The Effects of Thinning on Groundwater Levels in the Jarrah Forest and the Implications For Management of Salt Sensitive Areas

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Summary

This paper reviews the effects of reductions in density of jarrah forest on groundwater levels. Clearing for agriculture, heavy logging and regeneration, and thinning all lead to rising groundwater levels. In treatments where there is regeneration of forest the groundwater level only rises for three or four years and then begins to fall. However, following thinning, groundwater level has been observed to rise steadily for the five years since the thinning. The patterns in groundwater level following treatment match the patterns in recovery of vegetation cover. Therefore, we can infer that groundwater levels in thinned areas will continue to rise for many years. In salt sensitive areas the rises in groundwater

level following thinning could lead to unacceptabe increases in stream salinity. Extensive thinning of these areas is not recommended. However, thinning of limited portions of catchments in salt sensitive areas may be acceptable if groundwater levels in the valley are well below the ground surface.

Introduction

1. Review of the Effects of Forest Density Reductions on Groundwater Levels in the Jarrah Forest.

1.1. Clearing for agriculture.

Five small forested catchments in the Collie Basin were instrumented in 1974 to quantify the effects of agricultural clearing on hydrology. Two adjacent catchments, Salmon and Wights (~ 1200 mm yr^{-1} average rainfall), were selected in the high rainfall zone. Three catchments, Lemon, Dons and Earnies (~ 800 mm yr^{-1} average rainfall) were selected in the low rainfall zone (see figure 1 for locations). Forest clearing treatments were carried out in 1976 on Wights catchment (totally cleared), Lemon catchment (54 per cent cleared) and Dons catchment (38 per cent cleared in a mixture of

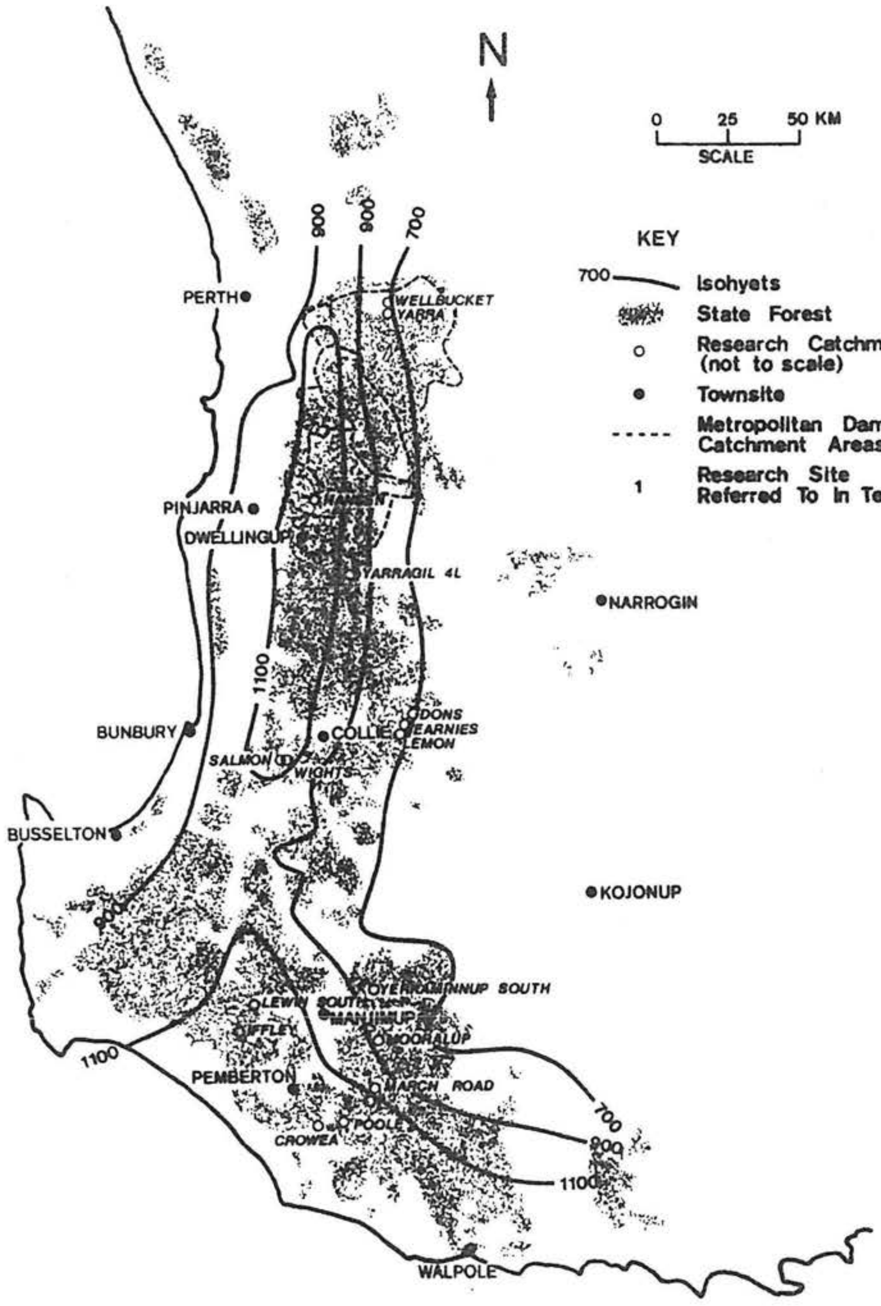


Figure 1: Research catchments in the jarrah forest.

parkland clearing, strip clearing and selected soil unit clearing in different parts of the catchment). This was followed by establishment of annual agricultural plant species. Experimental details and data analyses to 1983 are described by Williamson *et al.* (1987). Peck and Williamson (1987) found that groundwater piezometric levels on Wights catchment rose at the rate of 2.6 m yr^{-1} in the seven years following clearing in comparison to Salmon catchment which was the control. Groundwater recharge increased by half as much in Lemon catchment as in Wights, and one sixth as much in Dons catchment as in Wights.

1.2. Selective logging.

In 1974 a paired-catchment study was established in the east of the Helena catchment to investigate the effect of selective logging on catchment hydrology. Of the two catchments, Wellbucket was logged in 1977 and Yarra was retained as a control (both ~700 mm yr^{-1} average rainfall). The logging reduced canopy density from 38 per cent to 20 per cent and basal area from 16 m^2 ha^{-1} to 11 m^2 ha^{-1} (Stokes and Batini 1985) (see figure 1 for location). The logging had no effect on groundwater level.

1.3. Heavy logging and regeneration.

Seven small forest catchments in the southern jarrah forest were instrumented in 1976. The aim was to determine the impact of clearfelling or heavy selective logging, followed by regeneration, on water resources in the southern forest of Western Australia. Of the seven catchments, four were treated over the period from early 1982 to early 1983 and three remained untreated as controls. March Road catchment (~1070 mm yr^{-1} average rainfall) was clearfelled and regenerated, reducing crown cover from 65 per cent to 0 per cent. April Road North catchment (~1070 mm yr^{-1} average rainfall) was clearfelled and regenerated, except for a 100 m wide stream buffer. Crown cover was reduced from 65 per cent to 0 per cent over the 90 per cent of the catchment that was treated. Lewin South catchment (~1220 mm yr^{-1} average rainfall) was heavily logged and regenerated, reducing crown cover from 70 per cent to 11 per cent and basal area from 44 m^2 ha^{-1} to 7 m^2. Yerraminnup South catchment (~850 mm yr^{-1} average rainfall) was heavily logged and regenerated except for a 50 m wide stream buffer. Crown cover reduced from 70 per cent to 10 per cent and basal areas reduced from 44 m^2 ha^{-1} to 5 m^2 ha^{-1} over the 88 per cent of the catchment that was treated. Experimental details and results to 1985 are described by Borg *et al.* (1987a) (see figure 1 for locations). Borewater levels rose by between 0.5 m and three m in four years following heavy cutting and regeneration. The greatest increase was in the first two years before the regeneration was well established. Taking the values for this two year period, borewater levels in Lewin South catchment rose by 1.4 m yr^{-1}, borewater levels in April Road North catchment rose by 0.7 m yr^{-1}, borewater levels in March Road catchment rose by 0.8 m yr^{-1} and borewater levels in Yerraminnup South catchment rose by 0.4 m yr^{-1}.

Another group of four small catchments in the southern forest were instrumented in 1976. All catchments were treated over the period from the end of 1976 to early 1978. There were no control catchments although there were control boreholes. The aim was to get an early indication of the effects of clearfelling or selective logging, followed by regeneration, on the water resources of the southern forest. Crowea catchment (~1380 mm yr^{-1} average raifall) was 83 per cent clearfelled and regenerated, 13 per cent selectively cut and four per cent not treated. Poole catchment (~1310 mm yr^{-1} average rainfall) was 74 per cent clearfelled and regenerated, 25 per cent selectively logged and regenerated and one per cent not treated. Iffley catchment (~1200 mm yr^{-1} average rainfall) was 83 per cent selectively cut and regenerated and 17 per cent not treated. Mooralup catchment (~880 mm yr^{-1} average rainfall) was 86 per cent selectively cut and regenerated and 14 per cent not treated (see figure 2.4 for locations). Experimental details and results are given by Borg *et al.* (1987b). Borewater levels rose by between one m and 5.5 m in the first four years following heavy cutting and regeneration, and then declined in the subsequent six years by between one m and three m. The greatest increase in borewater level was in the first two years before the regeneration was well established. Taking the values for this two year period, borewater levels in Crowea catchment rose by 1.8 m yr^{-1}, borewater levels in Poole catchment rose by 2.5 m yr^{-1}, borewater levels in Iffley catchment rose by 0.6 m yr^{-1} and borewater levels in Mooralup catchment rose by 0.3 m yr^{-1}.

1.4. Thinning.

Yarragil 4L catchment (1120 mm yr^{-1} average rainfall) was thinned in 1983 (Stoneman 1986) (see figure 1 for location). Canopy cover was reduced from 55 per cent to 22 per cent, baob from 35 m^2 ha^{-1} to 11 m^2 ha^{-1} and leaf area index from 1.9 to 0.6. Regeneration from ground and stump coppice was poisoned about one year after the thinning. The groundwater level in the midslope borehole in 4L dropped from a level of 18 m below the surface in 1976 to 23 m in 1983. The level then rose following thinning (figure 2). In the pretreatment period the control boreholes had similar depths to groundwater and showed similar patterns in level. The declining groundwater level is because of below average rainfall. The groundwater level in the midslope borehole in 4L showed a steady rise of one m yr^{-1} relative to control bores in the four years following the thinning (figure 2). After four years, groundwater level in this borehole had risen four metres in comparison to control boreholes.

The groundwater level in the valley borehole in 4L ranged seasonally between two m and seven m in the pretreatment period (figure 3). During this period the groundwater level in the control

large range intermediate

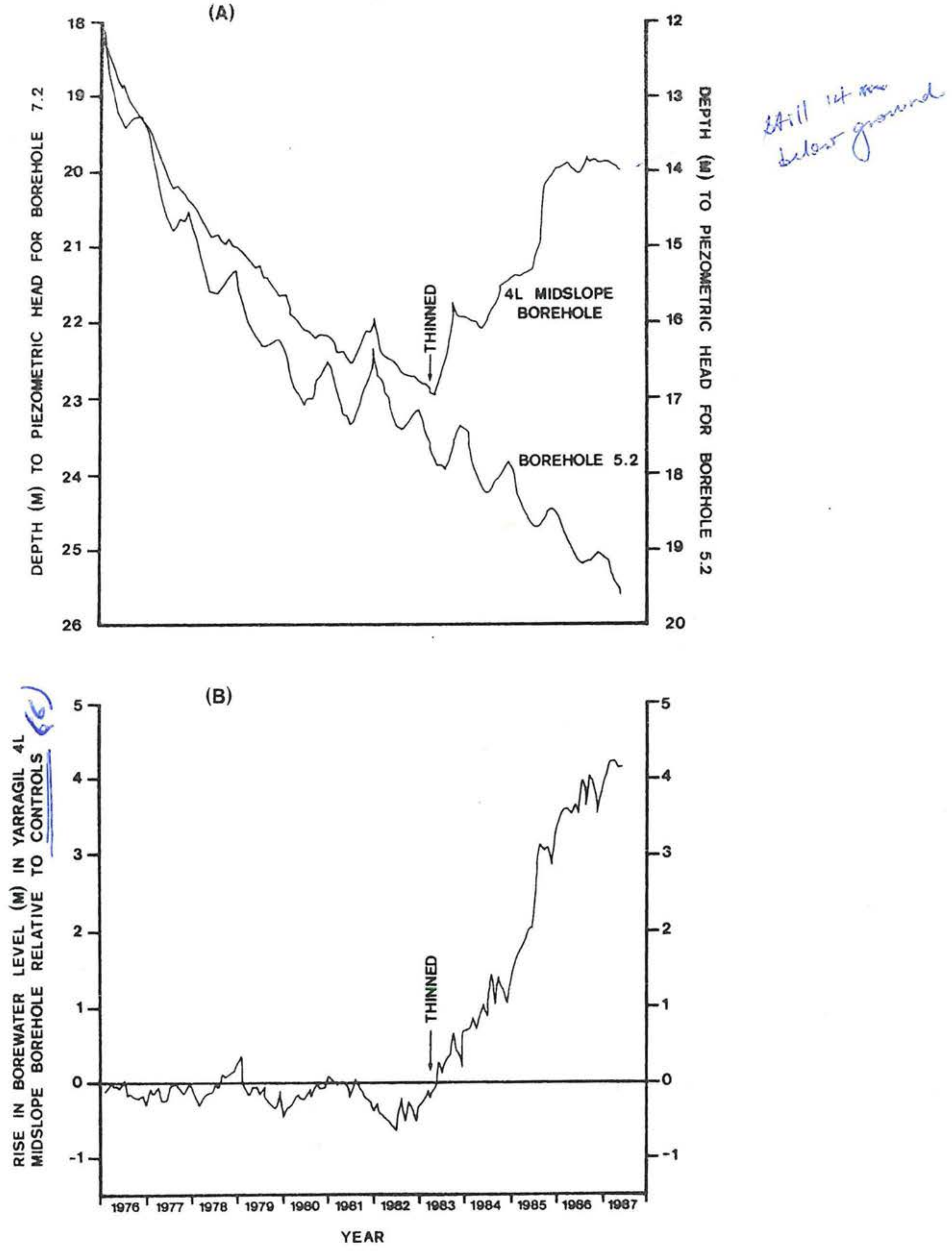


Figure 2: Increase in groundwater level in Yarragil 4L midslope borehole following thinning.

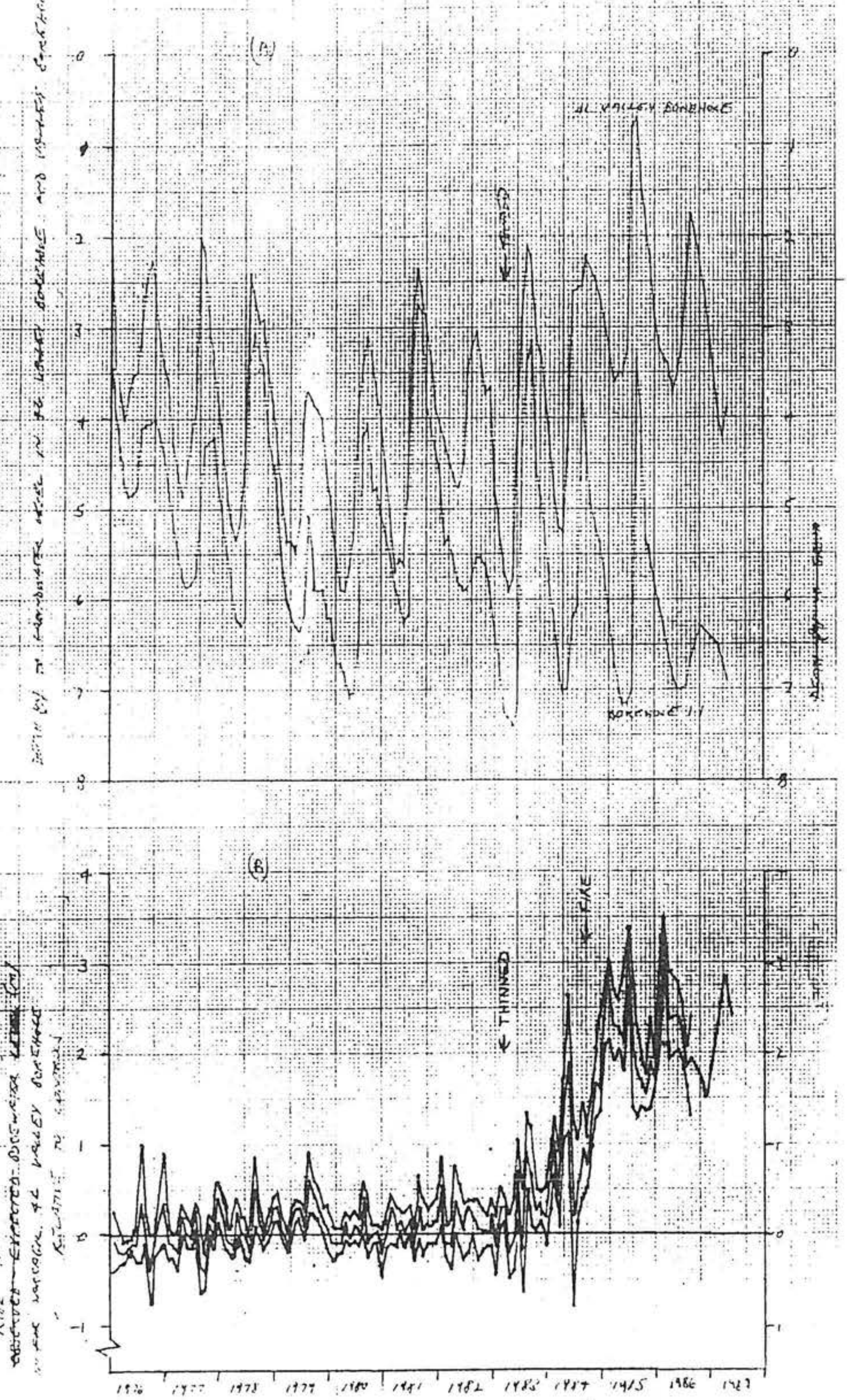


Figure 3: Increase in groundwater level in Yarragil 4L valley borehole following thinning.

boreholes showed similar depths to groundwater and similar seasonal fluctuations in level. The pattern of response of groundwater level in the valley borehole was different to that in the midslope borehole. There was little increase in level in the first year, but a large response in the second year after the thinning. Most of this response was following a spring fire in the catchment which burnt off most of the swamp vegetation in the valley. After two years, groundwater level in the valley borehole had risen more than two metres in comparison to control boreholes. In the third and fourth years after the thinning groundwater levels in the valley borehole did not rise significantly more.

Hansen catchment (1340 mm yr^{-1} average rainfall) was thinned from 35 m^2 ha^{-1} to 7 m^2 ha^{-1} in 1985 (see figure 1 for location). The groundwater table at a midslope location has shown a substantial rise in the short period since the thinning (figure 4).

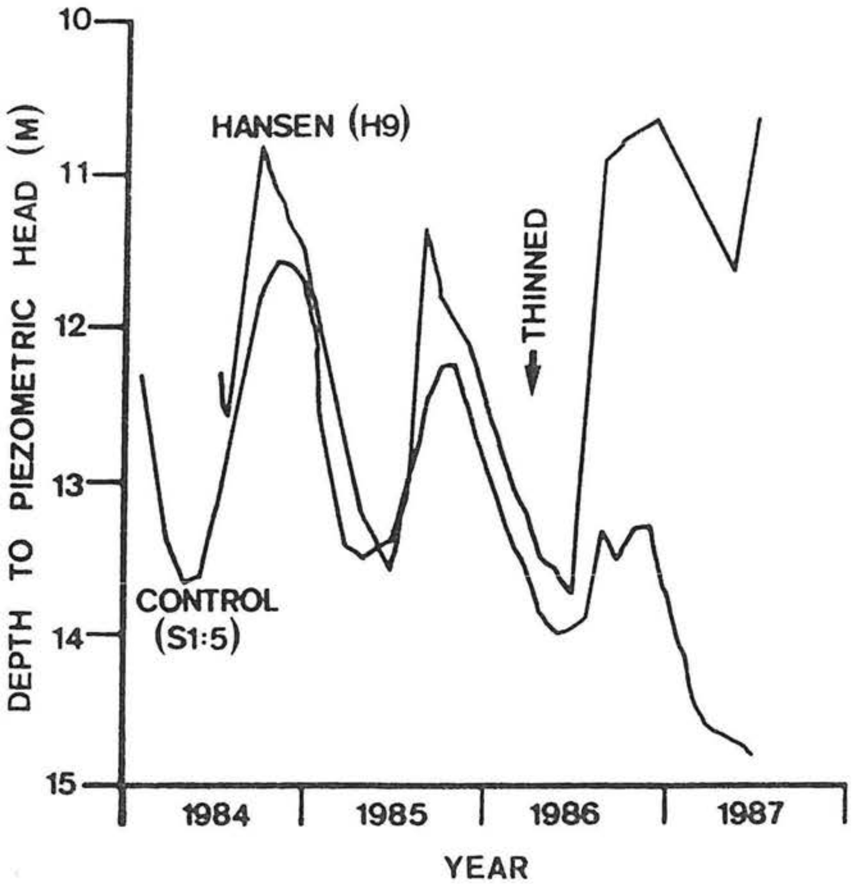


Figure 4: Increase in groundwater level in a midslope borehole in Hansens catchment following thinning.

1.5. Summary of groundwater response to forest density reduction.

Table 1 and figure 5 summarise the results from the literature dealing with increases in groundwater level following reductions in jarrah forest density. It is clear that reductions in forest density will lead to increases in groundwater recharge and rises in groundwater level. Other things being equal, the greater the reduction in forest density then the greater the increase in groundwater level. In the jarrah forest the other major factor influencing the increase in groundwater level is rainfall. Other things being equal, the greater the annual rainfall then the greater the increase in groundwater level.

1.6. Comparison of groundwater response to thinning with that to heavy logging and regeneration.

The temporal pattern of groundwater response following the 4L thinning is different to that observed following logging and regeneration in southern jarrah forest catchments. Borg *et al.* (1987a b) showed that groundwater levels increased rapidly for the first one to two years. Groundwater levels then increased more slowly for

Catchment	Average rainfall (mm y^{-1})	Treatment	Forest density reduction *	Post norm
...ights	1200	Agricultural ~~Cleared~~ development	PCF 100-0	1977
...mmon	800	"	PCF 100 - 46	1977
...s	800	" Strip & parkland clearing.	PCF 100 - 62	1977
...llbucket	700	~~Logged~~ Selection cut and regenerated	CD 38 - 20 BA 16 - 11	1977
...in South	1220	Selection cut and regenerated	CC 70 - 11 BA 44 - 7	1982 -
...l Road Nth	1070	Clearfelled except 100m stream buffer and regenerated	CC 65 - 0 over 90% of area	1982 -
...k Rd	1070	Clearfelled and regenerated	CC 65 - 0	1982 -
...mmup South	850	Selection cut except 50m stream buffer and regenerated	CC 70 - 10 BA 44 - 5 over 88% of area	1982 -
...ren	1380	3.5% not treated 33.3% clearfelled. 13.2% selectively cut. Regenerated.	BA 44 - 3	197
...oole	1310	0.8% not treated 74.4% clearfelled 24.8% selectively logged Regenerated	BA 44 - 3	19
...ffley	1200	16.6% not treated 83.4% selectively cut and regenerated.	BA 44 - 16	19
...oralup	880	14.3% not treated 85.7 selectively cut & regenerated.	BA 44 - 16	19
...l +		Thinned	BA 35 - 11	198

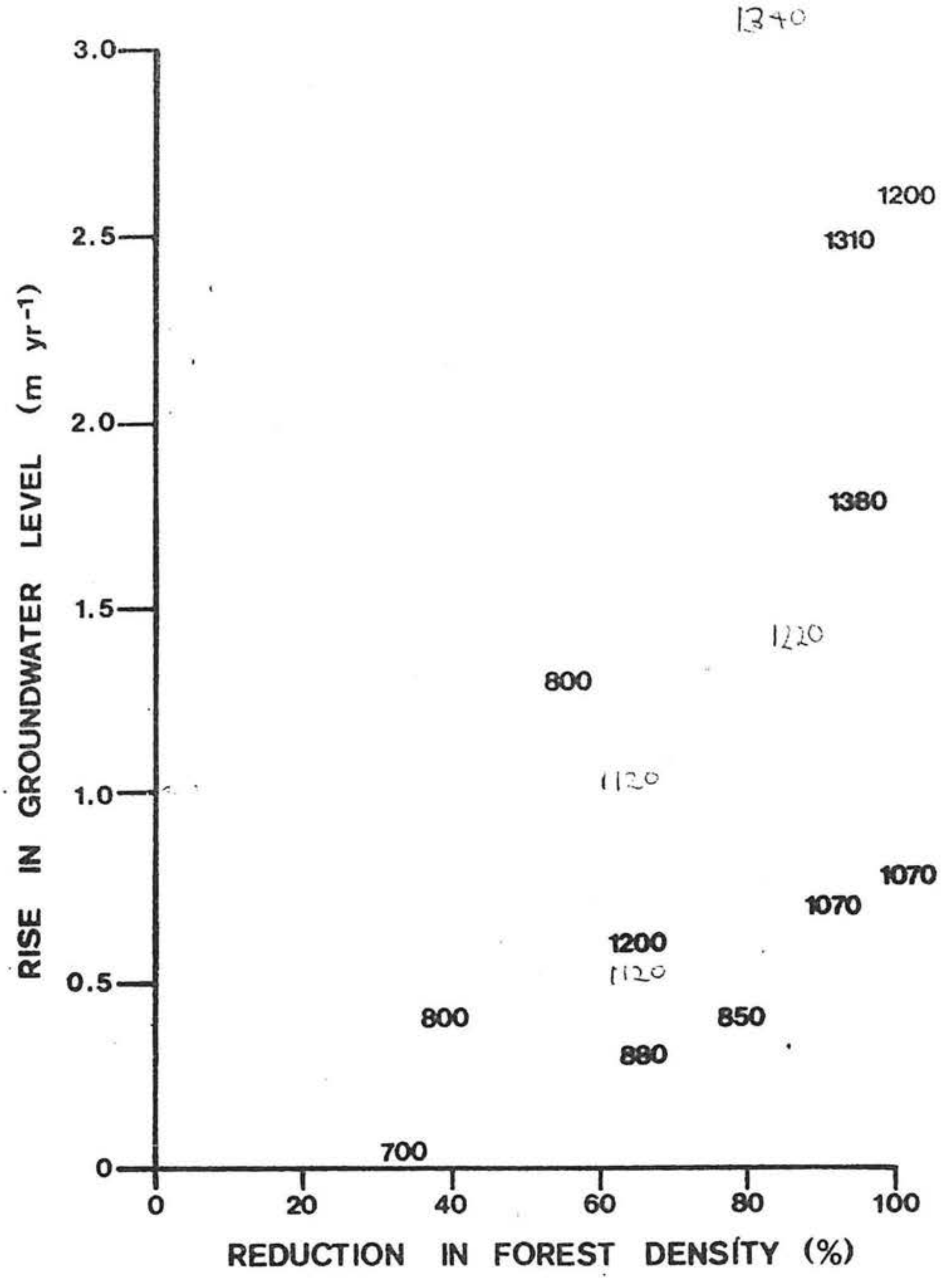


Figure 5: Relationship between rise in groundwater level and the reduction in jarrah forest density.
Numbers indicate mean annual rainfall of study area.

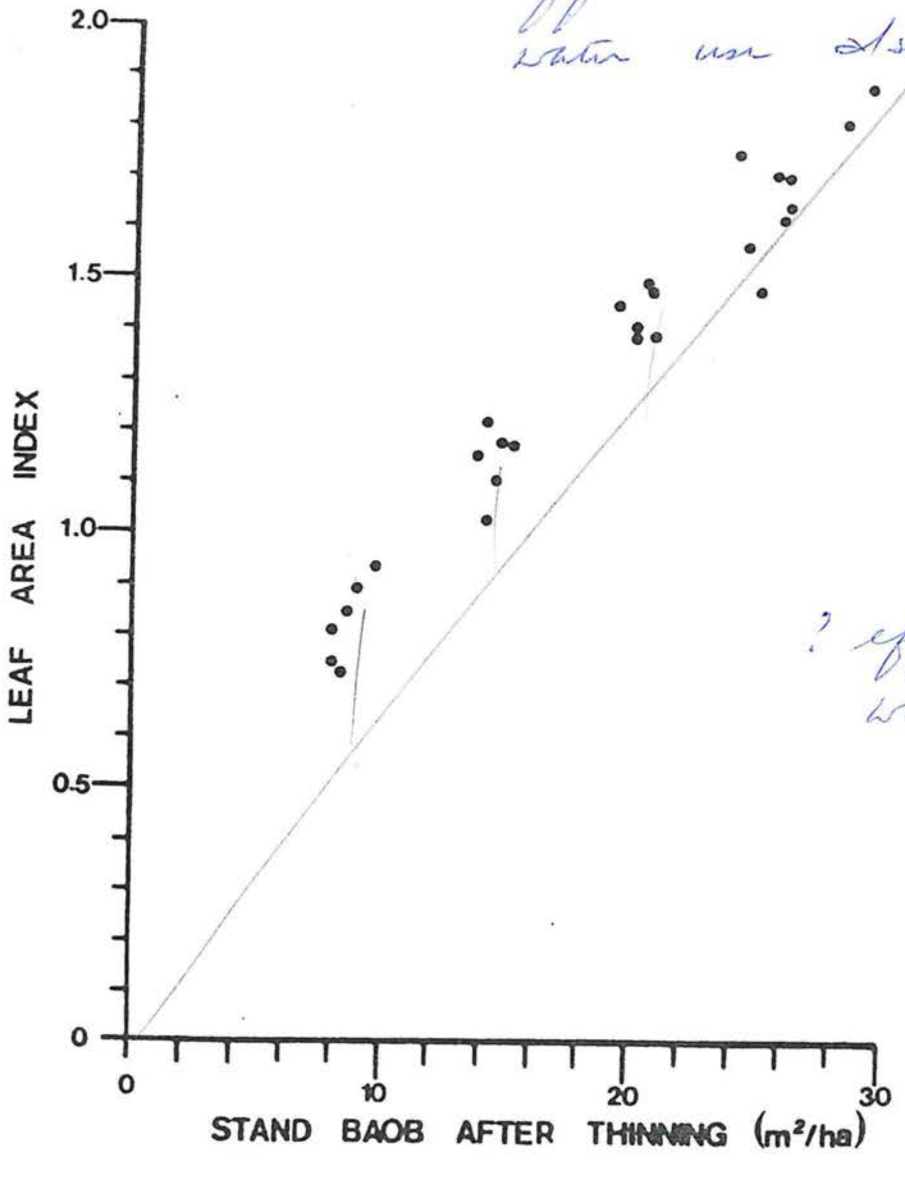
the next two to three years, followed by a four year steady decline in groundwater levels.

The different patterns in groundwater response from thinning compared with logging and regeneration are due to the different patterns in response of forest density. Stoneman *et al.* (1988) reported that forest density recovered rapidly following logging and regeneration in the southern jarrah forest. Groundwater levels lower after about five years of regeneration. This corresponds with the age at which total cover is within 80 per cent or 90 per cent of unlogged values. However, following thinning, forest density does not recover rapidly. Stoneman and Schofield (in press) reported that the leaf area index of a stand thinned to the same level as Yarragil 4L would still be approximately 50 per cent less after 21 years in comparison to an unthinned stand (figure 6).

2. Implications For Management of Salt Sensitive Areas.

Rising groundwater level is not of concern in the high rainfall zone where it normally leads to increases in fresh streamflows. However, it is of

growth and water use are linked
growth becomes more efficient, why not water use also?



? efficiency of water use.

Figure 6: Effect of stand basal area over bark on stand leaf area index for a 61-year-old jarrah pole stand 21 years after thinning.

concern in the salt sensitive intermediate and low rainfall zones. Whether or not thinning results in stream salinity and potable water quality problems in these zones depends on a number of factors including:

(i) Whether groundwater will rise to the ground surface under thinning treatments.

(ii) The relative quantities and solute concentrations of groundwater, shallow throughflow and overland flow contributing to stream salinity.

(iii) Whether the resultant stream salinity significantly impacts the salinity of reservoirs.

Thus, thinning in the intermediate and low rainfall zones may result in the salinity of some streams increasing to unacceptably high levels. This would occur in areas of high salt storage and where groundwater had risen to the ground surface. If extensive thinning is to be carried out in the intermediate rainfall zone, simple techniques would be required to identify areas where this would not lead to unacceptable stream salinities (Steering Committee 1987).

Whilst extensive thinning in salt sensitive areas is undesirable, thinning over limited portions of catchments may be acceptable. The upper slopes and ridges of the jarrah forest are the areas with stand structure and site quality most suitable for intensive wood production. These areas are also the most buffered hydrologically due to considerable depths to groundwater and considerable distances to streamlines and groundwater discharge areas. Thus, thinning of limited portions of appropriate catchments on the upper slopes and ridges is unlikely to lead to groundwater levels in the valleys rising to the ground surface and leading to an increase in stream salinity. Appropriate catchments are those where groundwaters in the valley are a considerable depth below the ground surface.

References

Borg, H.; King, P.D. and Loh, I.C. (1987a). Stream and groundwater response to logging and subsequent regeneration in the southern forest of Western Australia. Interim results from paired catchment studies. Water Authority of Western Australia, Water Resources Directorate, Hydrology Branch, Rep. No. 34.

Borg, H.; Stoneman, G.L. and Ward, C.G. (1987b). Stream and groundwater response to logging and subsequent regeneration in the southern forest of Western Australia. West. Aust. Dep. Conserv. Land Manage., Tech. Rep. No. 16. 114pp.

Peck, A.J. and Williamson, D.R. (1987). Effects of forest clearing on groundwater. J. Hydrol.,94 (1/2): 47-66.

Steering Committee For Research On Land Use And Water Supply (1987). Forest management to increase water yield from the northern jarrah forest. Water Authority of Western Australia, Report No. WS3.

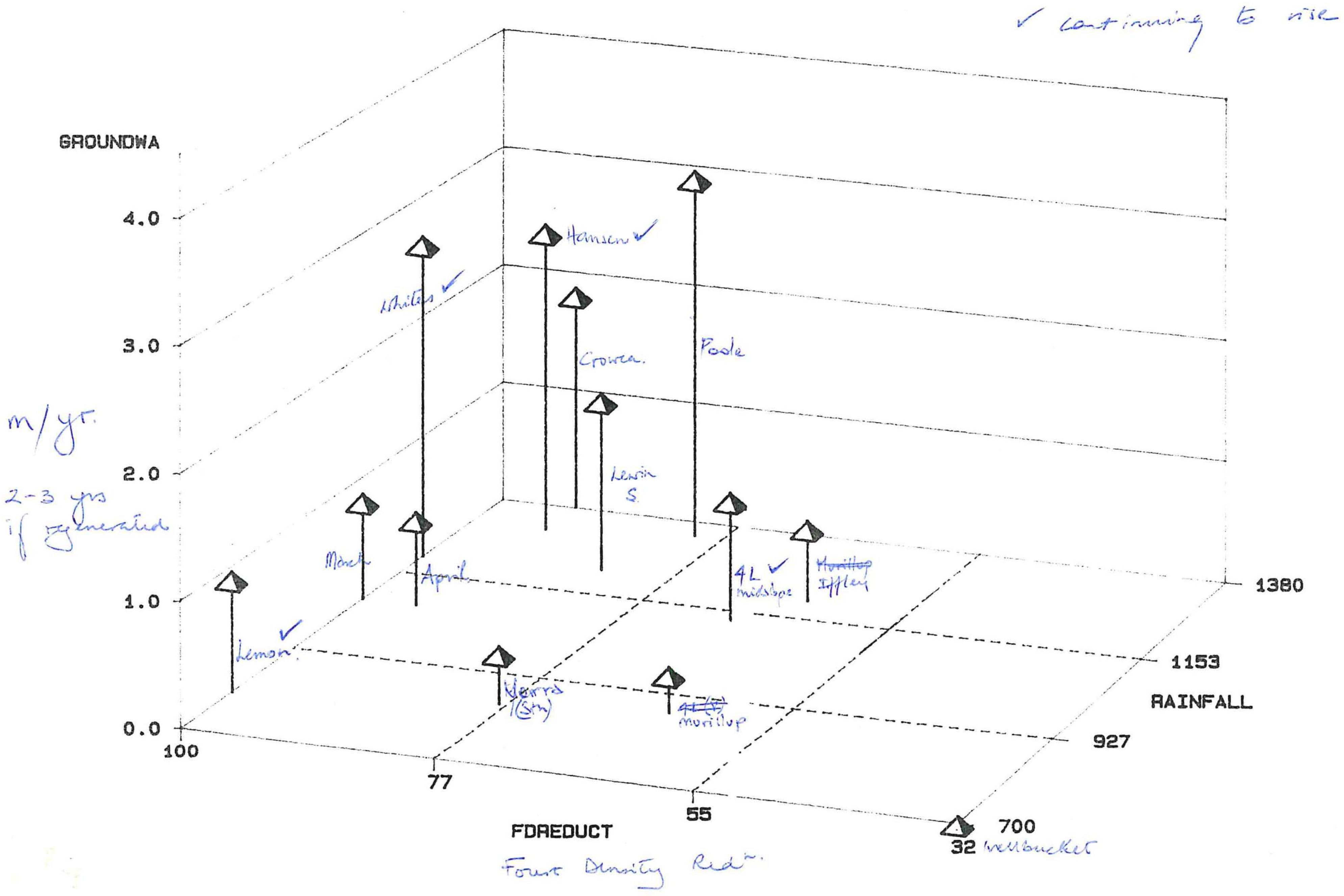
Stokes, R.A. and Batini, F.E. (1985). Streamflow and groundwater responses to logging in Wellbucket Catchment, south Western Australia. Water Authority of Western Australia, Report No. WH3.

Stoneman, G.L. (1986). Thinning a small jarrah forest catchment: streamflow and groundwater response after 2 years. *In*: Hydrology and Water Resources Conference, Aust. Inst. Eng. Nat. Publ. No. 86/13: 223-227.

Stoneman, G.L., Rose, P.W. and Borg, H. (1988). Recovery of forest density after intensive logging in the southern forest of Western Australia. West. Aust. Dep. Conserv. Land Manage., Tech. Pap. No. 19. 26pp.

Stoneman, G.L. and Schofield, N.J. (in press). Silviculture for water production in jarrah forest of Western Australia: an evaluation. For. Ecol. Manage.

Williamson, D.R.; Stokes, R.A. and Reuprecht, J.K. (1987). Response of input and output of water and chloride to clearing for agriculture. J. Hydrol., 94 (1/2): 1-28.



✓ continuing to rise
GROUNDWA
4.0
3.0
2.0
1.0
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m/yr.
2-3 yrs if regenerated
Hansen ✓
Whites ✓
Crowea.
Poole
Lewin S.
March
April
4L ✓ midslope
Morillup Iffley
Lemon ✓
Kerr 1(Sth)
morillup
1380
1153
RAINFALL
927
700
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55
32 Wellbucket
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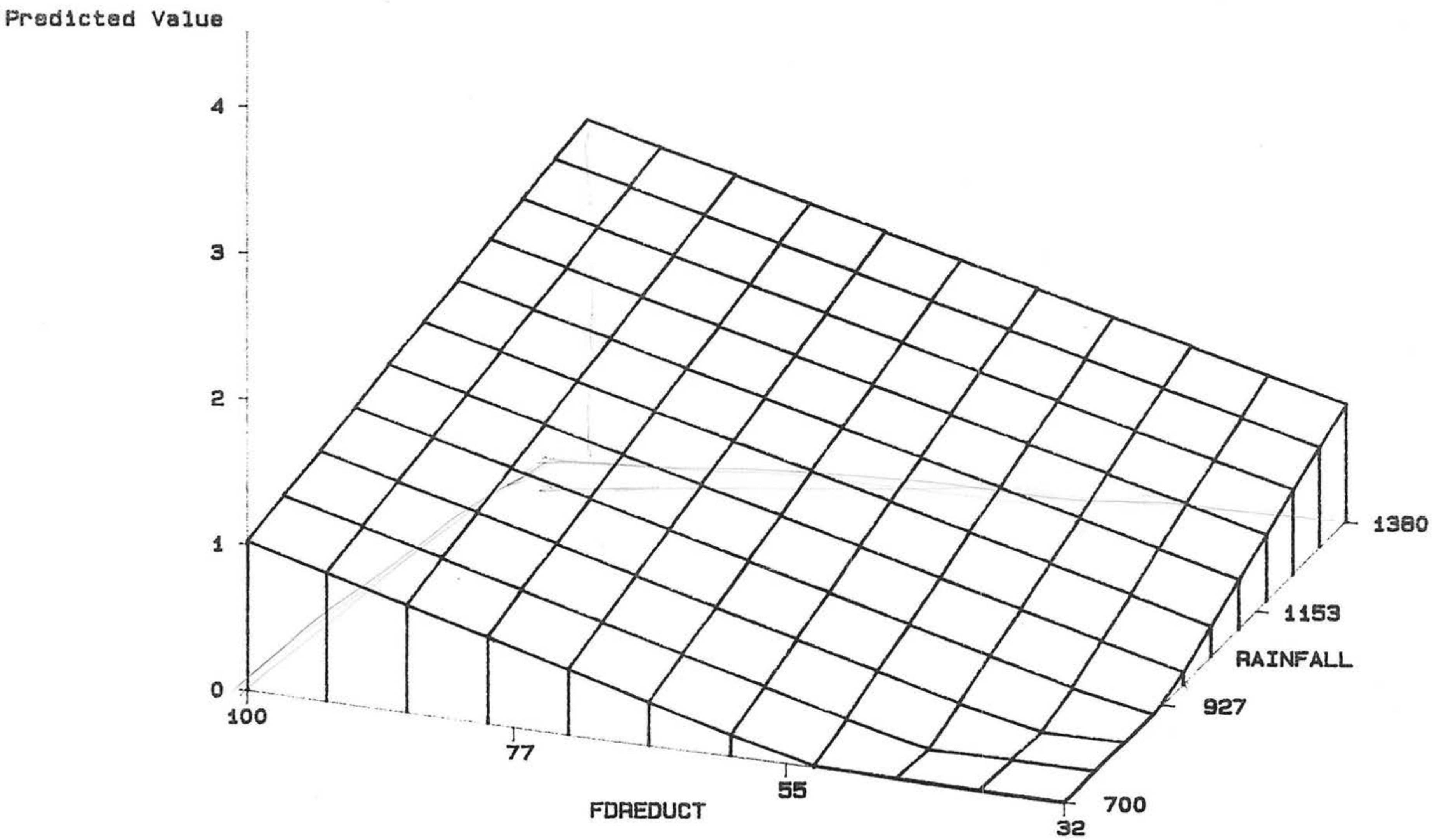
Predicted Value
4
3
2
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0
100
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32
FDREDUCT
700
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1380
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