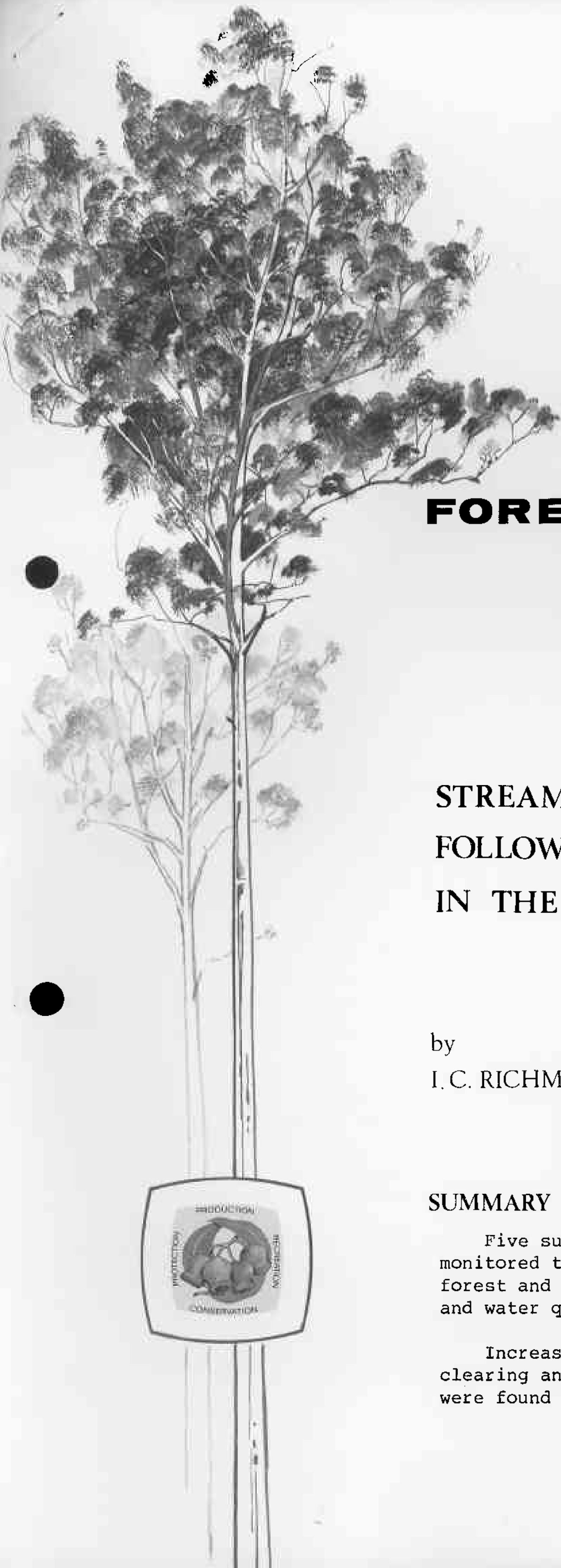
ODC 116.38

Research Paper 58
1980



FORESTS DEPARTMENT
OF WESTERN AUSTRALIA

STREAMFLOW AND WATER QUALITY FOLLOWING PINE ESTABLISHMENT IN THE DONNYBROOK SUNKLAND

by
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SUMMARY

Five subcatchments in the Donnybrook Sunkland were monitored to assess the effects that clearing native forest and planting radiata pine produced on streamflow and water quality.

Increased streamflows were recorded following clearing and planting. However, no significant changes were found in water quality.

INTRODUCTION

The Donnybrook Sunkland plantation programme involves the conversion of 60 000 ha of low quality and diseased jarrah (*Eucalyptus marginata* Sm.) forest to radiata pine (*Pinus radiata* D. Don.) plantations. The area contains a considerable water resource (Sadler and Field, 1975) which is currently utilized to only a limited extent. However, greater use of this resource is anticipated, therefore it is important to determine what impact the conversion to pine has on the quantity and quality of the water.

McKinnell(1976) reported low salinity levels in streams draining the Sunklands. Furthermore, there were no significant increases in stream salinity where forest had been converted to pasture or killed by disease. However, analysis of cores from a drilling programme in the Apostles Brook Catchment indicated the presence of localized concentrations of salt.

Consequently, a short term catchment study was commenced in 1975 to determine what impact the conversion of native forest to pine had on streamflow and water quality. This paper reports the results of three years monitoring of five subcatchments at various stages of conversion to pine in the Apostles Brook Catchment.

Topography and soils

Topography in the Sunkland is gently undulating with slopes rarely exceeding 3 degrees. Valleys are broad and surface drainage is slow. Streams are mainly broad waterways, with incised stream beds developing only low down in the drainage systems. The soils are lateritic gravels

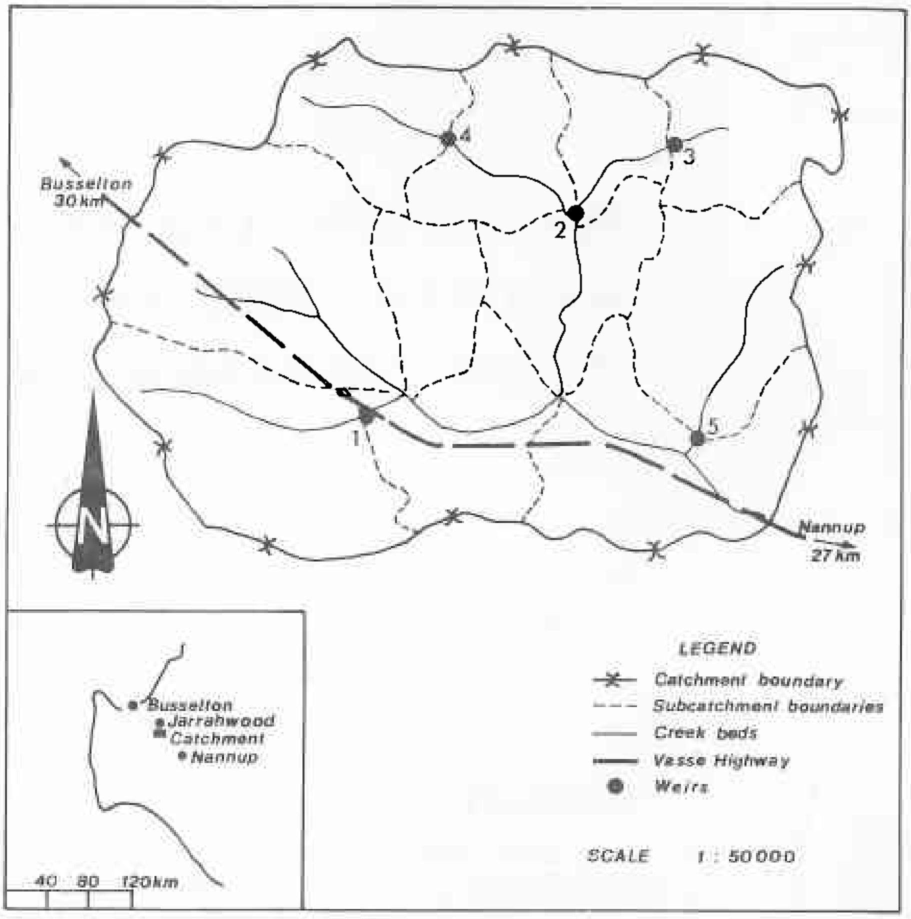

FIGURE 1: Apostles Brook Catchment, showing subcatchment boundaries.

Inset: location of catchment.

on the ridges with clayey sands on the slopes. Close to the drainage lines soil textures are heavier and the depth to clay is reduced. Bores in the area indicate the strata are discontinuous and vary considerably in thickness over short distances. This complexity results in a range of aquifer types with various degrees of confinement.

METHOD

V-notch weirs were established in streams of five subcatchments (Fig. 1) in 1975. Methods of weir construction were those outlined by Herbert and Ritson (1976), although the shape of the valleys generally required long embankments each side of the weir. Stream stage heights (head of water above the bottom of the V-notch) were measured initially with staff gauges graduated to 0.1 mm and read three times weekly. In 1976 Leupold and Stephens type F recorders were installed on three of the weirs. The calculations relating stage height to streamflow are outlined by Herbert and Ritson (1976).

Water samples were collected from the weirs in 1975 and 1976 at fortnightly intervals, and in 1977 at weekly intervals. All samples were analysed for electrical conductivity. Samples were analysed for pH in 1976 and 1977 and for chlorides in 1977. Analyses for turbidity, nitrate and phosphate were carried out on monthly samples, using the methods described by Hatch (1976).

Rainfall was estimated from seven 5 inch (127 mm) standard rain gauges. These were located in forest openings to avoid rainfall interception, and sited randomly within the Apostles Brook Catchment. Gauges were read three times a week and the readings were supplemented by pluviograph measurements taken at the mouth of the catchment.

The stage of development in conversion to pine at each subcatchment is shown in Table 1.

TABLE 1

Water yields and stages of development in conversion from native forest to pine plantations at five subcatchments in the Donnybrook Sunkland from 1975 to 1977

Year	Subcatchment	Development stages	Water yield (mm)	Water yield (per cent*)
1975	1	Native forest	79.5	9.4
	2	Cleared and planted	126.9	15.3
	3	Native forest	31.3	3.7
	4	Native forest	16.9	2.0
	5	Not Installed	N.A.	N.A.
1976	1	Native forest	19.2	2.6
	2	1- and 2-year-old pines	41.2	5.0
	3	Native forest	0	0
	4	Cleared	0	0
	5	Native forest	48.8	6.6
1977	1	Native forest	31.6	3.8
	2	2- and 3-year-old pines	52.4	6.3
	3	Native forest	6.6	0.8
	4	1-year-old pines	83.1	10.0
	5	Cleared	110.5	13.3

* Yield expressed as a percentage of the annual rainfall in mm

N.A. = not available.

TABLE 2

Major rainfall events in the five subcatchments for 1975 to 1977

Year	Minimum period for 50% of annual rainfall		Number of rainfall events	Average rain/event (mm)
	Days	Period		
1975	34	27/6 - 31/7	8	40.7
1976	78	31/5 - 16/8	19	19.4
1977	66	7/6 - 12/8	23	18.1

TABLE 3

Runoff characteristics in the five subcatchments following two heavy storms in 1976 and 1977

Year	Rainfall as percentage of annual total	Percentage of annual runoff in each subcatchment				
		1	2	3	4	5
1976	21	19	57	0	0	22
1977	21	19	54	33	43	20

RESULTS

Comparison of water yields from the five subcatchments was difficult because of variations in patterns of rainfall distribution and annual rainfall over the three years of the study, and differences in runoff characteristics of the subcatchments (Tables 2 and 3).

Annual rainfalls were 846 mm (1975), 739 mm (1976) and 831 mm (1977): all were well below the annual average of 1100 mm. A large proportion of the annual rainfall and runoff was produced from a few individual storms. Two individual storms in each of 1976 and 1977 produced 21% of the annual rainfall. There was wide variation in the percentage of the annual runoff produced from these storms in the subcatchments. In 1976 the percentage of the annual runoff ranged from 19% in subcatchment 1 to 57% in subcatchment 2. A similar range of yields occurred in 1977 (Table 3).

This difference in subcatchment behaviour precludes the use of multicatchment analysis. However, subcatchment 1, which remained uncleared throughout the study period, provided a control for a before/after comparison with subcatchments 4 and 5.

Subcatchments 1, 2 and 5 produced more uniform runoff data than subcatchments 3 and 4. No flow was recorded for subcatchments 3 and 4 in 1976 (see Table 1). There were increases in percentage runoff immediately following clearing in subcatchments 4 and 5. In 1975, prior to clearing in subcatchment 4, the water yield from this subcatchment was 21% of that from subcatchment 1. In 1977, one year after clearing, the comparative runoff from subcatchment 4 was 263% of that from subcatchment 1. Subcatchment 5 followed a similar pattern: the pre-clearing runoff in 1976 was 254% of that from subcatchment 1, compared with 350% after clearing in 1977. This represents a disproportionate increase in runoff following clearing.

Subcatchment 2, which had been cleared previously and was under pine for all the study period, showed consistently higher runoff yields than subcatchment 1 under native forest. However, in the absence of pre-clearing data the yield differences cannot be specifically attributed to the effects of clearing.

Water quality

Electrical conductivity (a measure of total dissolved solids) and chloride ion concentrations were low in each of the five subcatchments and showed no consistent relationship with the stage of plantation development (Table 4). However, higher conductivity levels appeared to be associated with the subcatchments that were lower in the landscape.

Nitrate and phosphate levels in runoff water were below detectable levels (0.02 ppm nitrate and 0.001 ppm phosphate). Turbidity levels were below 1 NTU unit (using formazin standards) (APHA, 1976), and the water was classed as non-turbid.

Weighted mean pH levels ranged from 5.8 to 6.2 and individual readings reached the extremes of 4.3 and 6.7 (Table 5).

There were no marked differences in pH levels between cleared subcatchments and those under native forest.

DISCUSSION

The results showed that the establishment of pine caused an increase in streamflow but no degradation in water quality. Increases in streamflow following clearing have been attributed to decreases in evapotranspiration and rainfall interception (Langford and O'Shaughnessy, 1977). The increases in streamflow varied widely between subcatchments and could not be related only to clearing. Rainfall throughout the three years was well below average and the relative increase in runoff following clearing could be expected to be greater in years of higher rainfall.

Contrary to expectations, no flow was recorded at subcatchment 4 following clearing. This resulted from the clearing windrows traversing the drainage lines thus impeding flow. This increased

TABLE 4

Weighted mean conductivity ($\mu s \cdot m^{-1}$) and chloride concentrations ($mg \cdot l^{-1}$) in runoff

Year	Parameter	Subcatchment				
		1	2	3	4	5
1975	Conductivity	39.5	40.4	41.8	39.1	N.A.
1976	Conductivity	32.2	32.2	No flow	No flow	34.8
1977	Conductivity	32.1	35.0	31.0	26.7	41.4
1977	Chloride ion	93.8	96.9	90.6	70.5	120.5

N.A. = not available

TABLE 5

Weighted mean pH (and range) of runoff water, 1976 and 1977

Year	Subcatchment				
	1	2	3	4	5
1976	5.8 (5.6 to 6.2)	6.4 (6.1 to 6.6)	No flow	No flow	5.8
1977	6.1 (5.6 to 6.6)	6.4 (6.2 to 6.6)	6.2 (5.9 to 6.7)	6.8 (6.1 to 6.9)	6.2 (4.3 to 6.3)

infiltration and resulted in streamflow by-passing the weir.

The stream conductivities were low (well below the upper limit of 280 μs·m^{-1} for low saline water (Hart, 1974)) irrespective of the condition of the subcatchment.

The extremely low levels (or absence) of nitrates and phosphates in the runoff is consistent with the very low nutrient status of soils in the Donnybrook Sunkland. The maintenance of pine plantations on these soils requires large inputs of nitrogenous and phosphatic fertilisers. Without adequate precautions taken with fertiliser application, nitrate levels in the water may increase.

Turbidity levels were surprisingly low when the extent of soil disturbance in clearing and preparing the ground for planting is considered. This is probably a reflection of the sandy nature of the soils utilized for pine planting.

To overcome the deficiencies of these subcatchment studies, and to minimize the influence of variability, the research is being extended to include large representative basins. These basins, approximately 2500 ha each, are located in proposed future plantation cells.

CONCLUSION

This study supports the conclusion reached by McKinnell (1976) that gross changes in the vegetation in the Sunkland would cause only minimal change in stream salinities. Increased streamflows can be expected to follow clearing of the native forest, but the magnitude cannot be determined from this study. No degradation in water quality takes place following clearing.

ACKNOWLEDGEMENTS

I wish to thank Alan Hatch and his laboratory staff for carrying out the chemical analysis, and Bob Hingston for assistance in carrying out the research programme.

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