5. CONCLUSIONS AND PRACTICAL IMPLICATIONS

The shallow-rooted pasture species which replaced forests following clearing have not been as effective as forest trees in removing moisture from the sodic subsoils. This has resulted in a higher B horizon moisture content in cleared catchments throughout the year and has markedly increased the incidence of percolation beyond the root zone as soil saturation has been reached far more readily. This increase in deep percolation inevitably has resulted in the raising of regional groundwater tables in the sedimentary bedrock, leading to saline groundwater discharge in lower parts of the landscape, and accounts for the numerous observed saline seeps and increased stream salinities.

With increasing volumes of water moving vertically through the soil in cleared areas, soluble salts have been more effectively leached to the underlying bedrock groundwater system, than is the case under forest. Now the cleared land contains less than half the mass of salts preset in adjacent forested areas.

Soil water movement values are generally consistent and very low for the B and B/C horizons, except on the rocky ridges where they are frequently higher and much more variable. This indicates that recharge is greater on the supper slopes, although recharge occurs generally when the slowly permeable sodic subsoils become saturated.

The low permeability of the sodic subsoils indicates definitely that soil throughflow is not adequate to account for salinisation. Perched watertables in soils on the slopes are ephemeral and this, combined with insignificant throughflow, suggests that vertical percolation is dominant. Finally, the porosity of both the fresh and weathered bedrock, being very low (generally less than 10%), indicates that percolation beyond the solum must be through fractures in the rock.

The practical implications of the study relate to the technical feasibility and economic viability of the various alternatives available for dryland salinity amelioration.

Effective salinity control can only be achieved by management practices designed to reduce the amount of groundwater recharge. As recharge occurs over the whole landscape, management procedures designed to treat specific locations in isolation can only be partially successful. On the other hand, tree planting to completely reforest vast areas is not a viable alternative for farmers operating within present agricultural cropping and grazing system. A possible compromise would be to incorporate tree planting on the upper slopes and rocky ridges, where agricultural production is low, with the use of vigorous deep-rooted perennial pasture to achieve optimum water usage on the more productive slopes. The suggested use of perennials however, is largely intuitive at present as insufficient data are available on comparative water usage by different pastures on sodic duplex soils. A pilot study by the Soil Conservation Authority in the Axe Creek catchment near Bendigo to test the soil water usage under established *Phalaris* and unimproved pastures is not encouraging. Limited data for lucerne at Kamarooka (J. Cooke, pers. Comm.) however suggest high water usage relative to native pasture.

As the principal groundwater recharge mechanisms on central Victorian Ordovician sedimentary bedrock terrain are now known, it has become essential to determine the specific hydrological effects of various land management systems, including the performance of different pastures and crops.

Table 3 – Field capacity data for Eppalock Catchment No. 1

Geomorphic situation	Soil horizon	Mean field moisture capacity % Vol	Number of samples	Standard Deviation	Confidence level of mean at 95% level of significance +/-
Upper slope	A	32.8	1		
	A2	31.9	15	5.6	3.1
	B1	30.9	5	4.9	6.1
	B	35.2	42	3.2	1.0
	B/C	32.5	29	3.8	1.4
Intermediate slope	A	38.2	3	2.8	
	A2	24.3	2	0.2	
	B1	34.7	8	3.4	2.8
	B	37.1	62	3.4	0.9
	B/C	34.9	26	4.1	1.7
Lower slope	A	33.0	5	3.6	4.4
	A2	33.9	16	3.4	1.8
	B1	34.0	8	4.5	3.8
	B	38.2	76	3.1	0.7
	B/C	37.7	26	3.0	1.2
Valley floor	A	38.3	17	5.4	2.8
	A2	33.3	22	3.7	1.7
	B1	34.1	23	5.2	2.3
	B	34.6	76	5.6	1.3
	B/C	30.9	36	5.7	1.9

Table 4 – Macroporosity data for Eppalock Catchment No. 1

Geomorphic situation	Soil horizon	Mean macroporosity % Vol	Number of samples	Standard Deviation	Confidence level of mean at 95% level of significance +/-
Upper slope	A	12.3	1		
	A2	13.5	15	3.6	2.0
	B1	10.4	5	3.0	3.7
	B	7.6	42	2.6	0.8
	B/C	6.7	29	3.1	1.2
Intermediate slope	A	11.4	3	3.4	
	A2	17.3	2	5.0	
	B1	7.4	8	2.1	2.2
	B	6.8	62	2.9	0.7
	B/C	6.2	26	2.6	1.4
Lower slope	A	14.2	5	9.1	4.2
	A2	14.2	16	2.3	2.7
	B1	8.9	8	2.6	1.8
	B	6.0	76	3.0	0.7
	B/C	5.5	21	3.4	1.0
Valley floor	A	14.4	17	4.7	2.4
	A2	12.7	22	4.3	1.9
	B1	6.2	23	7.6	3.3
	B	6.0	76	3.8	0.9
	B/C	6.8	36	4.5	1.5

Table 5 – Hydraulic conductivity (saturated) data for B and BC Horizons – Eppalock catchment No. 1

Geomorphic situation	Mean hydraulic conductivity metres/day	Number of determinations	Standard deviation	Confidence level of mean at 95% level of significance +/-
Upper slope	0.06	6	0.07	0.08
Intermediate slope	0.05	6	0.05	0.05
Lower slope	0.04	6	0.02	0.02
Valley floor	0.04	9	0.03	0.02

Table 6 – Electrical conductivity data (1:5 aqueous extracts) for Eppalock Catchment No. 1

Geomorphic situation	Soil horizon	Mean electrical conductivity µS/cm	Number of samples	Standard Deviation	Confidence level of mean at 95% level of significance +/-
Upper slope	A	127	1		
	A2	162	15	66	36
	B1	134	3	43	
	B	168	29	45	17
	B/C	150	51	62	17
	C	96	10	46	33
Intermediate slope	A	105	4	24	
	A2	100	2	36	
	B1	120	10	39	27
	B	174	57	119	32
	B/C	162	31	58	21
	C	130	20	54	25
Lower slope	A	144	5	27	33
	A2	143	16	56	30
	B1	111	11	38	25
	B	119	88	58	12
	B/C	120	28	38	15
	C	78	7	45	42
Valley floor	A	193	14	61	35
	A2	155	22	39	18
	B1	147	23	46	20
	B	150	70	58	14
	B/C	132	39	57	18
	C	90	8	79	66

Table 7 – Bulk density data for Eppalock Catchment No. 2

Geomorphic situation	Soil horizon	Mean bulk density g/cc	Number of samples	Standard Deviation	Confidence level of mean at 95% level of significance +/-
Upper slope	A	1.56	12	0.19	0.12
	B1	1.64	19	0.11	0.05
	B	1.66	34	0.10	0.04
	B/C	1.69	4	0.17	
	C	2.26	5	0.18	0.22
Intermediate slope	A	1.62	18	0.18	0.09
	B1	1.62	27	0.24	0.09
	B	1.70	56	0.26	0.07
	B/C	1.78	16	0.11	0.06
	C	2.38	4	0.29	
Lower slope	A	1.66	15	0.16	0.09
	B1	1.71	11	0.12	0.11
	B	1.74	44	0.22	0.07
	B/C	1.65	10	0.13	0.09
	C	2.35	1		
Valley floor	A	1.49	14	0.22	0.13
	B1	1.71	14	0.17	0.16
	B	1.76	33	0.09	0.03
	B/C	1.79	10	0.10	0.04
	C	2.17	1		

Table 8 – Total Porosity data for Eppalock Catchment No. 2

Geomorphic situation	Soil horizon	Mean calculated total porosity %	Number of samples	Standard Deviation	Confidence level of mean at 95% level of significance +/-
Upper slope	A	44.06	12	7.50	4.77
	B1	40.73	19	3.92	1.89
	B	40.24	34	3.50	1.23
	B/C	38.88	4	6.40	
	C	18.44	5	6.55	8.13
Intermediate slope	A	41.65	18	6.38	3.17
	B1	41.65	27	8.57	3.39
	B	37.24	56	8.77	2.35
	B/C	35.81	16	3.80	2.02
	C	14.19	4	10.22	
Lower slope	A	40.24	15	5.95	3.30
	B1	38.27	11	4.35	2.93
	B	37.18	44	7.37	2.25
	B/C	40.40	10	4.76	3.40
	C	15.26	1		
Valley floor	A	46.38	14	7.75	4.47
	B1	38.12	14	6.23	3.61
	B	36.66	33	3.37	1.20
	B/C	35.59	10	3.68	2.63
	C	21.68	1		

Table 9 – Mid summer water content for Eppalock Catchment No. 2 (B and BC horizons at wilting point)

Geomorphic situation	Soil horizon	Mean summer moisture	Number of samples	Standard Deviation	Confidence level of mean at 95% level of significance +/-
Upper slope	A	8.99	12	5.57	3.54
	B1	11.07	19	4.41	2.13
	B	18.76	34	6.79	2.38
	B/C	18.02	4	4.99	
	C	4.60	5	3.45	3.04
Intermediate slope	A	8.75	18	3.37	1.68
	B1	11.49	27	4.15	1.64
	B	20.28	56	10.37	2.78
	B/C	18.31	16	3.46	1.84
	C	7.55	4	5.16	
Lower slope	A	9.64	15	4.15	1.01
	B1	13.98	11	4.16	2.79
	B	23.64	44	6.44	1.96
	B/C	20.33	10	4.83	3.45
	C	5.02	1		
Valley floor	A	9.18	14	3.11	1.80
	B1	14.14	14	3.92	2.27
	B	21.84	33	6.12	2.18
	B/C	21.74	10	3.47	2.48
	C	4.19	1		

Table 10 – Available water for Eppalock Catchment No. 2

Geomorphic situation	Soil horizon	Available water	Number of samples	Standard Deviation	Confidence level of mean at 95% level of significance +/-
Upper slope	A	35.07	12	11.63	7.39
	B1	29.65	19	6.64	3.20
	B	21.46	34	7.32	2.56
	B/C	20.86	4	9.99	
	C	13.84	5	8.47	10.52
Intermediate slope	A	32.91	18	7.03	3.50
	B1	28.57	27	11.61	4.59
	B	18.24	56	7.96	2.13
	B/C	17.50	16	4.47	2.38
	C	7.03	4	7.53	
Lower slope	A	30.60	15	8.51	4.71
	B1	24.29	11	7.16	4.81
	B	17.16	44	12.00	3.66
	B/C	20.07	10	8.32	5.95
	C	15.23	1		
Valley floor	A	37.20	14	8.75	5.06
	B1	24.41	14	9.09	5.25
	B	14.51	33	4.86	1.73
	B/C	13.85	10	2.32	1.66
	C	21.68	1		

Table 11 – Hydraulic conductivity data for B and BC horizons, Eppalock Catchment No. 2

Geomorphic situation	Mean hydraulic conductivity metres/day	Number of determinations	Standard deviation	Confidence level of mean at 95% level of significance +/-
Upper slope	0.1	5	0.05	0.06
Intermediate slope	0.06	8	0.04	0.03
Lower slope	0.11	12	0.24	0.15
Valley floor	0.05	16	0.04	0.02

Table 12 – Electrical conductivity data for Eppalock Catchment No. 2 (1:5 aqueous extracts)

Geomorphic situation	Soil horizon	Mean electrical conductivity µS/cm	Number of samples	Standard Deviation	Confidence level of mean at 95% level of significance +/-
Upper slope	A	81	17	52	27
	B1	72	18	39	19
	B	93	31	68	25
	B/C	159	3	57	
	C	27	4	8	
Intermediate slope	A	96	25	75	13
	B1	69	25	32	13
	B	183	54	163	13
	B/C	370	15	224	45
	C	100	4	133	124
Lower slope	A	111	22	63	28
	B1	238	10	116	83
	B	437	46	349	104
	B/C	326	8	124	104
	C	362	3	483	
Valley floor	A	189	15	177	98
	B1	137	16	79	42
	B	388	27	280	111
	B/C	648	11	273	185

Table 13 – Bulk density data for Kamarooka area No. 1

Geomorphic situation	Soil horizon	Mean bulk density g/cc	Number of determinations	Standard deviation	Confidence level of mean at 95% level of significance +/-
Intermediate slope with red duplex soils	A	1.67	60	0.20	0.05
	B1	1.63	48	0.12	0.03
	B	1.55	113	0.09	0.02
	B/C	1.73	9	0.20	0.15

Table 14 – Total porosity (calculated) for Kamarooka area No. 1

Geomorphic situation	Soil horizon	Mean calculated total porosity	Number of determinations	Standard deviation	Confidence level of mean at 95% level of significance +/-
Intermediate slope with red duplex soils	A	39.8	60	7.2	1.8
	B1	41.3	48	4.5	1.3
	B	43.9	113	3.4	0.6
	B/C	37.6	9	7.1	5.5

Table 15 – Electrical conductivity data for Kamarooka area No. 1 (1:5 aqueous extracts)

Geomorphic situation	Soil horizon	Mean electrical conductivity µS/cm	Number of determinations	Standard deviation	Confidence level of mean at 95% level of significance +/-
Intermediate slope with red duplex soils	A	45	1		
	A2	149	58	208	55
	B1	214	44	181	55
	B	613	104	597	116
	B/C	325	6	242	254

Table 16 – Bulk density data for Kamarooka catchment No. 1

Geomorphic situation	Soil horizon	Mean bulk density g/cc	Number of samples	Standard Deviation	Confidence level of mean at 95% level of significance +/-
Upper slope: stony shallow red duplex soils	A	1.54	4	0.06	0.10
	B1	1.66	7	0.04	0.08
	B	1.75	29	0.18	0.07
	B/C	1.72	14	0.14	0.08
Intermediate slope: shallow red duplex soils	A	1.74	3	IS	
	B1	1.72	4	0.009	0.02
	B	1.80	16	0.16	0.09
	B/C	1.82	3	IS	
Lower slope: shallow red duplex soils	A	1.75	2	IS	
	B1	-	-	-	-
	B	1.67	6	0.12	0.13
	B/C	1.79	3	IS	
Valley floor: Shallow red duplex soils	A	1.52	16	0.14	0.08
	B1	1.75	5	0.04	0.05
	B	1.80	10	0.23	0.16
	B/C	-	-	-	-

IS = insufficient number of samples

Table 17 – Total porosity data for Kamarooka catchment No. 1

Geomorphic situation	Soil horizon	Mean total porosity % Vol	Number of samples	Standard Deviation	Confidence level of mean at 95% level of significance +/-
Upper slope	A	44.4	4	0.06	0.8
	B1	39.8	7	3.9	3.5
	B	36.8	29	14.8	5.6
	B/C	37.0	7	6.7	6.2
Intermediate slope: shallow red duplex soils	A	37.2	3	IS	
	B1	37.5	4	1.4	2.2
	B	34.9	16	5.9	3.1
	B/C	34.3	2	IS	
Lower slope: shallow red duplex soils	A	36.8	2	IS	
	B1	-	-	-	-
	B	39.7	6	4.2	4.4
	B/C	35.4	2	IS	
Valley floor: Shallow red duplex soils	A	45.2	16	5.1	2.7
	B1	36.9	5	1.4	1.7
	B	34.3	10	7.7	5.5
	B/C	-	-	-	-

IS = insufficient number of samples

Table 18 – Electrical conductivity data for Kamarooka Catchment No. 1

Geomorphic situation	Soil horizon	Mean electrical conductivity 1:5 aqueous extracts µS/cm	Number of samples	Standard Deviation	Confidence level of mean at 95% level of significance +/-
Upper slope	A	109	3	96	238
	B1	-	IS	-	-
	B	1293	8	237	211
	B/C	947	17	74	89
Intermediate slope: shallow red duplex soils	A	78	5	23	28
	B1	548	17	351	180
	B	655	3	210	137
	B/C	736	16	177	94
Lower slope: shallow red duplex soils	A	52	IS		
	B1	490	5	389	482
	B	-	-	-	-
	B/C	982	5	160	198
Valley floor: Shallow red duplex soils	A	43	6	25	26
	B1	294	12	200	127
	B	690	18	155	77
	B/C	500	16	130	69

IS = insufficient number of samples

Table 19 – Total porosity of Ordovician rock

Rock type	Mean total porosity % Vol	Number of samples	Standard deviation	Confidence level at 95% level of significance +/-
Sandstone	3.4	9	3.0	2.3
Fine grained sandstone	5.8	9	3.7	2.9
Weathered shale	16.7	5	2.3	2.9
Slate	8.8	5	2.9	3.6

(Particle density assumed to be 2.65)