Tasmania; (3) it does not show the increase in water yield that occurs after harvest in small catchments; (4) the starting point and end point for the Kuczera curve is old growth (200 year old) forest.

The Koonya uplands have a mean annual rainfall of 1000–1100 mm (Brown 1997) and a cover of ‘wet’[1] *Eucalyptus obliqua*-*E. regnans*-*E. globulus* forest and small areas of ‘dry’ *E. obliqua*-*E. globulus* forest at <250 m altitude and *E. delegatensis* forest at highest altitudes. Of the catchments studied in the Victorian highlands, the Picaninny catchment (Vertessy et al. 2001, fig. 3) has a mean annual rainfall (1200 mm) most resembling the rainfall of the Koonya uplands and is therefore the most relevant research catchment for predicting effects of forest harvest on water yields on the Koonya uplands. The Picaninny catchment had a cover of old-growth *E. regnans* and was 78% clearfelled in 1972. It should be noted that the soils of the deeply weathered granites of the Victorian Highlands probably hold more plant-available water than the soils derived from dolerite on the Koonya uplands, and that evaporation and evapotranspiration losses are likely to be higher in the Picaninny catchment. The effect of the deeper soils in Victoria may be to delay the effects on streamflow of vegetation changes at the soil surface.

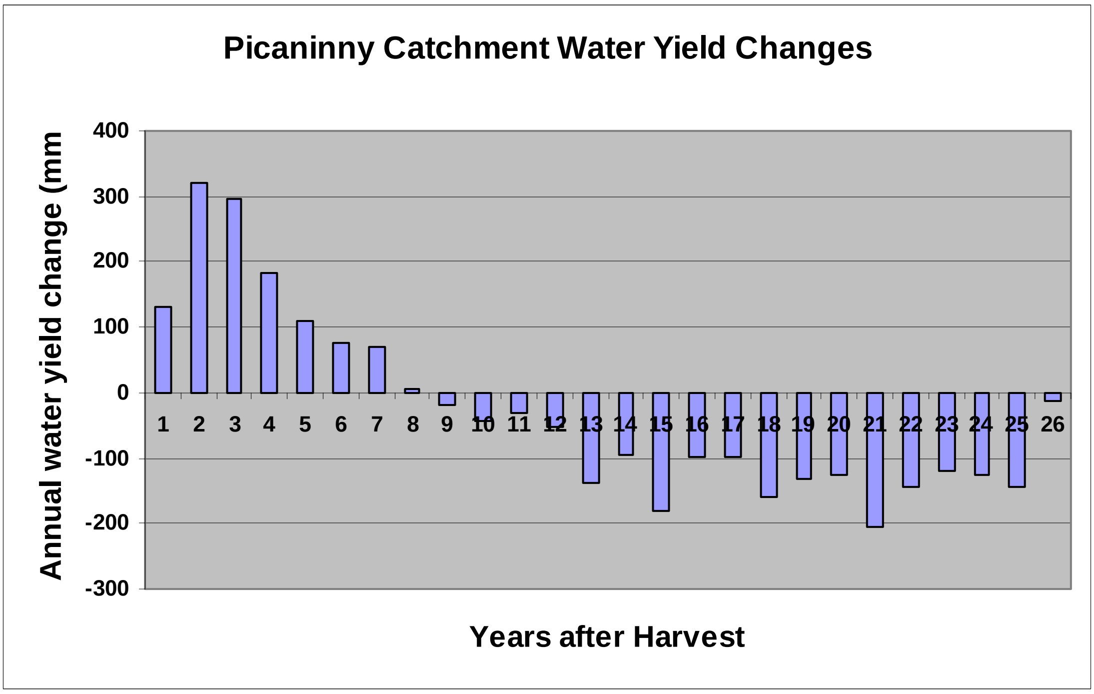

Figure 2. Mean annual water yield changes after 78% clearfelling, Picaninny catchment, Central highlands, Victoria, 1969–1998, based on analysis reported in Watson et al. (1999) and illustrated in Vertessy et al. (2001, fig 3).

The annual streamflow changes for the Picaninny catchment are shown in Figure 2. After 78% old-growth forest harvest in 1972, streamflow increased to a maximum in the second year after harvest, decreased to close to its original flow in year 8, and decreased further to a smoothed (average) minimum of 132.5 mm less than its original flow in years 18–25 after harvest.

METHODS FOR APPLICATION OF VICTORIAN STUDIES TO KOONYA

When applying the Picaninny results to the Koonya uplands the size and nature of the Koonya uplands catchment and its forest is an important factor to consider. The geological

[1] The terms ‘wet’ and ‘dry’ forest refer to sclerophyll forest types with dense broadleaved understorey and more open understorey with heathy shrubs respectively. The terms ‘wet’ and ‘dry’ forest are entrenched in the literature and are therefore used in preference to the more scientific terms such as ‘forest with dense broadleaved understorey’ or ‘forest with open heathy understorey’.

investigations by Forsyth (2003) and various observations from small catchments in dolerite elsewhere (e.g. McIntosh, unpublished reports) indicate that the surface topography in dolerite terrain may not determine catchment boundaries for streams.

Two models can be considered for infiltration and drainage for the Koonya uplands. The first model assumes that deep infiltration occurs into a large fractured-rock subsurface aquifer that underlies most of the dolerite mapped on the Koonya uplands and, in layman's terms, is 'leaky' in all directions including to the west (for example, to the Koonya B spring). The second model assumes that the Koonya B spring has a catchment slightly larger than expected from surface topography and that it collects water from east of the topographic divide, via deep fractures in the dolerite. These two models are considered in turn.

For each of the models below the Picaninny data has been used. The irregularities in yield in the Picaninny catchment, resulting from variable annual rainfall, have been retained, as they produce a more realistic and variable yield pattern. All data is presented on an annual basis. Other assumptions are given under the headings below.

MODEL 1

This model assumes that underlying the Koonya uplands is a large subsurface fractured-rock aquifer with a base that is inclined at a low angle towards the east. Most subsurface flow is assumed to be in an easterly direction (as is borne out by the size of the streams draining into the headwaters of Newmans Creek and Kennedys Creek), but there is also significant flow to the north and to the west. Such flow to the north and west may occur along faulted fractures or along the dolerite–sedimentary rock contact (Forsyth 2003). While all parts of the conjectural aquifer are likely to be connected, it is assumed that flow from one part of the aquifer to another is restricted, i.e. it takes time for effects in one part of the aquifer to be transmitted to other parts, and for hydrostatic equilibrium to be established.

Although there is no direct evidence for a subsurface aquifer, the fact that the Koonya B spring did not dry up in the 2002–2003 summer, despite this summer being the driest on record, indicates that the Koonya B 'catchment' is likely to be larger than 50 ha, or has a deep 'slow release' source, as on the Tasman Peninsula most streams in catchments of 50 ha or less (Class 4 streams in Forest Practices Code (Forest Practices Board 2000) terminology) dried out in this dry season.

The area of the postulated subsurface aquifer is difficult to estimate but could be about 2.5 km^2. Although it is assumed that the total subsurface aquifer is connected, effects on springs and streams will depend in part on the location of any surface effects. For example, increased infiltration over the crest of the postulated subsurface aquifer (Forsyth 2003, figure 12) would be more likely to have an effect on spring water quantity at Koonya B than increased infiltration over the far east of the subsurface aquifer.

Streamflow as a proportion of rainfall

Under 870 mm annual rainfall in New South Wales evapotranspiration, soil evaporation and rainfall interception accounted for 600 mm of rainfall, and streamflow (from deep infiltration) accounted for 269 mm of rainfall, or 31% of the input (Vertessy 1999, table 6). Under a 60 year old *E. regnans* stand under 1800 mm rainfall streamflow accounted for about 33% of inputs (Vertessy et al. 2001, figure 7). It appears reasonable to assume, therefore, that on the Koonya uplands about one third of the rainfall (about 350 mm) will infiltrate deep into the soil and eventually appear as streamflow.

Assumptions for calculations

The Koonya forests are the result of regeneration following fires in 1937 and 1945. The forests are therefore about 60 years old and have passed their age of maximum water usage – water yield is now increasing slowly. The Picaninny catchment data, when smoothed and adjusted for

100% clearfell, indicates that water yield was lowest (–186 mm) in years 18–25 after harvest. The Kuczera curve indicates that by year 60 the water yield decline will be about two thirds of this minimum value (i.e. about –124 mm). It follows that infiltration (and eventual streamflow) under the *present* forest cover is about 124 mm less than it would be under old-growth forest. Therefore the effect of harvest or burning of the present forest cover will be an increased streamflow of about 124 mm *over and above* the first-year yield predicted using the Picaninny model. No adjustment needs to be made for older forests harvested in the future, since the reduced gain from harvesting forest with lower evapotranspiration than the present 60-year old forest will be balanced by the greater infiltration of these forests. Other assumptions made are that the 2.5 km^2 area with the subsurface aquifer will be harvested in five 50 ha coupes, with a harvest interval of 5 years between coupes. In addition it is assumed that, as in the Picaninny catchment, only 78% of each coupe is harvested, the balance being retained as streamside reserves, wildlife habitat clumps etc. The unharvested forest, which will cover about 22% of the 2.5 km^2 area after harvest is completed, will gradually yield more water as it ages.

The above assumptions and others are summarised below:

- The Koonya forest is 60 years old.
- The Koonya forest has passed its period of maximum water utilisation and evapotranspiration and interception losses in the present forest are about two thirds of those of the smoothed maximum losses (at about age 18-25).
- The information for the Picaninny catchment is the best match for what is likely to occur on the Koonya uplands after harvest.
- In the future water yield ‘losses’ will follow those predicted by the shape of Kuczera curve and gradually approach nil (relative to old growth forest) by the time the forest is about 200 years old.
- On the Koonya uplands the area of soils in dolerite than can reasonably be assumed to have a subsurface aquifer has an area of 2.5 km^2.
- This area will support 5 coupes of 50 ha each. About 78% of each coupe will be harvested by clearfell operations.
- The Picaninny catchment probably has slightly higher rainfall than the Koonya uplands; no attempt has been made to adjust the Picaninny data for rainfall as: (1) the rainfall on the Koonya uplands is not accurately known; (2) the effect of higher rainfall may be compensated to some extent by the likely lower evapotranspiration on the Koonya uplands.
- The Picaninny data has not been smoothed, as it is assumed that the annual variation displayed (relative to the control catchment) is typical of that to be expected in a small catchment.

Results

Using the above assumptions, the average predicted water yield[2] (increase and decrease) over the 2.5 km^2 area resulting from coupe harvest at 5-year intervals has been calculated and plotted (Figure 3), relative to present-day yield. For comparison predicted yields resulting from a wildfire with total forest cover destroyed are also given, as are yields under a no-harvest scenario. Figure 3 shows that as the coupes are harvested there will be five peaks in water yield. The maximum yield increase over the 2.5 km^2 area will be 128 mm and the average increase over years 1–29 will be 79 mm or 23% more than the estimated water yield at present. For years 30–45 average water yield will be 2.5% lower than at present, as the young stands take up and intercept the maximum amount of water. From year 46 onwards yield will steadily increase and in years 46–60 it will be slightly higher than at present. In practice yields from year 30

[2] This term as used in this discussion paper refers to deep infiltration that will eventually appear as streamflow. References to streams include springs.

onwards are likely to be indistinguishable from present-day flows, because of natural flow variation.

There are two reasons why no significant yield decline is predicted: (1) the yield decline from harvesting young forest is less than the decline from harvesting old-growth forest; (2) significant unharvested forest will remain within the 2.5 km^2 area throughout the harvest schedule, so that 22% of the forest remains unharvested after year 20, and this forest will transpire less water than the present-day (2003) forest.

As expected, the wildfire scenario gives a more drastic increase in yield immediately after the fire, and then a quicker and more severe decline and recovery. The 525 mm maximum increase in yield is the sum of the maximum increase of yield for the Picaninny catchment (adjusted for 100% clearance) plus the difference between old growth yield and estimated 60-year old forest yield for the Picaninny catchment. By year 60 the yield of water returns to about the same value as at present, because the present forest is about 60 years old.

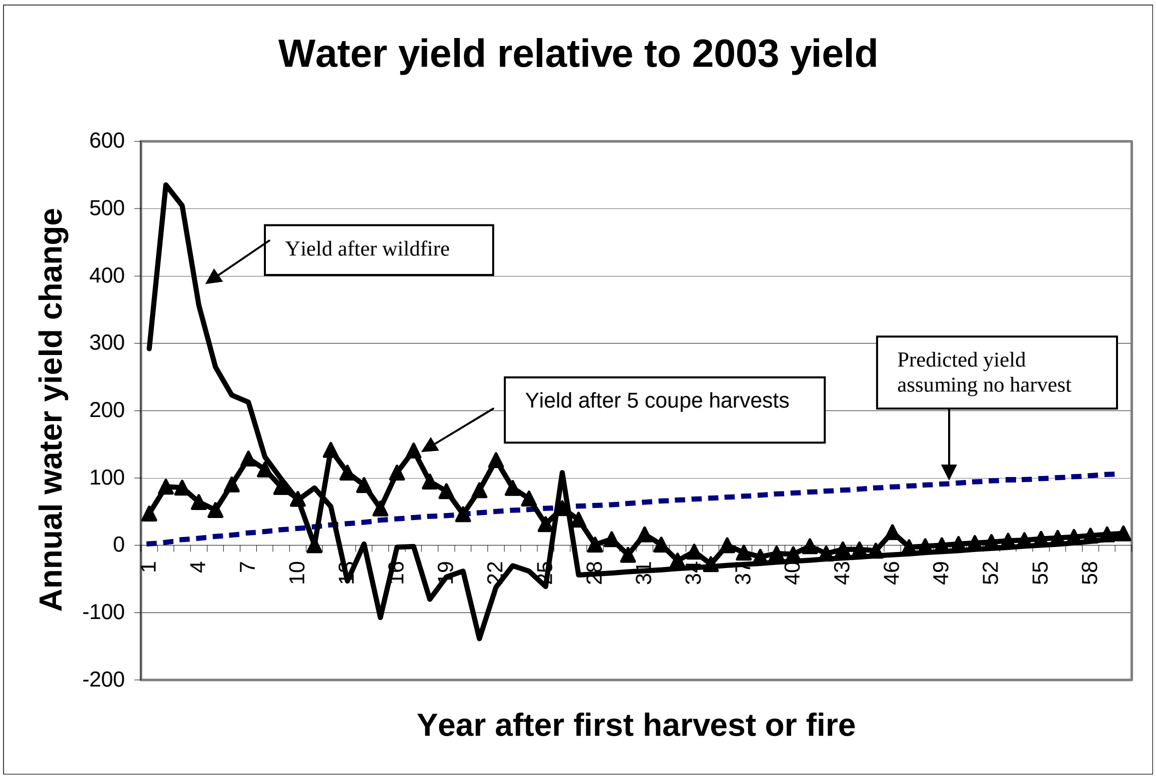

Figure 3. Predicted water yield after five coupe harvests, relative to water yield in 2003.

Conclusions

The predicted effect of harvest on water yields relative to those at present (2003) is for yields to increase by an average of 23% for years 1–29 after harvest and then to fall to levels approximately equal to those at present for the next 40 years. I conclude that forest harvest is unlikely to have a deleterious effect on water quantity.

MODEL 2

Catchment size

Model 2 assumes that the Koonya B spring is fed from a catchment that extends in a 90° arc upslope to about 200 m beyond the Mt Koonya-Kingston's Pinnacle Divide (Figure 4). As height above sea level increases southwards, common sense suggests that the catchment should have a greater area to the south than the north, and this has been assumed. The angular boundaries of the catchment are unlikely to occur in practice but have been retained to facilitate area calculations – defining catchment boundaries in dolerite hill country is difficult, and 'rounded-off' boundaries would not necessarily be more accurate. The total catchment in Model 2 has an area of 58.5 ha. This is over the catchment limit for Class 4 streams in the Forest Practices Code (Forest Practices Board 2000). It is unlikely that the catchment is larger than that shown as qualitative assessment of the Koonya B stream suggests it has the characteristics of a Class 4 stream as defined in the Forest Practices Code (Forest Practices Board 2000), not a Class 3 stream[3].

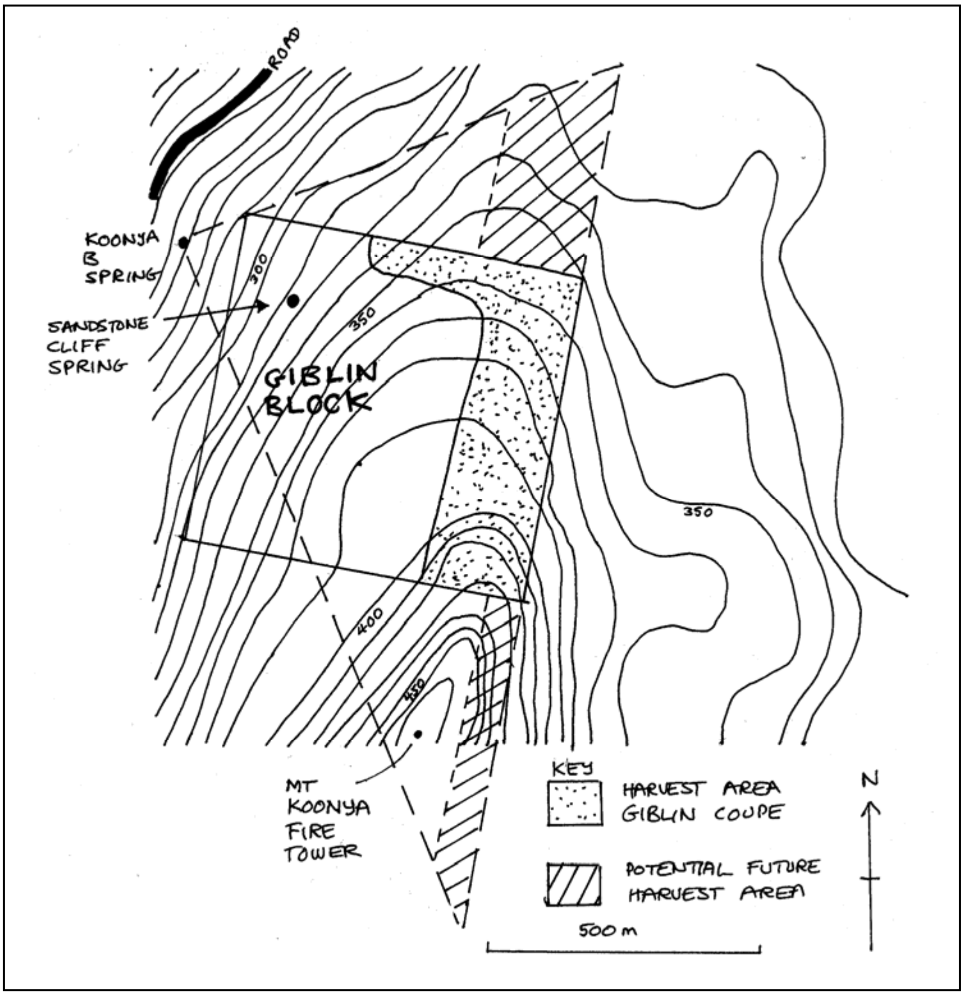

Figure 4. Sketch map of possible catchment boundaries and harvest areas in the Koonya B catchment, assuming model 2 applies. The indicated catchment boundaries are diagrammatic.

Assumptions

The previously harvested area of the Giblin coupe (harvested April 1998) has an area of 13 ha (22.2% of the catchment) and areas east of the divide and within the estimated Koonya B catchment that may be harvested by Forestry Tasmania in the future (Figure 4) have an area of 14.5 ha (25% of the catchment). It is assumed that forest cover in the vicinity of the crest around the Mt Koonya fire tower will not be harvested. For the sake of the simple calculations made in the following modelling exercise, it is assumed that the mean rainfall is the same (1050 mm) over all the catchment, that at the time of harvest in the Giblin coupe the forest was 60

3 Class 4 streams have a maximum catchment size of 50 ha; Class 3 streams have a catchment size of 50–100 ha.

years old[4], and that the Picaninny water yield model applies. It is also assumed that, as for Model 1, deep infiltration eventually appearing as streamflow is one third of the mean annual rainfall, i.e. 350 mm.

It must be emphasised that errors are likely to be larger for models of small catchments than for models of large catchments. There is a catchment definition problem as discussed above; in addition patchy vegetation, insect damage, windthrow, variable soils and unforeseen water flow pathways may affect a greater proportion of small catchments than large catchments, and therefore have a larger proportional influence on results.

Results
Model 2 predicts that the effect of harvest on the Giblin coupe alone has caused a peak increase in yield of 122 mm, and an average increase in yield of 92 mm, over the first five years after harvest (Figure 5, square symbols). The model predicts that there will be no decline below the 1998 baseline yield as there is a gradual increase in yield under the maturing 60-year old forest. This maturing forest covers most of the catchment and therefore has a dominant effect on water yields.

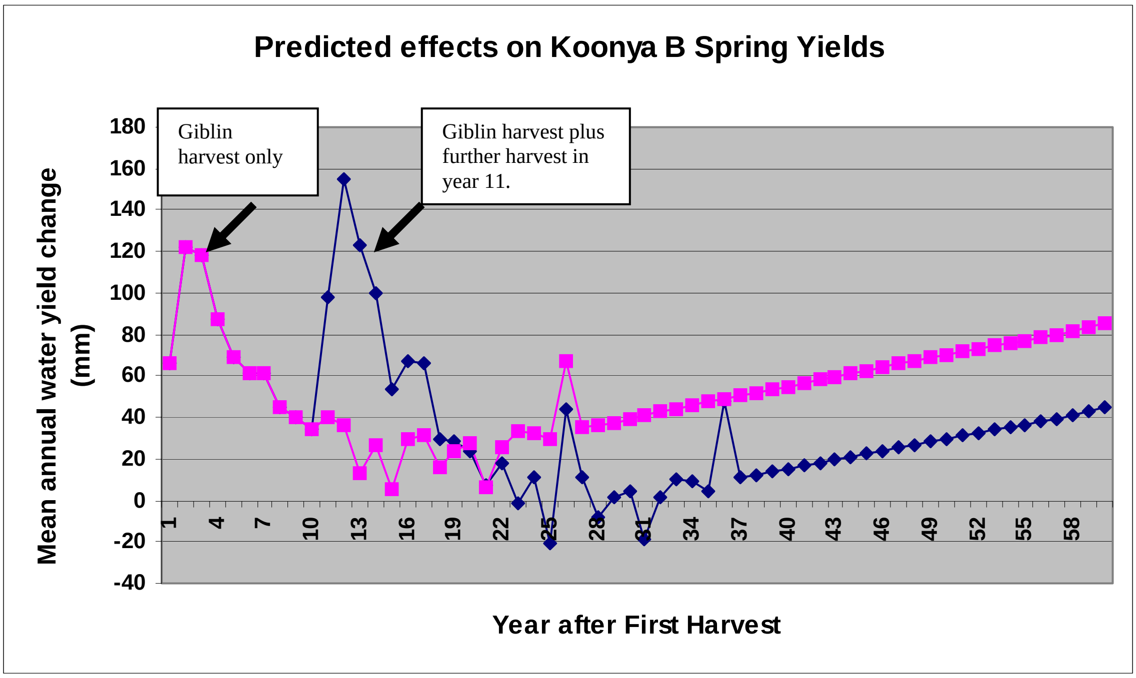

Figure 5. Predicted water yields relative to 1998 yield as a result of harvest on the Giblin coupe (square symbols) and as a result of harvest on the Giblin coupe plus projected adjacent Forestry Tasmania harvest in 2008 (diamond symbols).

A further harvest of 25% of the catchment area in year 11 causes another yield peak followed by a decline (Figure 5, diamond symbols). There will be a period in which the decline is to levels similar to 1998 flows (the 10-year mean is within 1% of 1998 flows) and then the yield will increase slowly following the predictions of the Kuczera curve.

If the further harvest occurs before 2008 (not illustrated), the yield increase and subsequent yield decrease will tend to be partly superimposed on the respective yield increase and decrease from the Giblin harvest, and the overall increase and decrease will be exaggerated. To avoid

[4] Note that in Model 1, with first harvest occurring in 2003, the forest was also assumed to be 60 years old, which introduces a small yield error. The same age has been assumed so that graphs can be readily compared.

possible yield decreases below 1998 levels, it is recommended that harvest adjacent to the Giblin harvest area should not occur until 2008 or later.

Conclusion

The negative effect of the Giblin harvest on Koonya B water quantity will be cancelled by the increased yield resulting from the maturing forest in the remainder of the Koonya B catchment. The predicted net effect on Koonya B water quantity is for yields to remain at or above 1998 levels. Provided further harvest adjacent to the Giblin block occurs in 2008 or later, average yields should not decrease below 1998 levels at any time. Natural variation of yields will continue to occur as a result of seasonal and annual rainfall variation.

GENERAL CONCLUSIONS

If the doleritic Koonya uplands are assumed to be supplied from a large interconnected subsurface aquifer, the predicted effect of harvest on water yields relative to those at present (2003) is for yields to increase by an average of 23% for years 1–29 after harvest and then to fall to levels approximately equal to those at present for the next 40 years. It can be assumed that if the Koonya B spring is supplied by discharge to the west from this subsurface aquifer, that it will maintain average flows at levels equal to or above present levels. Flows may also be affected by natural seasonal and annual variation.

If the Koonya B spring is assumed to be supplied from a more local 60 ha catchment that extends about 200 m east of the topographic divide, modelling shows that the negative effect of the Giblin harvest on Koonya B water quantity will be partly cancelled by the increased yield resulting from the maturing forest in the remainder of the Koonya B catchment. The predicted *net* effect on Koonya B is for yields to remain at or above 1998 levels. Provided further harvest adjacent to the Giblin coupe occurs in 2008 or later, average yields should not decrease below 1998 levels. As pointed out above, flows may also be affected by natural seasonal and annual variation.

Therefore, if the above precautionary measure (i.e. no harvest adjacent to the Giblin block before 2008) is taken into account during planning, it appears unlikely that clearfell and regeneration forestry operations on the Koonya uplands will have a negative effect on water quantity in streams, and on Koonya B spring yields in particular.

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