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RECONNAISSANCE SURVEY OF THE ECOLOGY AND LAND-USE IN THE CATCHMENT OF THE GLENMAGGIE RESERVOIR

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CONTENTS

SUMMARY 1
I. INTRODUCTION. 3
II CLIMATE. Rainfall. 4
III. GEOLOGY AND PHYSIOGRAPHY. 12
IV. SOILS. 14
V. VEGETATION. 20
VI. SOIL EROSION. 26
VII. LAND FORMS. 29
VIII. LAND USE 30
IX. LAND SYSTEMS. 33
X. SUGGESTIONS FOR FURTHER INVESTIGATION. 51
XI. ACKNOWLEDGMENTS. 52
REFERENCES 56

List of Figures

Figure 1 – Average Annual Rainfall distribution in the Glenmaggie Catchment 4
Figure 2 – Graphs of Mean Monthly Rainfall for selected Rainfall Stations 6
Figure 3 – Graphs of Mean Monthly Temperatures for Maffra & Hotham Heights 9
Figure 4 – Relationship between elevations of boundary & internal ridges in the Glenmaggie Catchment 10
Figure 5 – Diagrammatic representation of relationships between the major soils in the Glenmaggie Catchment 18
Figure 6 – Snowy Plains Land System 35
Figure 7 – Barkly Land System 39
Figure 8 – Wellington Land System 41
Figure 9 – Yangoura Land System 44
Figure 10 – Glenmaggie Land System 46
Figure 11 – Macalister Land System 48

List of Plates

Plate 1 – Glenmaggie Catchment Panorama 2
Plate 2.-Montane wet sclerophyll forest of *E. delegatensis* alliance. 21
Plate 3.-Tall dry sclerophyll forest of *E. obliqua-E. rubida* alliance. 23
Plate 4.-Short dry sclerophyll forest of *E. melliodora-E. macrorhyncha-E.* 23
Plate 5.-Shrub woodland of *E. melliodora-E. polyanthemos* alliance on a steep northern aspect in the Barkly River valley. 24
Plate 6.—Snowy Plains land system—exposed plain north of Mt. Reynard. 34
Plate 7.—Exposed plain land-form—west aspect of Mt. Reynard. 35
Plate 8.-Sub-alpine valley land-form—"The Valley". 36
Plate 9.—Damaged and sheet-eroded sod-tussock grassland of *Poa* australis. Note pedestalled tussocks. 37
Plate 10.-A degenerate bog on a main stock route. 37
Plate 11.—Partly cleared low montane land-form—Target Creek area. 43
Plate 12.—Glenmaggie land-system—gully erosion in prairie soils between the rounded hills. 47
Plate 13.-Macalister land-system--river flats south of Licola. 49

SUMMARY

This report describes a broad-scale survey of the catchment of the Glenmaggie Reservoir. It contains brief descriptions of the climate, geology and physiography, and the soils and vegetation of the area. Areas having a regular pattern of land-forms are delineated. These areas are referred to as Land Systems. The environments of the land forms in each land system are described in terms of the above factors. Each land system is illustrated by a diagram which summarizes the relationships between the factors of the environment. The forms of erosion found in the catchment are described, and the present land-use is discussed. A broad classification of land is made into land-use classes and recommendations for future land-use are made in the descriptions of the land systems.

Plate 1 – Glenmaggie Catchment Panorama

I. INTRODUCTION.

Glenmaggie Reservoir is on the Macalister River about two miles downstream from the settlement of Glenmaggie and four miles north of the sawmilling town of Heyfield. The Reservoir, when completed in 1929, had a capacity of 104,500 acre feet, which was increased to 154,310 acre feet by installation of "crest gates" on the spillway above the " fixed crest ", or normal supply level of the dam, in 1957. Water was originally supplied to only the Maffra-Sale Irrigation District where approximately 27,311 acres are irrigable. Extensions to the system include the newly opened Central Gippsland Irrigation District, which embraces the Nambrok-Denison Soldier Settlement area and other adjacent lands, where another 35,629 acres are regarded as irrigable. (Annual Report State Rivers and Water Supply Commission 1957-58.)

The catchment for the reservoir has an area of approximately 813 square miles, most of which is mountainous and inaccessible. The catchment was proclaimed the "Glenmaggie Water Supply Catchment" in the *Victoria Government Gazette* of December 4, 1957, in accordance with section 22 of the *Soil Conservation and Land Utilization Act* 1947. Under section 23 (1) of this Act:

"The Authority, after consultation with the Land Utilization Advisory Council shall determine -

(a) the most suitable use in the public interest of all lands in catchment areas;

(b) which of such lands should be permanently used for forest purposes and which may (without deterioration of or detrimental effect to water supply catchment) be used for pasture, agriculture or any other purpose; and

(c) the conditions under which various forms of land use may be permitted."

In order to meet the obligations placed on it by the Act, the Authority has carried out this survey, which was designed to provide information to be used as a guide to the most suitable use for land in the catchment.

This survey delineated land systems and described the land forms in terms of the factors of the environment.

The land system is an area in which a limited number of land forms is present in a characteristic pattern. It is used for convenience in mapping of large areas on a broad scale of detail.

In a survey of this type, the amount of detail is necessarily limited. Prior to commencement of the survey the limits of detail for the various environmental factors were decided upon. These are set out in Appendix I.

II CLIMATE. Rainfall.

Rainfall records for the majority of the catchment are scanty and not very reliable. Reliable records are available only for Glenmaggie over 30 years (25.69 inches).

Figures for rainfall at Licola and Licola North (Willow Creek) have been obtained but must be regarded with caution because they are only for a short period.

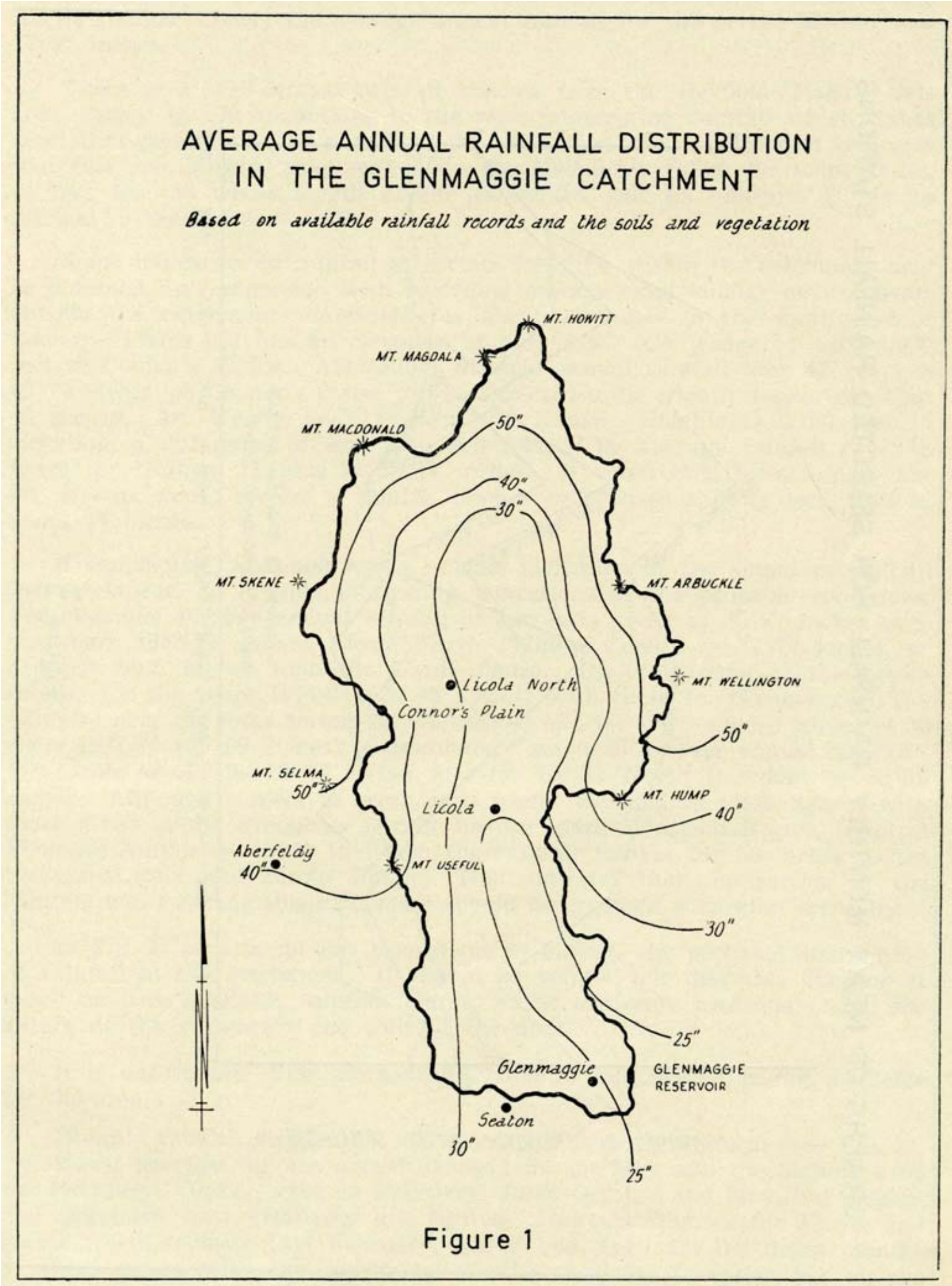

Figure 1 – Average Annual Rainfall distribution in the Glenmaggie Catchment

TABLE 1.-AVERAGE MONTHLY AND ANNUAL RAINFALL.
(in points.)

Station	No. of years of record.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Average
*Seaton	13	283	270	225	117	185	131	209	178	339	230	207	253	2,727
Glenmaggie	30	227	^{2}66	222	185	154	228	181	172	237	252	224	221	2,569
Glenmaggie Reservoir	11	265	210	205	208	2^{2}7	231	87	143	163	194	269	172	2,274
Licola	5	350	217	170	^{2}53	344	438	187	385	287	390	385	296	3,577
Licola North	5	348	144	146	240	366	363	288	461	313	464	364	294	3,777
*Hotham Heights	18	431	332	462	499	535	538	481	610	529	579	386	429	5,811
*Maffra	30	197	198	211	167	140	188	155	145	191	244	194	222	2,252
*Aberfeldy	42	263	258	270	326	369	377	352	433	409	407	307	308	4,079

• Stations outside the catchment.

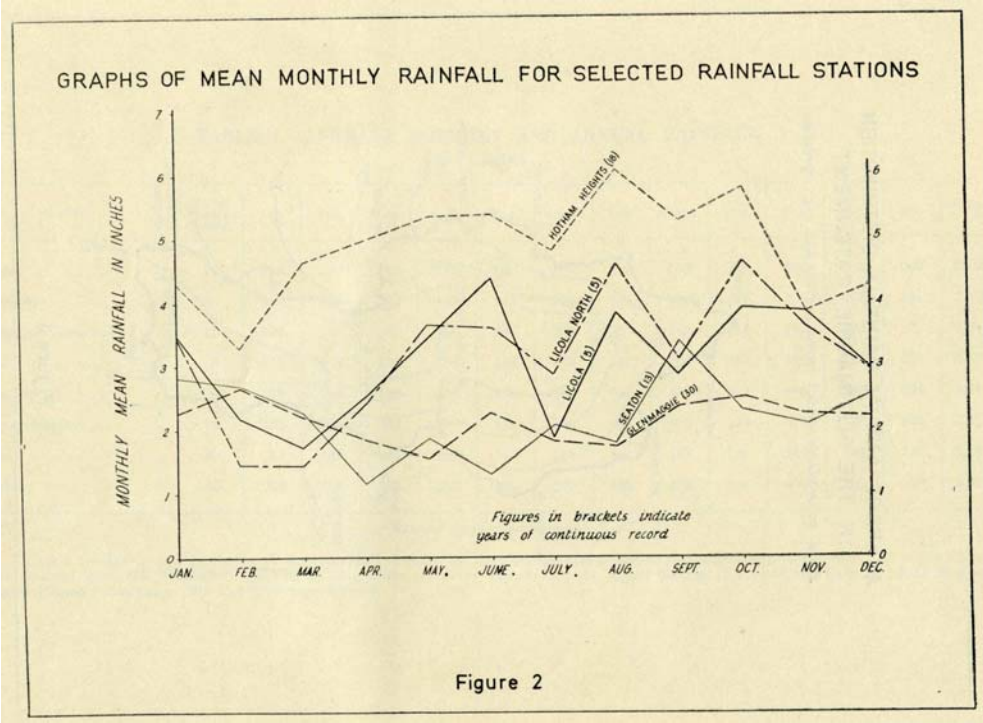

Figure 2 – Graphs of Mean Monthly Rainfall for selected Rainfall Stations

Figures for Licola and Licola North were supplied directly by the Commonwealth Meteorological Bureau, Melbourne. All other figures were obtained from the "Climate" sections in the resources survey reports for the Upper Murray (Vic.) and the East Gippsland Regions (Central Planning Authority 1949 and 1954 respectively).

The average annual rainfall at Licola for the period 1911-1920 was 28.42 inches and for the period 1953-57 it was 35.77 inches (see Table 1). At Licola North (Willow Creek) the average annual rainfall for the period 1953-57 was 37.77 inches.

There is a well-defined rainfall shadow over the Heyfield, Maffra, Sale area, caused by the mountains to the west intercepting rainfall which comes from that direction. The nature of the vegetation in the catchment indicates that this rain shadow may extend up the Macalister valley for many miles, in fact for the whole length of the catchment, but its influence is not so marked in the extreme north.

Some indication of rainfall at certain localities within the catchment may be obtained by comparison with recording stations with similar environments outside the catchment. Aberfeldy is about 12 miles to the south-west of Connor's Plains but has an elevation of only 3,300 feet compared with 4,000 feet at Connor's Plains. Aberfeldy's average annual rainfall over 42 years is 40.79 inches, so Connor's Plains can be expected to be slightly higher or about 45 inches. Mt. Howitt is 5,718 feet and Hotham Heights is 6,100 feet in elevation, a difference of less than 400 feet. The average rainfall over 18 years for Hotham Heights is 58.11 inches. It could then be assumed that Mt. Howitt would receive a similar amount or perhaps slightly less, that is, about 55 inches.

These figures, although not a reliable indication of the actual rainfall in the catchment, do provide interesting indications of the probable conditions. For example, average annual rainfall at Licola is given as 35.77 inches over the years 1953-57 and at Licola North (Willow Creek) as 37.77 inches, or 56 per cent higher than the Licola figure. By comparison of the Licola records for the years 1911-21 (28.48 inches) with those for Glenmaggie (The Laurels) over the same period (25.46 inches) and for the standard period of 30 years 1911-40 (25.69 inches), a calculated "standard average annual rainfall" for Licola would be 28.74 inches and for Licola North it would be 30.35 inches. Although subject to error, it is useful to compare these figures with those given in the Resources Survey for the East Gippsland Region (Central Planning Authority, 1954) in which the rainfall isohyet for 50 inches passes between Licola and Licola North. This indicates that the section of the rainfall map covering this catchment should be regarded somewhat critically.

In Fig. 1, an attempt has been made to indicate the probable distribution of rainfall in the catchment. It should be pointed out that this diagram is based on both available rainfall figures, which are quite inadequate, and the nature of the vegetation and soils of the area.

It is unfortunate that more useful climatic information is not available for the area.

Monthly rainfall distribution at Glenmaggie is fairly uniform (see Fig. 2), the lowest average for any month being 1.54 for May and the highest 2.66 for February. Peaks occur in February, June, October and May, but August and December have relatively low figures. However, figures for Licola and Licola North indicate that February, March and April are the driest months at these places with the remaining months receiving irregular but always higher amounts. The relative drought conditions in late summer in the centre of the catchment, contrast with the more regular monthly distributions of rainfall at the southern end of the catchment. Glenmaggie, being at the inland edge of the East Gippsland coastal plain, may receive some rain from the east in the summer months. It also appears that the effect of the rain shadow is to reduce winter rainfall, which comes chiefly from the west.

Occurrence of snow.

Snow has been known to fall over most of the catchment. The high plains areas on the eastern boundary ridge and the higher mountain peaks such as Mt. Macdonald, Mt. Clear, Mt. Magdala, Mt. Howitt, Mt. Reynard and Mt. Wellington can be expected to be snow-covered for at least several months of the year, usually between May and October.

Snow lies longest in patches on the eastern side of ridges. It seldom lies for very long on exposed situations.

The occurrence of snow on the high country is of importance for several reasons. It forms a blanket over the soil and ground vegetation thus protecting them from extremes of cold. Snow is also of importance in acting as a reserve of water which is released, usually slowly, throughout the spring and early summer. This results in a more even release of water to the streams than would be the case if all the precipitation was rain.

Temperatures.

The complete absence of any temperature recording stations in the catchment makes it difficult to indicate likely temperature ranges. The temperatures at Hotham Heights may be a reasonable indication of those for Mt. Howitt and a similar comparison can be made of Maffra with Glenmaggie. (See Table 2.) This provides an indication of the temperature ranges to be expected at the highest and most northerly point and at the lowest and most southerly part of the catchment.

By generalising it may be said that in the higher mountains and high plains country, summer maxima are mild, minima are low and winter temperatures would be low and very low, respectively. During summer the range of temperature from day to night can be very high, perhaps of the order of 40°F. In the lower country and in the south of the catchment summer maxima would be fairly high, minima moderately low and winter temperatures would be moderately low and low, respectively.

Although it is not possible to comment directly on the effect of temperature on plant growth in the Glenmaggie catchment, a discussion of this subject based on figures for Maffra and Hotham Heights may be useful. It is assumed here that Mt. Howitt and perhaps much of the high country have similar temperatures to Mt. Hotham, and Glenmaggie is similar to Maffra in this respect.

It has been suggested by Taylor (1958) that no significant plant growth occurs in a month which has a mean temperature of below 42°F. and it is commonly accepted that mean monthly temperatures of 50°F. or lower severely restrict plant growth. On the basis of this it can be seen from Fig. 3 that at Hotham Heights from mid-April until late October, about 6. months, growth is prevented entirely. From early November until mid-December, and again from mid-March to mid-April, about 2½ months, temperatures are low enough to severely restrict plant growth. Thus, only for about 3 months of the year, are temperatures favourable for plant growth. The temperatures experienced by plants covered by a depth of snow would not be as low as those recorded in the open above the snow, but plant growth would not occur whilst the snow cover persisted. This is probably the situation on much of the country above 4,500 feet.

TABLE 2 - AVERAGE MONTHLY MAXIMUM TEMPERATURES °F.

Station.	No. of years of Record.	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.	Average Annual.
Hotham Heights	11	60·9	60·1	56·6	47·9	41·0	35·0	32·6	34·5	38·4	46·2	52·6	57·0	46·9
Maffra.	38	78·1	78·8	74·8	68·7	62·8	57·5	56·7	59·5	63·3	67·9	72·0	76·1	68·0

AVERAGE MONTHLY MINIMUM TEMPERATURES °F.

Hotham Heights	11	43·6	44·6	43·0	**35**·2	31·1	26·5	25·1	25·7	28·0	34·0	37·7	41·9	34·7
Maffra	38	54·5	55·1	52·6	47·8	42·8	39·7	38·4	39·9	42·9	46·0	49·2	52·5	46·8.

The graph of temperatures for Maffra in Fig. 3 shows that in no month is growth inhibited by low temperatures but from early June until about mid-August, about 2½ months, temperatures are low enough to severely restrict plant growth. This allows 9½ months when temperatures are favourable for plant growth. This situation would probably apply equally well to the lowland country around Glenmaggie.

Frosts are common and become more severe as elevation increases. Where snow lies, frosts do little more than harden the snow; however, where there is no snow, frosts can cause considerable soil movement due to solifluction and frost heave accompanied by wind and/or water erosion (see under Soil Erosion).

The effect of aspect on the temperature range is also important.

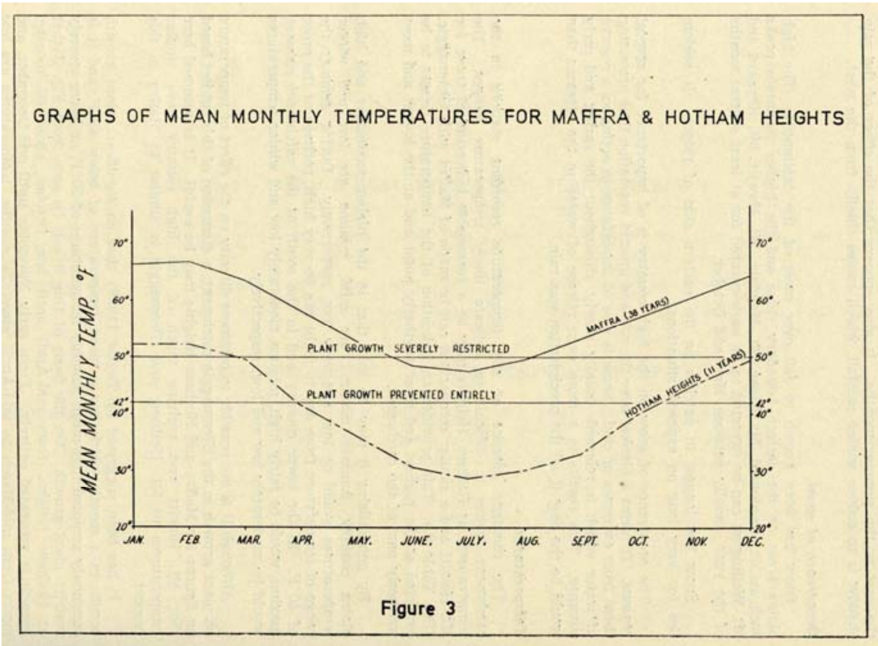

Figure 3 – Graphs of Mean Monthly Temperatures for Maffra & Hotham Heights

Effect of physiography on climate.

Rainfall distribution.—The boundary ridges have a higher average elevation than any of the ridges within the catchment. From the western boundary ridge there is a decrease of elevation towards the centre and an increase again towards the eastern boundary. This apparently causes a high rainfall area on the western boundary, a low rainfall area at the centre of the catchment and another higher rainfall area on the eastern side of the catchment. This contrast is most marked north of Licola where the catchment widens, as far north as a line from Mt. Macdonald to Bryce's Plain, further north of which the boundary ridges converge until they meet at Mt. Howitt. South of Licola, the catchment again narrows and the rain shadow caused by the western ridge is probably less severe, although higher country further west is still effective in restricting rainfall. The eastern ridge is of much lower elevation to the south of Licola, and probably there is not a very great increase in rainfall from the Macalister River valley to the eastern boundary ridge here. (See Fig. 1 and Fig. 4.)

This suggestion is supported by the relative distributions of the high rainfall and the drier types of vegetation within the catchment.

Temperature and moisture available for plant growth.—The regional climate is modified by aspect and elevation and to a certain extent topography to provide a great diversity of microclimates.

At high elevations, where winter snow accumulates, the average annual precipitation is relatively high. Summer is generally fairly dry. The temperature ranges from mild or warm in summer to cold or very cold in winter. This combination of climatic factors results in a very short growing period for plants. During winter and spring, when soil moisture is adequate, temperatures are low enough to inhibit or severely restrict plant growth. As temperatures rise, the snow melts, and the soil dries out so that during much of the summer the vegetation suffers some degree of water stress although temperatures are suitable for growth. Late autumn can be expected to be somewhat wetter than summer and temperatures are lower.

The effective growing season is thus limited to the period between early spring and late spring or early summer, and a short period in late autumn before temperatures become too low again. Also, because of the high elevation and generally exposed nature of this country, rapid cooling of the air and surface soil results after sunset. This is severe enough during the spring and autumn to cause frequent heavy frosts which limit seedling establishment because of frost heave.

Vegetation on north-westerly aspects, facing the prevailing winds, suffer more from desiccation, and possibly physical damage, due to the wind, than vegetation on south-easterly aspects. Thus, at high elevations, woody vegetation is frequently absent from northern to western aspects because of the severity of the micro-climate. Forest-type vegetation, common to lower elevations, may occur at high elevations in situations sheltered from the prevailing winds and receiving adequate solar radiation, mainly on easterly aspects.

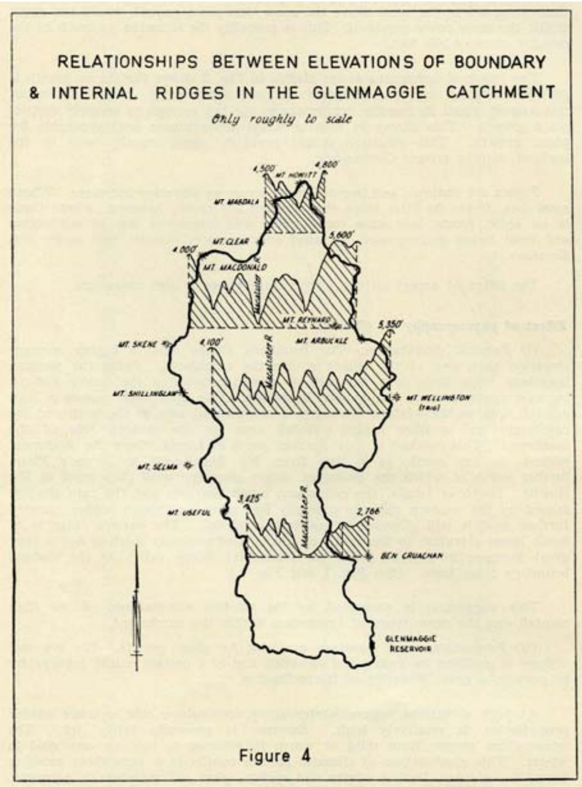

Figure 4 – Relationship between elevations of boundary & internal ridges in the Glenmaggie Catchment

Below the tract where snow accumulates, temperatures are not as severe during the cooler months, and the precipitation, being mostly as rain, is more readily available for plant growth. Because northern aspects receive a greater concentration of solar radiation, they are warmer, and drier than southern slopes.[*] This affects the distribution of vegetation types, both structurally and floristically. The cooler and more continuously moist southerly aspects support a more dense and much more mesophilous vegetation than northern aspects.

At still lower elevations, where rain shadow conditions exist, and winter rainfall is reduced, conditions of water stress may continue well into the winter months. The effect of aspect is very marked and

[*] Jacobs (1955) demonstrates that on northerly, north-westerly and north-easterly slopes, the amount of solar radiation received in the course of a year first rises as slope increases from the level to about 30° and then falls off for steeper slopes. Thus very steep northern slopes may have similar vegetation to lesser sloping country. However, more rapid drainage of soil moisture from the steeper slope could cause significant differences.

Also, Jacobs shows that the amount of solar radiation received falls off very quickly on southerly, south-easterly, south-westerly, easterly and westerly aspects as the slope increases.

The slopes receiving the greatest concentration of solar radiation vary as the course of the sun varies from season to season.

topography plays a part in influencing the availability of soil moisture. Steep slopes drain rapidly, and therefore dry out more rapidly than lesser slopes. When rainfall is low, this becomes of greater importance than when it is high. Vegetation on steeper slopes thus suffers water stress for longer periods than does vegetation on less steep slopes. The effect of aspect is to accentuate this. Thus, it is usual to find the most xerophilous vegetation communities on the steeper northern slopes in these drier areas.

III. GEOLOGY[*] AND PHYSIOGRAPHY.

As may be expected, geology and geological history of the catchment have influenced the physiography.

Folding of the Ordovician–Silurian–Carboniferous sedimentary beds with roughly north-south striking of the folds has resulted in a marked north-south parallelism in the physiography. The eastern boundary of the catchment is part of the Wellington anticlinorium, and the Macalister River has cut its valley in the syncline to the west. The Mt. Useful anticlinorium forms part at least of the western boundary.

Faulting has been common, particularly to the west of the Barkly River where faults striking north-west to south-east and others striking east-west have complicated the geology. The main fault in this area is the Mansfield–Barkly fault, which runs north-west and south-east just to the west of the Barkly River. It has brought Cambrian diabases, limestone and tuff to the surface in several places.

Another region of faulting is in the Wellington–Dolodrook Rivers area where a narrow band of Cambrian and Ordovician rocks has been exposed by several irregular faults with a roughly north-west to south-east strike.

That part of the catchment north of the Mansfield–Barkly fault is of Carboniferous sandstones, shales and conglomerates. Rocks of this age also extend in a tongue down the east side of the Macalister River as far as Cheynes Bridge. The remainder of the rocks in the catchment are predominantly of Silurian age. A neck of Silurian extends northwards up the eastern catchment boundary from the reservoir. North of Cheynes Bridge it keeps to the east of the catchment boundary. However, the sharp eastward trend of the boundary ridge south of Mt. Wellington results in the northern extremity of this neck occupying most of the upper Wellington and Dolodrook River basins. A thin bed of Upper Devonian rhyolites and rhyodacites with basal conglomerates forms a strip between the Carboniferous and Silurian rocks, except at the Mansfield–Barkly fault, where it is lacking.

Tertiary sands and gravels occur in the far south-east of the catchment around Glenmaggie. A small north-south block fault has upthrust Ordovician rocks into the Silurian, to the north of Glenmaggie. Tertiary basalt forms a capping on numerous hills to the north-west of Glenmaggie and residuals are also to be found on the divides at various points, for example, on Spring Hill, Connor's Plains and Mt. Howitt.

Because of the inaccessibility of much of the northern part of the area it is doubtful whether its geology has been studied in any detail. It may well be more complex than is indicated in published maps of the area. One observation which would tend to indicate a more complex geology is the sudden change in the courses of the Wellington, Caledonia and Macalister Rivers, at various places, from roughly north-south to east-west and in the case of the Macalister and Caledonia Rivers a sudden change back to a north-south course. These changes in course may be the result of faulting in the bed rocks.

The whole area is mountainous except for a small area at the south-eastern end. The highest point is Mt. Howitt (5,718 feet) at the northern-most part of the catchment boundary. Other prominent peaks on the boundary are Mt. Arbuckle (5,520 approximately[*]), Mt. Wellington (5,355 feet), Mt. Hump, on the eastern side and Mt. Magdala (5,600 feet approximately), Mt. Clear (5,660 feet approximately*), Mt. Macdonald (5,360 feet approximately`-), Mt. Shillinglaw (4,230 feet approximately*) and Mt. Useful (4,712 feet) on the western side. Notable peaks inside the boundary are Mt. Reynard (5,600 feet approximately*), Mt. Tamboritha (5,381 feet approximately*) and Mt. Crinoline. Undulating to hilly country at high elevations on the eastern boundary between Mt. Howitt and Mt. Wellington, forms part of the high plains country of Victoria.

The main river is the Macalister which has its source on Mt. Howitt. Important tributaries are Coleman's Creek, the Caledonia River system, which includes the East and Middle Caledonia and Shaw's Creek ; the Wellington River system, which includes the Carey River, Dolodrook River and Middle Branch of the Wellington ; the Barkly River system including the East and West and Mt. Skene branches and Mountain Ash Creek; Serpentine Creek; Mt. Useful Creek and the Glenmaggie Creek system, both East and West branches.

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[*] Details of the geology were obtained from Harris and Thomas (1954) and Central Planning Authority (1954).

[*] Heights marked thus have been derived from Forests Commission topographic maps and are interpolations between contour lines.

Dissection of the upper catchment is deep and slopes are steep. Ridges and spurs have narrow tops except on the previously mentioned high plains country on the north-east boundary.

About six miles south of Licola, the Macalister swings to the west in a large arc and returns to its south-south easterly course some two miles further south. Retardation of the down-cutting of the river at about this point is indicated by the occurrence of undulating foothill country and broad river flats between Licola and the deviation. This country is in marked contrast to the narrow and gorge-like valley of the river above Licola and for several miles below its arc-like deviation to the west.

A small area of alluvial flats and undulating country at Glencairn may have been caused by a similar obstruction of the Glencairn Creek. It seems probable that this small valley was once the course of the Macalister. Headward erosion of a small tributary which joined the river below its old junction with the Barkly may have resulted in capture of the main stream.

Dissection of the lower catchment is more mature, although slopes may be as steep in many places. Much undulating to rolling country occurs near Glenmaggie, and the flats of the Macalister River and Glenmaggie Creek become more extensive.

The basalt capping on many of the hills to the north of Glenmaggie has resulted in the preservation of fairly flat to undulating areas on the top of the hills and shallow valleys with steep floors, between them. Occasional deep dissection gives a rounded appearance to the topography.

IV. SOILS.

Soil classification.

The soil classification system used in this report is that of Hallsworth and Costin (1950), as applied by Costin (1954), together with the modifications proposed by Hallsworth, Costin and Gibbons (1953).

Ten Great Soil Groups are represented by the soils found in the area, and of these the following seven are the most important: -

Alpine Humus Soils
Crypto-podsols
Leptopodsols
Prairie Soils
Solodic Soils
Brown Earths
Lithosols

Those groups which occur to a lesser extent are:

Alluvial Soils Krasnozems Amphipodsols.

The classification used differs in some respects from others commonly used, and the groups most affected are the alpine humus soils, amphipodsols, leptopodsols, cryptopodsols and solodic soils.

The first of these groups, the alpine humus soil, which has been described in detail by Costin, Hallsworth and Woof (1952), includes soils called elsewhere, moor peats (Stephens 1953) or simply mountain soils.

The leptopodsol and solodic groups separate soils which have been included together in the grey-brown podsolic group and part of the red podsolic group of Stephens.

Red amphipodsols correspond to part of the red-podsolic group of Stephens, and the crypto-podsols appear to correspond with the brown-podsolic group of Stephens.

Descriptions of soils.

(i) Alpine humus soils.

A typical alpine humus soil consists of a black A_0 horizon, very rich in organic matter and undecayed plant remains. Below this, for a depth of 6 inches or more, is a very dark brown to black organo-mineral horizon which gradually becomes lighter in colour as the influence of the organic matter lessens. There is no horizon of clay accumulation. The organic part of the profile has good crumb structure throughout and a very friable to loose consistency. Parent material is usually encountered fairly close to the surface, say at 12 inches-20 inches depth.

These soils are formed where low temperatures limit the decomposition of organic matter and restrict chemical weathering of the parent material. They can be formed on a wide range of parent materials because climate is the controlling soil forming factor in this case.

The following is a description of an alpine humus soil from sub-alpine woodland of *E. pauciflora* on Carey Plain:

0"- 1" black, semi-humified plant remains.

1"- 3" dark reddish brown to dark brown (5 YR 3/2 to 7·5 YR 3/2); gritty loam ; medium to strong, fine, crumb structure ; moist, very friable consistency; many fine roots; merging gradually into

3"-15" dark brown (7·5 YR 3/2); gritty loam; medium to strong, fine, crumb structure; moist, friable consistency; fewer fine roots ; changing to

15" + brown to dark brown (7·5 YR 4/4); gravelly loam; weak to moderate, medium, crumb structure; moist, friable consistency; grass roots frequent.

Floaters of parent material throughout the profile becoming abundant below 18 inches.

In this catchment, these soils are restricted to the alpine-sub-alpine tract which extends from Mt. Skene around the Great Dividing Range to Mt. Howitt and thence south along the catchment boundary through Mt. Arbuckle to Mt. Wellington. Other smaller areas of alpine humus soils occur on spurs running off the catchment boundary in the north where the elevations of these spurs are high enough. Some of these soils have such a quantity of stone in the profile that they may be more correctly called lithosols.

(ii) Cryptopodsol.

General features of the cryptopodsol soils are a black A_0 horizon of decaying organic matter over a dark-brown loam to clay loam with good structure and very friable consistency. A slightly bleached A, horizon may or may not be apparent. The texture becomes slightly heavier and the colour lightens somewhat with depth. Structure and consistency are good throughout the profile. They are usually fairly deep soils with parent material at a depth of up to 48 inches or more.

They are formed in relatively high rainfall areas where plant growth is prolific and breakdown of organic matter is fairly rapid. They occur on a variety of parent materials varying from Silurian sandstones to Cambrian diabase.

A typical example is the following soil formed on Silurian sandstone under a wet sclerophyll forest of *E. delegatensis* near "The Springs":

0"- 2" black decaying leaf litter.

2"-14" dark reddish brown (5 YR 3/2); gritty clay loam; strong, fine to medium, sub-angular blocky structure; moist, very friable consistency; merging gradually into

14"-26" dark reddish brown (5 YR 3/4); gritty light clay; moderate, fine, sub-angular blocky structure; moist, very friable consistency; gradually merging into

26"-50" yellowish red (5 YR 4/8); gritty clay; moderate, medium, sub-angular blocky structure; moist, very friable consistency; floaters of parent material.

50" + abundant broken parent material with soil as for 26"-50" in between.

The distribution of these soils is closely associated with the distribution of the wet sclerophyll forest formation. The greatest extent of the crypto-podsols in this catchment is along the western boundary ridge. It is here that the conditions of high rainfall, 45"–60" per annum, with moderate temperatures are achieved.

(iii) Leptopodsol.

A typical leptopodsol from this catchment would have no A_0 horizon of organic matter except for a very thin layer of dry leaf litter. Texture at the surface varies from a loam to a coarse sandy loam and usually colours are reddish brown to yellowish brown or brown. There is a bleached A. horizon and below this the texture gradually becomes heavier through clay loam to clay. Structure throughout is poor, usually massive, breaking to single grain or fine crumb. Depths to clay vary depending on slope, parent material and probably rainfall. Profiles frequently are nearly lithosolic, but still show the typical leptopodsol features. The parent material is usually Silurian or Lower Carboniferous sedimentary rocks and in some areas Tertiary sediments. The Carboniferous rocks frequently impart a reddish to purplish colour to the soils derived from them.

These are the most widely distributed soils in the catchment. They are found under most of the drier vegetation types, particularly in the mountainous areas in the central parts of the catchment. In the south, they occupy the intermediate slopes between solodic soils on flatter areas and colluvial brown earths or lithosols on steeper slopes.

The following example occurred under regrowth of *E. camaldulensis,* on the Seaton road about half a mile from Glenmaggie, where parent material is Tertiary river gravels:

0"– 7" dark greyish brown (10 YR 4/2); coarse sandy loam; structureless, to weak, fine to very coarse, sub-angular blocky structure; moist, firm consistency; merging quickly into

7"–11" pale brown (10 YR 6/3); gravelly loam; massive; moist, firm consistency; merging quickly into

11"–14" light yellowish brown (10 YR 6/4); gravelly clay loam; massive structure; moist, very firm consistency; merging quickly into

14"–19" light yellowish brown to brownish yellow (10 YR 6/5); gravelly clay; massive structure; moist, very firm consistency; merging into

19"+ yellowish brown (10 YR 5/8); gravelly heavy clay; massive structure; moist, very firm consistency.

(iv) Prairie Soils.

A typical prairie soil has a high clay content throughout, is well-structured, and is usually dark brown, dark red brown or black. There is no accumulation of carbonates.

In this catchment these soils are confined to the areas where basalt is the parent material and rainfall is about 25"–30" per annum and temperatures are mild. Where basalt occurs as a capping to high mountain peaks, low temperatures have influenced soil development, and alpine humus soils or soils with krasnozem and cryptopodsol features occur. The fertility of soils derived from the basalt may be expected to be higher than that of soils derived from sedimentary rocks, under similar environmental conditions.

The following example is from under a woodland of *E. camaldulensis* about four miles from Glenmaggie on the Licola road, on Tertiary basalt:

0"– 2" black (10 YR 2/1); clay loam; moderate to strong, fine crumb structure; moist, friable consistency; small roots and organic matter abundant; merging into

2"– 5" black (10 YR 2/1); light clay; moderate, fine to medium, sub-angular blocky structure; moist, firm consistency; merging into

5"– 9" black (10 YR 2/1); clay; moderate to strong, fine to medium, angular blocky structure; moist, firm consistency; small ferruginous concretions numerous; merging quickly into

9"–14" + very dark grey (2·5 Y 3/1); heavy clay ; moderate to strong, medium, angular blocky, tending to columnar structure; moist, very firm consistency; fragments of decomposing basalt becoming more frequent with depth.

The occurrence of prairie soils is restricted to basalt capped tops of the rounded hills land form north of Glenmaggie; however, not all of the rounded hills have basalt capping.

(v) Solodic Soils.

The typical solodic soil in this catchment has a shallow A horizon, 8"–12" to the top of the B horizon, and is usually fairly gravelly. The A_1 horizon is usually a brown loam to gravelly loam; the A_2 horizon is pale brown to grey loam to gravelly loam. The change to the heavy clay B horizon is sharp. Colour of the B horizon clay is generally yellow brown.

These soils are formed on the gentler slopes of the more maturely dissected areas, for example to the south of Licola and around Glenmaggie. The parent material may be Tertiary gravels or derived from older sedimentary rocks. Soils derived from basalt on similar slopes in this area are prairie soils. In drainage lines below basaltic soils and other situations where basalt has indirectly influenced soil development, soils with some solodic features occur. The influence of the basalt, however, is often shown by the dark soil colours for example, or an extremely well-structured B horizon clay, or development of a friable A_1 horizon with abundant organic matter.

The following description is of a solodic soil from undulating country near the edge of the reservoir, on Tertiary sediments, where the vegetation is a tall dry sclerophyll forest of *E. obliqua–E. rubida* alliance:

0"– 4" very dark greyish brown (10 YR 3/2); sandy loam; structure-less, to weak, fine to very coarse, sub-angular blocky structure; moist, friable to firm consistency; merging quickly into

4"-13" brown (10 YR 5/3); coarse sandy loam; structureless, to weak, fine to very coarse, sub-angular blocky structure; moist, firm consistency; abruptly over

13"+ yellowish brown (10 YR 5/6) with faint orange mottles; coarse sandy heavy clay; massive structure; moist, extremely firm consistency.

Solodic soils are found only on the undulating to rolling country. Their chief occurrences are around Glenmaggie and the country just to the north and also around Licola and south to Mother Budd's Creek.

(vi) Brown Earths.

Brown earths typically have a loamy A_1 horizon and show only slight increase in texture. There is little or no increase of clay content with depth, the lighter texture of the surface horizons being due to organic matter. Colours are brown changing to yellowish brown at depth. The structure at the surface is usually good fine crumb and grades through to a poorly structured B horizon. The consistency of the whole profile is usually soft or friable.

The sub-group of colluvial brown earths is the one found commonly in this catchment. Typically the colluvial brown earths contain considerable quantities of unweathered rock fragments. Their colour and texture is largely governed by the parent rock. The Carboniferous sandstones are frequently a rich red, which impart a reddish-brown colour to the soils formed from them. Generally, however, colours are brown. The textures may be from sandy loams to clay loams. The texture shift down the profile is small.

These soils occupy the steepest slopes on which soils are formed in the drier parts of the catchment. Because of the steepness of these slopes, very gradual movement of material down the slopes is common. This results in constant additions in the form of unweathered rock fragments and also some soil material which has the effect of maintaining the base status and preventing podsolization (Costin, 1954).

The following is an example of a colluvial brown earth from a slope of 60 per cent on the south-west side of the Barkly River at the junction of Glencairn Creek. The parent material is Carboniferous sandstone and the vegetation is a shrub woodland of *E. melliodora-E. polyanthemos* alliance:

0"- 3" very dark greyish brown (10 YR 3/2); coarse sandy clay loam ; moderate to strong, very fine to medium, crumb structure; moist, friable consistency ; merging quickly into

3"- 8" very dark brown (10 YR 2/3); coarse sandy light clay; moderate, fine to medium, crumb to sub-angular blocky structure; moist, friable consistency; merging gradually into

8"-15" dark brown (7·5 YR 3/2); coarse sandy clay; moderate, fine to medium, crumb and sub-angular blocky structure; moist, friable consistency.

Rock fragments are common in the profile and abundant below 15 inches.

(vii) Lithosols.

These soils consist largely of rock fragments with small quantities of soil between them. They usually show no horizon differentiation.

They are to be found on steep slopes where rock fragments are constantly being added or in areas where, although slopes are steep, they are not steep enough to maintain a lithosol without the influence of other factors. On the high plains low temperatures and probably wind erosion have combined to restrict soil formation in many places, particularly on exposed situations. In the south of the catchment it seems that low rainfall and possibly sheet erosion have combined to cause profile degradation to a lithosol. Some lithosols from adjacent to the reservoir show weak leptopodsol features, for example, about 2"–3" of soil in which a slightly bleached A_2 horizon is apparent.

Because of the fairly widespread occurrence of areas of low temperatures, low rainfall and/or steep slopes, lithosols are fairly common in this catchment.

(viii) Soils with Less Extensive Distributions.

(1) Alluvial Soils.—These are, no doubt, of importance for agriculture, but they are not of great extent in the catchment. Generally the valleys are narrow and sloping so that the actual areas of alluvial soils are small. The most important occurrences are along the Macalister River between Licola and the reservoir along the Glenmaggie Creek for several miles above the reservoir and at Glencairn. Small occurrences along the Wellington River just north of Licola are also of some importance.

The following is an example of an alluvial soil from the Macalister River just north of Licola: —

0"– 2" dark brown fine sandy loam, abruptly over 2"–10" dark brown loam, abruptly over

10"–34" brown loam, abruptly over

34"–42"+ brown gravelly loam.

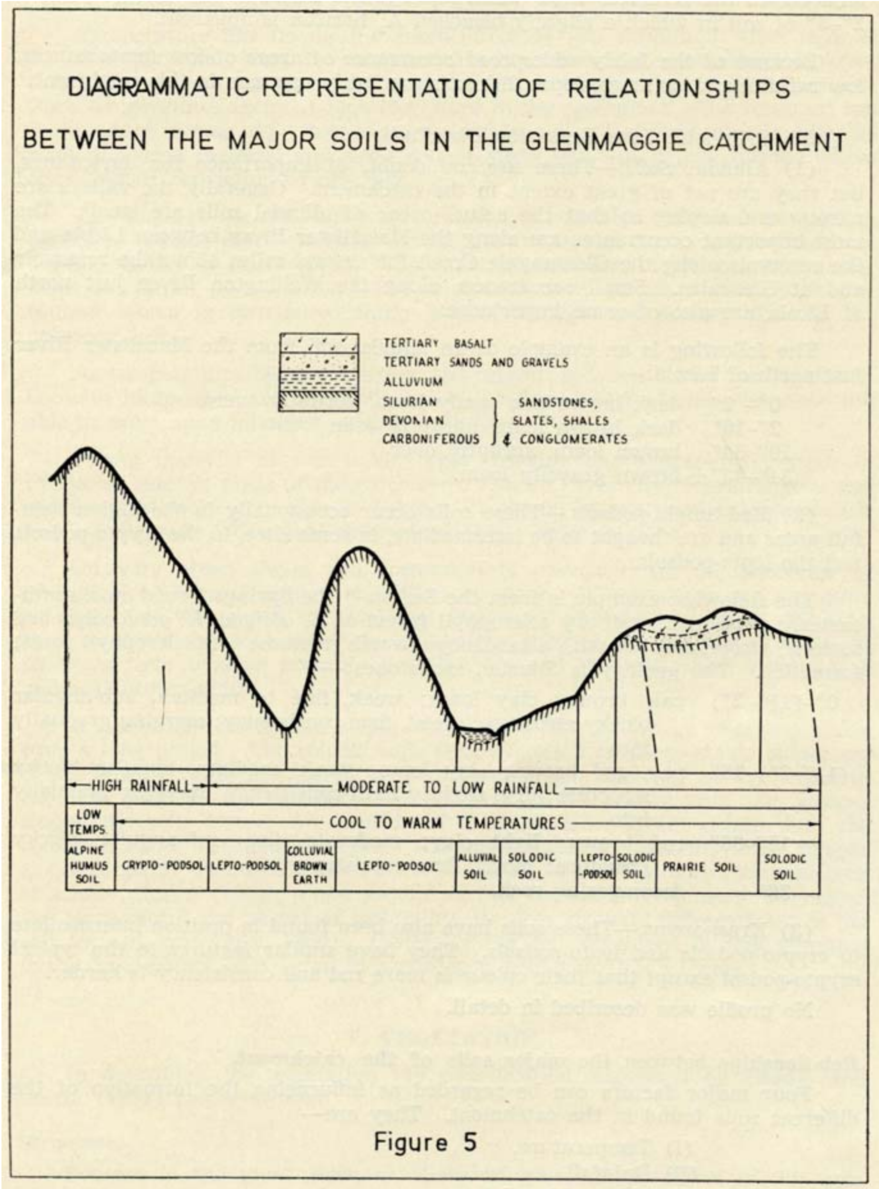

Figure 5 – Diagrammatic representation of relationships between the major soils in the Glenmaggie Catchment

(2) Red amphipodsols.—These soils occur occasionally in the higher rain-fall areas and are thought to be intermediate, in some sites, to the crypto-podsols and the leptopodsols.

The following example is from the Seaton–"The Springs" road on a south-easterly slope under tall dry sclerophyll forest of *E. obliqua, E. goincalyx* and some *E. sieberiana,* but with a tendency towards montane wet sclerophyll forest formation. The geology is Silurian sandstones:

0"-(1k"–2")	pale brown; clay loam; weak, fine to medium, sub-angular blocky structure; moist, firm consistency; merging gradually into
(1k"–2")–15"	pale red brown; clay loam; weak, medium, angular blocky structure; dry, slightly hard consistency; merging gradually into
15"–36"	red brown; light clay; moderate, fine, sub-angular blocky structure; moist, firm consistency;
36" +	decomposing rock.

(3) Krasnozems.—These soils have also been found in position intermediate to crypto-podsols and leptopodsols. They have similar features to the typical cryptopodsol except that their colour is more red and consistency is harder.

No profile was described in detail.

Relationships between the major soils of the catchment.

Four major factors can be regarded as influencing the formation of the different soils found in the catchment. They are

(i) Temperature.
(ii) Rainfall.
(iii) Parent Material.
(iv) Slope.

All act together in the development of the soil, but their relative importance varies. Reference to Fig. 5 will give a general idea of the relationships.

Temperature has its most marked effect on soil formation when it is at its lower extreme. Very low temperatures limit chemical weathering of parent material and restrict the breakdown of plant remains by micro-organisms. Such temperatures occur at high elevations in the catchment. The resultant soil is the alpine humus soil. Because of the dominance of temperature, other factors such as parent material and slope do not affect the type of soil formed unless slope causes restriction of drainage.

As temperatures rise, but where rainfall is still high, chemical weathering begins to become more effective. Plant growth is vigorous and breakdown of organic matter is fairly rapid. The rapid humification of the organic matter helps to restrict podsolization. The soil which develops has a fairly high clay content which is distributed fairly evenly through the profile. This is the cryptopodsol.

As temperatures become warmer and rainfall becomes lower, the vegetation becomes more open and xerophilous. Rainfall, parent material, and slope are able to exert more influence on soil formation.

Parent material of two broad types, basaltic and sedimentary, occur in the lower rainfall areas of the catchment. Basalt gives rise to prairie soils and sedimentary rocks give rise to lithosols, colluvial brown earths, leptopodsols and solodic soils. The final determinant here becomes slope.

On very steep slopes soil formation is prevented by the processes of geological or normal erosion and lithosols occur. Where slopes are not quite so steep, but where soil material and fragments of parent material still tend to move down the slope under the influence of gravity, the continuous additions of bases from upslope prevents podsolization and the soil which results is a colluvial brown earth.

It seems that the gentler slopes of the lower hills have been relatively stable over a long period. The solodic soils which develop on these stable slopes are polygenetic, and are considered to be of older origin than any of the others in the drier parts of the catchment, except perhaps the prairie soils. On steeper slopes, the soils formed are considered to be of more recent origin than the solodic soils of the gentle slopes. Although stable at present, these steeper slopes probably would have been unstable during one of the more recent periods of aridity, thus providing a new ground surface for soil development. Generally, the more recent the period of instability, the less strongly differentiated is the soil formed (van Dijk, 1959). Generally the soil developed in this situation is the leptopodsol, this being in accordance with van Dijk's theory.

V. VEGETATION.

In describing the vegetation the classification suggested by Beadle and Costin (1952) has been used.

Structure.

Because of the great diversity of major species to be found in this area (over 30 species of eucalypts alone), a primary subdivision of the vegetation according to structure will help to simplify the discussion.

Six major sub-formations are recognized

(i) Wet sclerophyll forest.
(ii) Dry sclerophyll forest.
(iii) Shrub woodland.
(iv) Sub-alpine woodland.
(v) Tall woodland.
(vi) Sod-tussock grassland.

Further subdivision can be made of wet sclerophyll forest into montane and riverine wet sclerophyll forest, and of dry sclerophyll forest into tall dry sclerophyll forest and short dry sclerophyll forest. The high plains area contains fragments of many vegetation sub-forms but they are not of great extent. Some of the more important are

(1) Alpine Herbfield.
(2) Heath.
(3) Raised Bog.
(4) Valley Bog.

The bogs are thought to be of great importance in regulating stream flow throughout the year. They consist of masses of water-holding sphagnum moss *(Sphagnum cristatum).* Costin (1957b) has described in detail the vegetation of the high mountain country.

Floristics.

During the field work, spot investigations of soil and vegetation were made. No conscious attempt was made to determine minimal areas of the vegetation types and thus, although the species present at the spot were recorded, there is no certainty that this represents an association as defined by Beadle and Costin. Thus the term "species group" is used in place of "association".

Vegetation floristics will be discussed under each of the sub-formation headings.

(i) Montane Wet Sclerophyll Forest.

The species occurring in this sub-formation have been grouped into three alliances, all of which are found in the mountainous areas.

(1) *E. delegatensis* alliance. The species groups known to be present in this alliance are

E. delegatensis
E. *delegatensis, E. goincalyx*
E. *delegatensis, E. rubida*
E. *delegatensis, E. nitens*
E. *nitens, E. pauciflora*
E. nitens
E. pauciflora

A dense understorey of such shrubs as *Acacia penninervis, A. dealbata, Coprosma nitida, Oxylobium alpestre, Daviesia corymbosa var. laxiflora, D. latifolia,* and *Veronica derwentia*, is usually present.

Plate 2.-Montane wet sclerophyll forest of *E. delegatensis* alliance.

(2) E. obliqua–E. viminalis alliance.—The main species groups known here are

E. obliqua, E. viminalis, E. goincalyx
E. viminalis, E. radiata
E. radiata, E. obliqua

The understorey is generally less dense than under the *E. delegatensis* alliance and contains such species as *Acacia dealbata, Daviesia latifolia* and *Cassinia spp.*

This alliance is generally found between the *E. delegatensis* alliance and the tall dry sclerophyll forest. It is a drier vegetation than the *E. delegatensis* alliance, but still within the wet sclerophyll forest sub-form.

(3) E. regnans alliance.—This alliance has only one dominant species—*E. regnans.* It is rarely that *E. regnans is* found growing in association with other eucalypts and then only at the limits of its range, where it may occur, for example, with *E. delegatensis, E. obliqua,* or *E. viminalis.*

The understorey vegetation is typically dense and consists of such species as *A. dealbata, Cassinia spp.* and *Pomaderris apetala.*

This alliance is found in wet, sheltered gullies at elevations between 1,500 feet and 3,000 feet. It has a fairly restricted occurrence in this catchment.

(ii) Riverine Wet Sclerophyll Forest.

As the name suggests this vegetation type is associated with perennial streams, where it forms a narrow strip following the course of the stream, generally through much drier vegetation types, for example in the Wellington River Valley.

(1) E. viminalis alliance. This is the only alliance recognized in this vegetation sub-formation. The species components are *E. viminalis* and rarely *E. bridgesiana.* Shrub species such as *Acacia melanoxylon, A. dealbata, Bursaria spinosa, Dodonaea cuneata* and *Leptospermum ericoides* are usually present.

(iii) Tall Dry Sclerophyll Forest.

Two alliances are recognized here. A large number of eucalypt species is associated with this subformation and it is difficult to separate more than the two alliances even although one consists of at least sixteen species groups.

(1) *E. obliqua-E. rubida* alliance. Of the two alliances this is the more mesophilic. Its main occurrence is on the western side of the catchment in the intermediate rainfall zone. The main species groups known are:

E. obliqua, E. viminalis
E. obliqua, E. sieberiana, E. radiate
E. obliqua, E. sieberiana, E. goniocalyx
E. goniocalyx, E. sideroxylon, E. muelleriana E. radiate
E. radiata, E. rubida, E. scabra
E. rubida, E. radiate
E. rubida.

The undergrowth is usually sparse and consists of such species as *Acacia pycnantha*, *Sty pandra glauca, Platylobium formosum,* and *Pteridium esculentum*.

(2) *E. melliodora-E. macrorhyncha-E. polyanthemos* alliance.--This alliance occurs over large areas in the central part of the catchment, mainly in the rain-shadow affected areas, for example in the Licola-Licola North area. It contains a large number of species groupings which, however, all appear to have affinities and cannot be satisfactorily separated even into sub-alliances. The known species groupings are:

E. melliodora, E. bridgesiana
E. melliodora, E. macrorhyncha, E. bridgesiana
E. melliodora, E. macrorhyncha, E. bridgesiana, E. polyanthemos
E. melliodora, E. macrorhyncha, E. polyanthemos
E. melliodora, E. macrorhyncha, E. elaeophora
***E.** melliodora, E. macrorhyncha*
E. macrorhyncha, E. maculosa
***E.** macrorhyncha, E. bridgesiana*
***E.** macrorhyncha, E. elaeophora*
***E.** macrorhyncha, E. rubida, E. radiate*
E. macrorhyncha, E. polyanthemos, E. camaldulensis
***E.** macrorhyncha, E. polyanthemos, E. sideroxylon*
E. macrorhyncha, E. polyanthemos
E. polyanthemos, E. scabra
E. polyanthemos, E. elaeophora
E. polyanthemos

Plate 3.-Tall dry sclerophyll forest of *E. obliqua-E. rubida* alliance.

Native grasses, notably kangaroo grass *(Themeda australis)* and tussock grass *(Poa spp.)* make up most of the ground flora, which is, in places, very patchy.

(iv) Short Dry Sclerophyll Forest.

The only alliance recognized with this structure has the same species groups as the *E. melliodora—E. macrorhyncha—E. polyanthemos* alliance of the tall dry sclerophyll forest form. This alliance is the drier counterpart of the tall dry sclerophyll forest alliance. The form of the trees approaches that of woodland trees or even shrubs at times and in many cases it may be more correct to call the structure a woodland or dry scrub. Undergrowth is also the same as for the other alliance.

The short dry sclerophyll forest form of this alliance is confined to the more severe rain-shadow areas and sites which are dry by virtue of northern aspect and steepness of topography, for example northerly aspects in the Wellington River valley near the Dolodrook River junction.

Plate 4.-Short dry sclerophyll forest of *E. melliodora-E. macrorhyncha-E. polyanthemos* alliance.

(v) Shrub Woodland.

Because of the inaccessibility of much of the country on which this type of vegetation grows it may be that some species groups have been omitted. Only one alliance is recognized here.

(1) *E. melliodora-E. polyanthemos* alliance. The species groups known are

E. melliodora, E. macrorhyncha, E. elaeophora
E. melliodora, E. elaeophora
E. melliodora
E. polyanthemos

The shrub species are usually *Exocarpos cupressiformis, Casuarina stricta, Bursaria spinosa* and sometimes *Acacia implexa* with scattered native grasses such as *Themeda australis* and *Poa* spp. Ground flora consists predominantly of annuals and during the summer, vegetative ground cover may be less than 60 per cent.

This vegetation grows in an extremely dry environment on steep slopes and northern aspects, for example the very steep northerly aspects in the Barkly River on the road to Licola North.

Plate 5.-Shrub woodland of *E. melliodora-E. polyanthemos* alliance on a steep northern aspect in the Barkly River valley.

(vi) Sub-alpine Woodland.

The alliance here is comparatively simple. The species groups known are

E. pauciflora
E. pauciflora, E. kybeanensis
E. kybeanensis, E. stellulata E. stellulata.

The alliance is referred to as the *E. pauciflora* alliance.

The species *E. kybeanensis* has not been seen in woodland formation; however, it does grow in association with woodland form of *E. pauciflora* and is included in the alliance. It usually has a mallee habit and is seldom more than 20 feet high. This form may not be climax because of the influence of fires and grazing. *E. kybeanensis is* found mainly around Mt. Useful.

The dominant species is *E. pauciflora,* which occurs almost continuously around the catchment boundary from Mt. Skene to Mt. Wellington. *E. stellulata is* found in situations, such as the Bennison Plain, where soil water availability is greater than on the ridges.

(vii) Tall woodland.

The species found growing in this form can be grouped into one alliance —*E. camaldulensis* alliance. However, because of differences in water requirements two sub-alliances are recognised.

(1) *E. camaldulensis* sub-alliance.

E. camaldulensis

(2) *E. macrorhyncha—E. polyanthemos* sub-alliance.

E. polyanthemos, E. macrorhyncha
E. melliodora.

The *E. camaldulensis* sub-alliance is normally found on undulating country adjacent to rivers. The other sub-alliance occurs on some of the drier slopes and ridge tops of the southern part of the catchment, for example, on the hills to the north of Glenmaggie.

(viii) Sod tussock grassland.

The alliance here is dominated by a single species - *Poa australis.*

Other associated species are *Danthonia nudiflora,* and occasionally *Celniisia longifolia.*

Its occurrence, in this catchment, is limited to the sub-alpine areas known as the high plains.

VI. SOIL EROSION.

The types of erosion to be found in the catchment are described here. Their occurrence is discussed in detail in Section IX. (Land Systems).

There are two prime causal agencies involved in soil erosion—wind and water. Both of these are active in this catchment, however, water erosion is the more obvious and the more important.

Erosion consists of three phases, detachment, transportation, and deposition of soil particles. Removal of soil material from its original position and deposition elsewhere results in loss of fertile top soil and usually the covering of other farming land by soil material often of low fertility. The finest soil particles, which are the source of most plant nutrients, are usually carried in suspension by wind or water, and may be lost to the sea or deposited in the beds of reservoirs. The net result is economic loss to the nation as well as to the landholder.

The problems in this area are those of actual loss of the soil from the land and its deposition in the Glenmaggie reservoir, both of which obviously affect landholders in the area. The soil loss affects those who have land in the catchment and the deposition affects those who are dependent on the reservoir for their water.

(i) Wind erosion.

Strong gusty winds will cause movement of soil particles from bare soil, even to the extent of transporting them in the air for long distances. Large particles may roll or bounce along the surface. The result is the removal of loose soil material from large areas where the soil is exposed to the wind. This is a form of erosion which occurs on the tops of land masses of high elevation in this catchment where extremely strong winds are experienced. Excessive exposure of the soil in these areas by damage or removal of the vegetation cover, usually by burning, over-grazing or deliberate clearing can lead to serious soil losses by wind erosion.

The high plains area in general and particularly those parts exposed to the westerly winds are extremely susceptible to this form of erosion.

(ii) Water erosion.

The usual forms of water erosion are to be found in this area, viz.:

Sheet erosion
Gully erosion
Tunnel erosion
Roadside erosion
Stream-bank erosion
Scouring of stock tracks.

(1) Sheet erosion.—Consists of removal of sheets of soil over large areas. Incomplete ground cover is a prerequisite for sheet erosion. Where a dense vegetation cover exists, run-off is slower and any soil particles which are carried will be trapped by the plant parts. Pedestalling of grass tussocks, exposure of tree roots and accumulation of soil on the up-slope sides of rocks, trees, posts, &c., are all evidence of the past occurrence of sheet erosion.

Lack of adequate vegetation cover over much of the central mountainous part of the catchment and the damaged condition of the vegetation on the high plains, are the main causes of the occurrence of this form of erosion. Burning and over-grazing may have been responsible for the development of the present type of vegetation on much of the country in the central mountainous part of the catchment and it seems probable that the condition of much of the high plains country is the result of similar practices. Erosion of these areas probably results from severe summer storms when the ground vegetation of the slopes is sparse. This type of erosion is the most widespread in the catchment.

(2) Gully erosion.—The concentration of run-off water in areas where soil cover is sparse and soil particles are unstable will result in the removal of soil from the area. The soil surface becomes cut into grooves, varying from a few to many feet in depth. There are two commonly recognized forms of gullies—those with a V-shaped section and those with a U-shaped section. The latter result when underlying layers are more easily eroded than those above them. The U-shaped gully is thus a result of the combination of both vertical and lateral erosion and caving-in of the undermined surface soil.

In this catchment, gully erosion is most common on the lower slopes where the soils are solodic or leptopodsols, and in the area of prairie soils. Gullies up to six feet deep have been seen in country adjacent to the reservoir. Occasionally gully-heads are found to be forming from tunnels (see next subsection for tunnel erosion). V-section gullies are the more common. This is no doubt due to the nature of the soils and the shallowness of the parent rock in these areas.

(3) Tunnel erosion.—As the name suggests this form of erosion results in the formation of tunnels through the subsoil. These are considered to result from the accumulation of run-off waters in depressions in the surface soil where infiltration is more rapid than elsewhere. Dispersion of the soil along cracks in the subsoil clay usually follows and the dispersed clay is carried in suspension down-slope and emerges through other lines of weakness. Early evidence of tunnel erosion is the appearance of mud flows from small holes in hillsides. Enlargement of the tunnel occurs and ultimately the roof caves in and a gully is formed. Downes (1949) has described in detail the method of tunnel formation around Dookie.

It does not appear to be a widespread problem in this catchment.

(4) Roadside erosion.—This usually takes the form of gullies along the sides of roads, but sometimes sheet erosion occurs with the gullying. Roadside erosion is considered a separate kind of erosion problem, as distinct from gully erosion, because of the means by which the run-off is concentrated. The eroding gullies are formed by the accumulation of excessive water in the road drains, a lot of which is derived from the country on the up-slope side of the road. The water is not permitted to follow its natural drainage lines because the road cuts across them. In addition, the impervious nature of the road surface results in additions of large quantities of water to the drains. If sufficient provision for the safe disposal of these accumulated waters is not made, serious erosion of the roadside drains will result. This is particularly so where road grades are steep and the soil is of an erodible type.

In this catchment, roadside erosion has caused bad gullies along some roads. Where roads are in steep country, proper disposal of drainage water can be achieved by providing sufficient culverts at close intervals to prevent large amounts of water accumulating and moving at high speeds in the drain.

(5) Stream-bank erosion. - The fairly fast and turbulent movement of the river waters when at high levels, erodes away the base of the banks of alluvial flats, particularly on the outside of bends. Once the undermining has proceeded far enough, the banks cave in and the soil is washed away. At normal low water levels the river flows much more slowly and has a much reduced erosion potential.

Stream-bank erosion is a problem along the Macalister river below Licola where extensive alluvial flats occur. Probably much of the siltation which is occurring in the Glenmaggie reservoir is derived from erosion of the banks of the river as it flows through these flats. That such a problem exists seems to indicate that the river is behaving abnormally. Severe flash floods and the maintenance of abnormally high flood flows, which will cause most of this type of erosion, are the result of excessively high run-off from areas higher up the catchment.

***(6) Scouring of Stock* Tracks.**—Both sheep and cattle tend to follow well-defined tracks. The constant trampling destroys the vegetation and pulverises the soil. During heavy rain, the lack of vegetation allows free movement of water down these tracks and the loosened soil is readily eroded. Continuance of this process can result in quite deep scours. In many places several stock tracks converge down the slope to the point of congregation of the stock. Concentration of water in this way can lead to quite serious erosion.

This fairly widespread form of erosion has been seen on the high plains country and on cleared hills in the south.

(iii) Mass Movement of Soil.

Included in this section are those forms of erosion in which large areas of soil are moved, usually by flowage, slippage or subsidence.

(1) Slumps
(2) Earth flows
(3) Solifluction
(4) Soil creep.

Other forms of mass movement, such as debris-avalanche, rock creep, talus creep and rapid slips, are rare in this catchment, and may be more correctly regarded as geological erosion.

(1) Slumps are common on steeply sloping land which has been cleared of all its native woody vegetation, which probably had a higher water usage than the native grasses which replace it. Certainly the root system of the native trees and shrubs would be a better soil holding mechanism than shallow rooted grasses.

This is a very common form of erosion over much of the cleared hill country.

(2) Earth flows result when a mass of soil moves slowly down-slope generally causing a sunken area at the head of the flow and a bulge at the base. Movement is aided by excessive water in the soil. This form of erosion does occur to a limited extent in the cleared country.

(3) Solifluction *is* movement of soil on slopes aided by the presence of excessive water as in the case of simple earth flows. However, freezing of the soil moisture enables the water to accumulate in the soil. When thawed out, this excessive water causes the mass soil movement in just the same manner as in the earth flow.

Freezing of soil moisture is most severe at high elevations and, thus, solifluction can be regarded as a major cause of the mass movement of soil in these areas. When an adequate vegetation cover is maintained the action of solifluction can be regarded as part of the normal or geological erosion. Adequate vegetative cover reduces the number of occasions when freezing can occur, because of the insulating effect of the cover. However, when the protective vegetation is damaged or removed, the exposed soil lacks both the insulating effect of the plants and the binding effect of the plant roots, and thus becomes more vulnerable to this form of erosion.

(4) Soil creep is a general, imperceptible movement of soil down the slope. Some of the signs that soil creep is occurring or has occurred are, greater depth of the soil at the base of the slope, and a down-slope lean on posts and trees.

This is probably a fairly common form of soil movement in steep country. Although it does occur under undisturbed conditions, removal of the native vegetation can cause acceleration of the movement.

Stock terracettes are considered by Costin (1950) to result, very often, from the combined action of solifluction and trampling by stock.

VII. LAND FORMS.

The fundamental unit of the land system is the land form which is a specific configuration of the land surface (Downes, Gibbons, Rowan and Sibley, 1957). A total of eight land forms have been identified in this area and were used in deciding the delineation of the land systems. They are:

(i) exposed plain
(ii) sub-alpine valley
(iii) rocky ridge
(iv) high montane
(v) low montane
(vi) rounded hills
(vii) foothills
(viii) river flats.

The terms used to describe slopes have the meanings described in the Soil Survey Manual of the United States Department of Agriculture, 1951.

***(i) Exposed* Plain.**—This land form consists of sloping land at high elevations which, because of its westerly aspect, is exposed to strong and cold winds. Mt. Reynard and the Long Spur are excellent examples. This land form occurs extensively along the western side of the eastern boundary ridge.

(ii) Sub-alpine Valley.—These are valleys at high elevations. They usually have gently sloping floors; the sides rise slowly at first but then more steeply giving the valleys a broad, shallow, U-shaped section. General orientation is in a north-south direction. Cold air drainage in these valleys is an important environmental characteristic. Examples of this land form are Holmes' Plains and The Valley, through both of which flows Shaw's Creek.

***(iii) Rocky* Ridge.**—It consists of a low ridge usually between two sub-alpine valleys. It is usually a long, fairly level-topped ridge with an abundance of rock exposed. The sides are usually fairly steep, occasionally one side being a low escarpment. Orientation is generally north-south. The ridge to the west of Holmes' Plain is a good example of this land form.

***(iv) High* Montane.**—The high montane land form consists of narrow-topped mountain ridges which have steep to very steep slopes and ridge-top elevations from about 4,000 feet to over 5,500 feet. It occurs around the boundary in the northern part of the catchment. Good examples of this land form may be seen at many places, however the most accessible is probably the Mt. Selma–Spring Hill section of the Great Dividing Range.

***(v) Low* Montane**.—This land form is related to the previous one and consists of narrow-topped mountain ridges with steep to very steep slopes and having ridge-top elevations of up to about 3,500 feet. It occurs in the upper central part of the catchment and forms a great deal of the southern part. An-example is the Horse Hill Ridge running north from Licola.

(vi) Rounded Hills.—The rounded hills land form consists of broadly rounded hills with relatively flat to undulating tops and with sides which become steeper as they fall away. The drainage pattern causes the hills to appear rounded in plan also. The valleys between the hills are V-shaped and have steep floors. Many of these hills are capped with Tertiary basalt. This land form is of only limited occurrence and may be seen along the Licola road to the north of Glenmaggie.

(vii) Foothills.—These consist of rolling to hilly slopes which usually connect the low montane or rounded hills land form with the river fiats. Good examples of this land form are to be found around Glenmaggie and to the south of Licola.

(viii) River Flats.—The river flats land form consists of level to undulating flood plain deposits. Where the speed of the river is slowed, some of the transported solid material is deposited. Thus the most extensive river flats are built up above points where the river is caused to slow down, as at a bar of erosion resistant rock or where the river reaches flatter grades. Such river fiats are to be found along the Glenmaggie Creek and the Macalister River before they enter the headwaters of the reservoir and on the Macalister River between Licola and Mother Budd's Creek.

VIII. LAND USE.

Present land-use.

The chief forms of land-use in the catchment are:

(i) Protection forest
(ii) Timber production forest
(iii) Cattle grazing
(iv) Sheep grazing
(v) Cultivation for seed crops.

***(i) Protection* forest.**—Somewhere in the vicinity of 90 per cent of the catchment is covered with forest of which about 75 per cent to 80 per cent is of little or no commercial value for timber production based on present methods of utilization. This forested area is mainly in steep to very steep country and is largely inaccessible except on foot or horseback. The forest cover helps to protect the slopes from erosion and assists in the regulation of stream flow. These two functions of the forested lands are of the utmost importance in the continued satisfactory operation of the catchment as a water supplying area. Water, then, can be regarded as the main produce of this country, and as such ranks with timber as the most valuable contribution from the catchment to the country's economy.

***(ii) Timber production* forest.**—About 10 per cent or less of the catchment may be regarded as carrying potentially utilizable forests. Two types of utilization are common at present. There is virtually complete utilization of trees in areas of high quality ash-type forest. The bulk of the timber is removed as logs for milling into construction and joinery timbers. The remaining timber, except for a few trees per acre, which are retained to re-seed the cut over area, is taken for use as pulpwood at the A.P.M. mill at Maryvale.

The other type of utilization is to be found in the lower quality mixed species eucalypt forests. Here, selections of trees suitable for sawing into construction and joinery timbers are made. Generally, there is no further utilization of the remaining timber. However, other trees may be selected for production of fencing materials, sleepers, poles, &c. If the timber is of a good burning type and is readily accessible, more complete utilization of the remaining timber may be carried out for fuel.

Timber for sawmilling from the catchment has provided the basis for development of a large sawmilling industry in the nearby town of Heyfield. Also, the population of Licola is almost entirely dependent on employment at the sawmill located there.

Provision of access roads and tracks has accompanied the exploitation of the stands of commercial timber. These roads will be of great value in providing access for the protection of the catchment from fire.

(iii) Cattle grazing.—This is the most important agricultural pursuit in the catchment. As well as the grazing of beef cattle on freehold lands, advantage has been taken of the availability of grazing in Crown lands.

The grazing of cattle on the high plains area is also a well established part of the grazing industry in this catchment. Cattle are taken up to the high country soon after the snow melts, about October, and they are mustered and brought down to the low-lands for sale or for winter grazing in about April.

(iv) Sheep grazing.—Grazing of sheep in the catchment is primarily for wool. Probably the relatively low rainfall, and the difficulty of improving pastures on the steep country restricts the grazing of sheep for meat, to the areas in the southern part of the catchment.

Wool production would rank second in importance, agriculturally, to the breeding of beef cattle in the catchment.

***(v) Cultivation for seed* crops.**—Use is made of the fertile soils found on the river flats for the cultivation of crops of maize, and occasionally sunflowers are also grown. Cultivation of the flatter slopes of the prairie soils for sunflowers is also carried out on a limited scale.

The availability of soils suitable for cultivation is not being fully exploited. Greater use could probably be made of the river flats for cultivation crops.

Cultivation of river flats for pasture improvement has recently been carried out in some parts.

Land-use classification.

Here the various types of country are arranged under the Six Land-use Classes as defined by Downes (1949), and extended in the amended Soil Conservation Authority Field Data Book. A more detailed discussion of recommendations is included in each Land System description.

Class 1. "Land suitable for cultivation without the need for erosion control measures to bring it to or to maintain it in its most productive state.

The only land which could come into this class is the river-flats land form along the Macalister River and Glenmaggie Creek and at Licola North. Its inclusion here may, however, be questioned as stream-bank erosion occurs on the river flats. However, this form of erosion is not aggravated by the land-use. Loss of top soil could perhaps be serious if the river was to flood when the land had just been cultivated. These considerations may cause the river flats form to be placed in Class 2 (a).

Class 2. "Land suitable for cultivation but in need of erosion control measures so that it may be brought to, or maintained in its most productive state

(a) no mechanical works are needed but broad rotations[*] and/or special cultivation practices[ƒ]- are essential;

(b) in need of the use of the contour principle; namely contour cultivation alone or together with closed banks, or graded banks and waterways."

Land with slopes of less than about 8 per cent, on the rounded hills land form would fit into Class 2 (a), for example, the undulating tops of many hills. Some of the Macalister River and Glenmaggie Creek flats may also be included in 2 (a).

Class 3. "Land unsuitable for cultivation but suitable for grazing without the need for erosion control measures to bring it to, or maintain it in its most productive state."

Parts of the rounded hills land form would belong in this class. Erosion in many of the steeper gullies would cause some of the land form to be placed in Class 4 (b). The inherent fertility of the basaltic soils is probably fairly satisfactory, but soils on this land form which are derived from sedimentary parent materials would belong in Class 4 or 5, depending on the steepness of the slopes.

Class 4. "Land suitable for grazing, but in need of erosion control measures so that it may be brought to, or maintained in its most productive state

(a) can be cultivated for pasture improvement and can be contour banked or furrowed;

(b) cannot be cultivated, but can be surface worked and contour furrowed for pasture improvement."

A good deal of the cleared country in the catchment belongs in this class. Areas of the rounded hills land form which have steep valleys and also those where the soils are derived from sedimentary material can be classed generally as 4 (b). Some of the undulating foothill land form, where slopes permit, would also belong in Class 4 (a) or (b). Cleared country to the north-east of the reservoir and some of the Target Creek and Licola North country, would also fit into Class 4 (a) or (b), depending on the slopes.

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[*] Broad rotations—with pasture 3 years out of 5 or more.

[ƒ] Special cultivation practices, for example: stubble mulching.

Class 5. "Land suitable for strictly controlled grazing where no erosion control measures or pasture improvement can be undertaken, except where special means of top-dressing are adopted, for example, by 'plane or blower."

The grassed areas of the high plains country could be included here. Any sort of cultivation may start active deterioration of the soils, vegetation and peats, because of the difficult climate. The economics of attempting to improve the grazing value of these areas has been considered by Costin (1958), and it seems unlikely that the attempt would be worthwhile. Top-dressing should produce an increase in the quantity of vegetation available; however, strict control of grazing in these areas is most essential. Probably fencing out of vulnerable parts of the area would be desirable, but very expensive, and maintenance costs would be high.

The remainder of the cleared country which has not been placed in any of the other classes could be regarded as Class 5. This includes the cleared low montane country around Licola. Strict control of grazing by landholders, including elimination of rabbits, is essential. Efforts to apply superphosphate may not necessarily meet with the desired effect. By encouraging legumes on this steep country the nitrogen level may be raised but this will encourage certain annual weeds which may result in elimination of the native perennials. Dying off of the annuals during summer would leave the soil exposed to erosion by summer and early autumn storms. Introduction of a perennial grass species which can compete with the annual weeds when fertility levels are raised may be a solution. Strict management control would be essential. This country, however, is a risky proposition for agriculture and would have been better left under timber.

Class 6. "Land unsuitable for agricultural production because of roughness, stoniness, wetness, infertility or extreme erosion hazard."

This class includes the greater part of the catchment. The high and low montane land forms really belong here. They are included, principally because of their steepness, stoniness and the probable low fertility of much of the soils.

IX. LAND SYSTEMS.

A land system is an area, delineated for the convenience of the survey, in which a limited number of land forms is present in a characteristic pattern (Downes, Gibbons, Rowan and Sibley, 1957). Delineation of the land system is followed by a description of the environment of each of the land forms within each land system.

In this catchment it has been found desirable, in order to simplify the description, to group a number of land forms together in some cases, and in others to regard areas in which only a single land form occurs as a land system.

The technique used in mapping has been a combination of field traverses and photo-interpretations. Vehicular tracks were used as far as possible and a certain amount of walking was done to cover the area as thoroughly as possible in the time available. Periodic examinations of the soils and vegetation were made along these traverses. The information on soils and vegetation was recorded, together with notes on topography and geology. As the survey progressed it was possible to recognize correlations between the soils, vegetation, topography and local climate.

In all, by these methods, six land systems have been distinguished. They are as follows:

Snowy Plains Land System.
Barkly Land System.
Wellington Land System.
Yangoura Land System.
Glenmaggie Land System.
Macalister Land System.

Snowy Plains Land System.

The Snowy Plains land system is located around the north-eastern, and parts of the northern boundary ridge and is all above 4,000 feet and the majority of it is above 4,500 feet elevation. It extends as a narrow strip from Mt. Magdala to Mt. Howitt and thence through the Howitt Plains to Bryce's Plain from where a broad extension continues down the spur between the Middle and East Caledonia Rivers. From Bryce's Plain it extends through the Snowy Plains to Mt. Reynard from which a broad extension runs down the Long Spur to the north-west towards the East Caledonia River. It continues as a broader strip from Mt. Reynard to Mt. Arbuckle from which Holmes Plain and Bennison Plain extend down Shaw's Creek. From Mt. Arbuckle the land system narrows and passes through the Carey, Plains and the Dry Hills to the Big Plain and Mt. Wellington. The ridge top from Mt. Wellington to Mt. Hump is included in this land system.

Three isolated occurrences of the land system are on Mt. Skene, Mt. Macdonald and on Mt. Clear, where part of the high ridge running between Coleman's Creek and the Macalister River is also included in the land system.

The Snowy Plains land system makes up about 12 per cent. of the catchment area. It consists almost entirely of Crown lands. However, the Mt. Macdonald area and part of the Mt. Clear area are State Forest and there is a small area of about 200 acres of freehold land on the Bennison Plain.

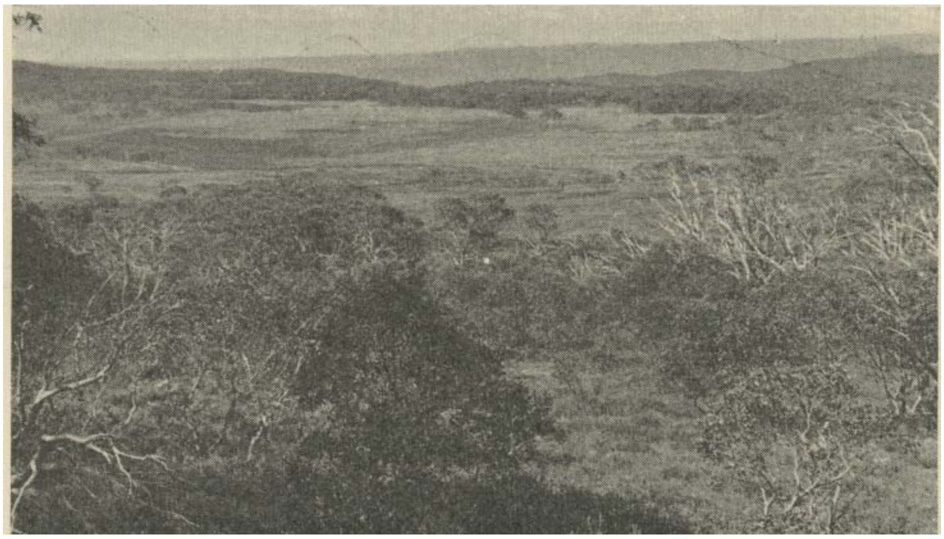
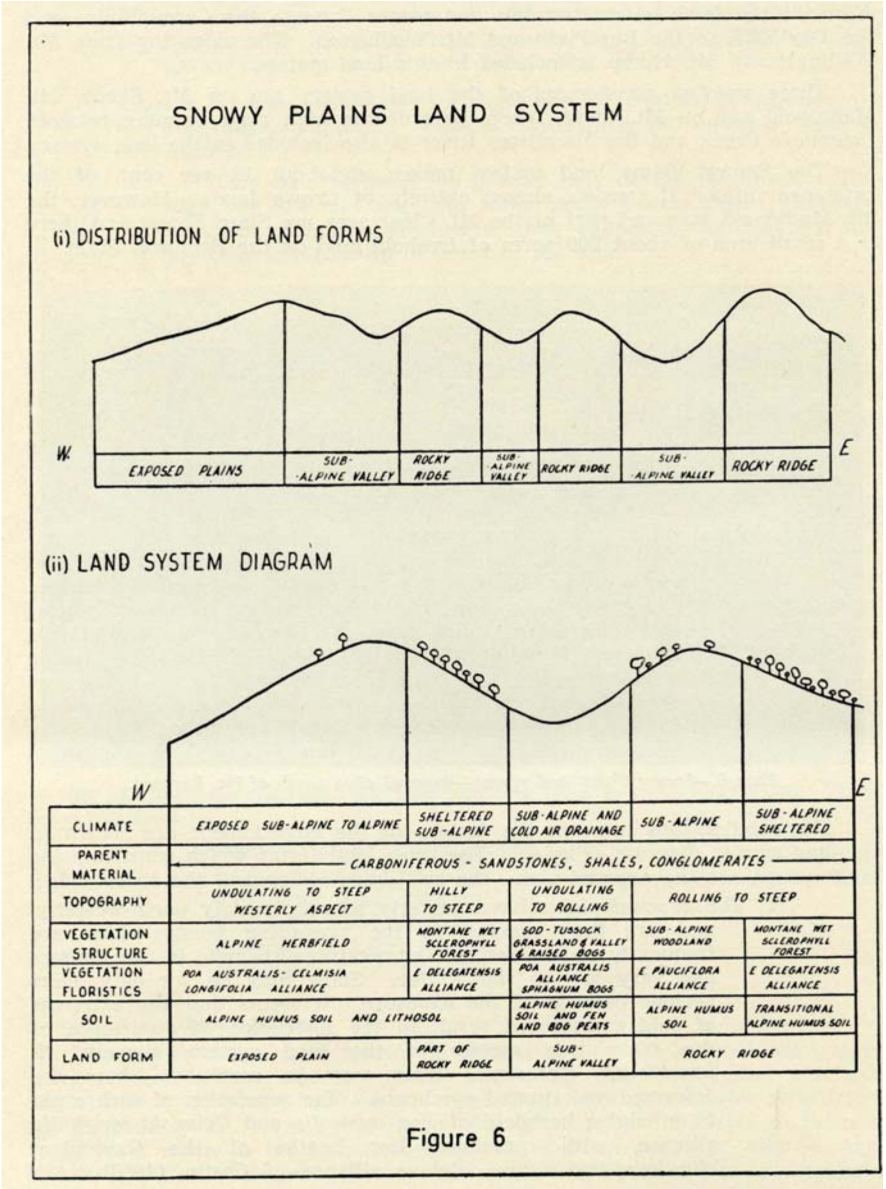


Plate 6.—Snowy Plains land system—exposed plain north of Mt. Reynard.

The relationships between the factors of the environment are shown in the land system diagram (Fig. 6). The three land forms which constitute the land system are the exposed plain, the sub-alpine valley and the rocky ridge.

(i) The ***exposed plains*** have westerly aspects, mainly north-westerly, and are thus exposed to the prevailing winds which are frequently of gale force. Temperatures are mild in the summer and very low in the winter. Snow may lie for only short periods because of the exposure. It seems that the extremes of cold experienced result in the restriction of occurrence of the main tree species of the land system, namely, E. *pauciflora.* Occasional trees may be seen but these are deformed and stunted specimens. The vegetation of such areas is an alpine herbfield of *Poa australis* and *Celmisia longifolia* alliance, with occasional low heaths of the *Oxylobium ellipticum-Podocarpus alpinus* alliance of Costin (1957b).

Slopes range from gently sloping to steep. Soils are lithosols or alpine humus soils.



	W				E
CLIMATE	EXPOSED SUB-ALPINE TO ALPINE	SHELTERED SUB-ALPINE	SUB-ALPINE AND COLD AIR DRAINAGE	SUB-ALPINE	SUB-ALPINE SHELTERED
PARENT MATERIAL	← CARBONIFEROUS - SANDSTONES, SHALES, CONGLOMERATES →				
TOPOGRAPHY	UNDULATING TO STEEP WESTERLY ASPECT	HILLY TO STEEP	UNDULATING TO ROLLING	ROLLING TO STEEP	
VEGETATION STRUCTURE	ALPINE HERBFIELD	MONTANE WET SCLEROPHYLL FOREST	SOD-TUSSOCK GRASSLAND & VALLEY & RAISED BOGS	SUB-ALPINE WOODLAND	MONTANE WET SCLEROPHYLL FOREST
VEGETATION FLORISTICS	POA AUSTRALIS-CELMISIA LONGIFOLIA ALLIANCE	E DELEGATENSIS ALLIANCE	POA AUSTRALIS ALLIANCE SPHAGNUM BOGS	E PAUCIFLORA ALLIANCE	E DELEGATENSIS ALLIANCE
SOIL	ALPINE HUMUS SOIL AND LITHOSOL		ALPINE HUMUS SOIL AND FEN AND BOG PEATS	ALPINE HUMUS SOIL	TRANSITIONAL ALPINE HUMUS SOIL
LAND FORM	EXPOSED PLAIN	PART OF ROCKY RIDGE	SUB-ALPINE VALLEY	ROCKY RIDGE	

Figure 6 – Snowy Plains Land System

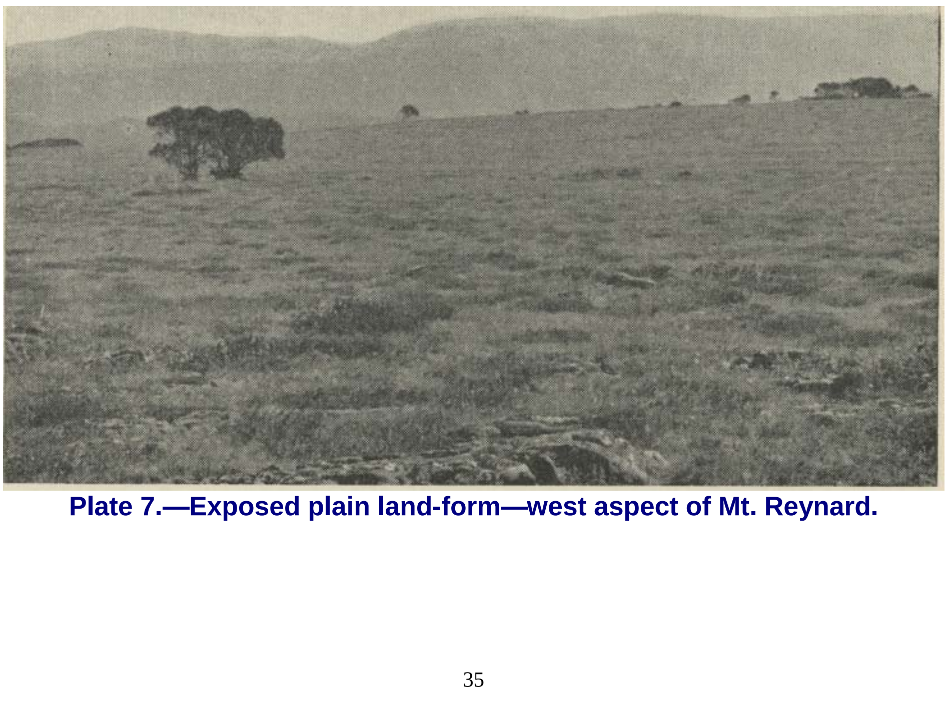


Plate 7.—Exposed plain land-form—west aspect of Mt. Reynard.

(ii) The ***sub-alpine valley*** land form exhibits an interesting restriction of occurrence of tree species due to low temperatures caused by the drainage of cold air from the slopes into the valleys. Creeks, drainage lines and bogs are to be found at the bottom of the valleys, where the vegetation is a fen of *Carex gaudichaudiana* or valley bog of *Sphagnum cristatum-Carex gaudichaudiana,* depending on the acidity (Costin 1957b). The floor of the valley, and for a short distance up the sides, sup-ports a sod-tussock grassland of *Poa australis* alliance with heaths and occasional savannah woodlands of *E. pauciflora* alliance as the sub-alpine woodland of the rocky ridge is approached.

The soils of the fen or valley bog are fen peats or acid marsh soils and valley bog-peats, respectively (Costin 1957b). Alpine humus soils occur under the sod-tussock grassland, heaths and savannah, or sub-alpine woodland. Slopes of the valley sides may be moderately steep but usually they are more gently sloping.

(iii) The ***rocky ridge*** land form consists of low, fairly broad ridges, running roughly north-south. Commonly the rock strata are exposed, particularly on eastern aspects, and on the tops of the ridges boulders or irregular rock outcrops are usually numerous. The vegetation is usually a sub-alpine woodland of *E. pauciflora* alliance on the western aspect and the top of the ridge. Eastern aspects, particularly where well sheltered, may have a montane wet sclerophyll forest of *E. delegatensis* alliance. The soils range from lithosols on the steeper slopes to alpine humus soil and transitional alpine humus soil on the sheltered slopes. Slopes may be steep though they are usually rolling to hilly.

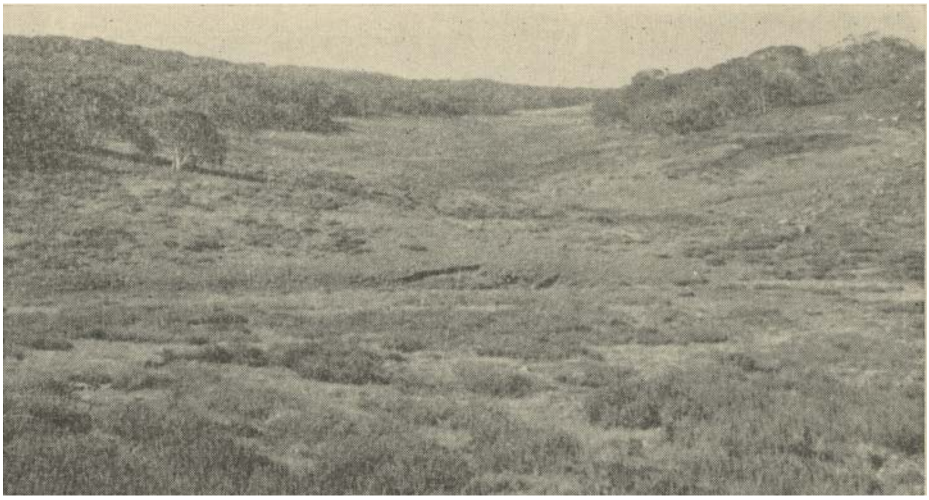


Plate 8.-Sub-alpine valley land-form—"The Valley".

This land system has a high erosion hazard, particularly to sheet erosion by wind and water and solifluction. Wind erosion is a hazard on the more exposed sites—for example, the exposed plains land form. Damage of the protective vegetation to the extent where bare soil is exposed could lead to serious erosion. Recovery would be very slow because of the shortness of the growing season at these elevations, and the susceptibility of regenerating vegetation on bare soil to frost heave, which can occur at all times of the year when the snow cover is absent.

Plate 9.—Damaged and sheet-eroded sod-tussock grassland of *Poa* australis. Note pedestalled tussocks.

Erosion of the water courses and bogs may have adverse results on regulation of stream flow and the water yield from the catchment.

At present some sheet erosion of most land forms does occur. This is evidenced by the pedestalled nature of the grass tussocks and bare soil between tussocks. This is not very serious yet, but continued damage of the ground cover can only result in further deterioration. Erosion of stream banks and stream entrenchment are both occurring and are fairly rapid where stock gather to drink. Stream entrenchment results in the drying out of bogs as the water table is lowered. Several degenerate bogs were seen in which the vegetation consisted of only scattered remnants of *Sphagnum* moss amongst the stones. Dryland heath species are beginning to invade many bogs indicating that they are drying out. Scouring of stock tracks is a common sight in this land system.

Plate 10.-A degenerate bog on a main stock route.

At present the Snowy Plains land system serves two land use purposes. First, and of greater importance, the area yields water. Because the winter snow does not melt for several months after it falls, water is released to the streams over a prolonged period. The indigenous vegetation of this land system when undamaged, has the ability to retard surface run-off, with a resultant slow release of water over a period. The second form of land use is the grazing of beef cattle which is a long established practice. Cattle are taken to the high plains in the spring and mustered and returned to the lowlands in about April. The actual quantity of stock carried per acre is not high but because of their preference for certain forms of vegetation the effective stocking on that particular vegetation type may be very heavy (Costin 1958).

On present knowledge, the optimum land use for this land system appears to be retention of all indigenous vegetation cover and preservation of the area as water catchment. Some strictly controlled grazing may be allowable. The fencing out of areas susceptible to damage by stock would be advisable but very expensive. Improvement of the vegetation by topdressing may prove uneconomical at present but may be possible in the future.

Burning of vegetation in this area must be controlled. Hot summer-fires are a menace to the efficiency of the area as a water catchment. It has been claimed that burning is necessary to promote fresh vegetative growth and to reduce the likelihood of wild fires by reducing the inflammable material. The only reasonable excuse for burning is as a fire protection measure. If it is necessary for this purpose it should be carried out at that time of the year when the minimum of damage will be done and also it should be carried out in such a manner as to provide a maximum of protection from an absolute minimum of burning. In wild fire control, strategically located strip burns should prove more effective than randomly burnt patches and much less harm will be done to the catchment efficiency. These are only a few of the many problems which require answers before a wholly satisfactory determination of land use can be made in these areas.

Barkly Land System.

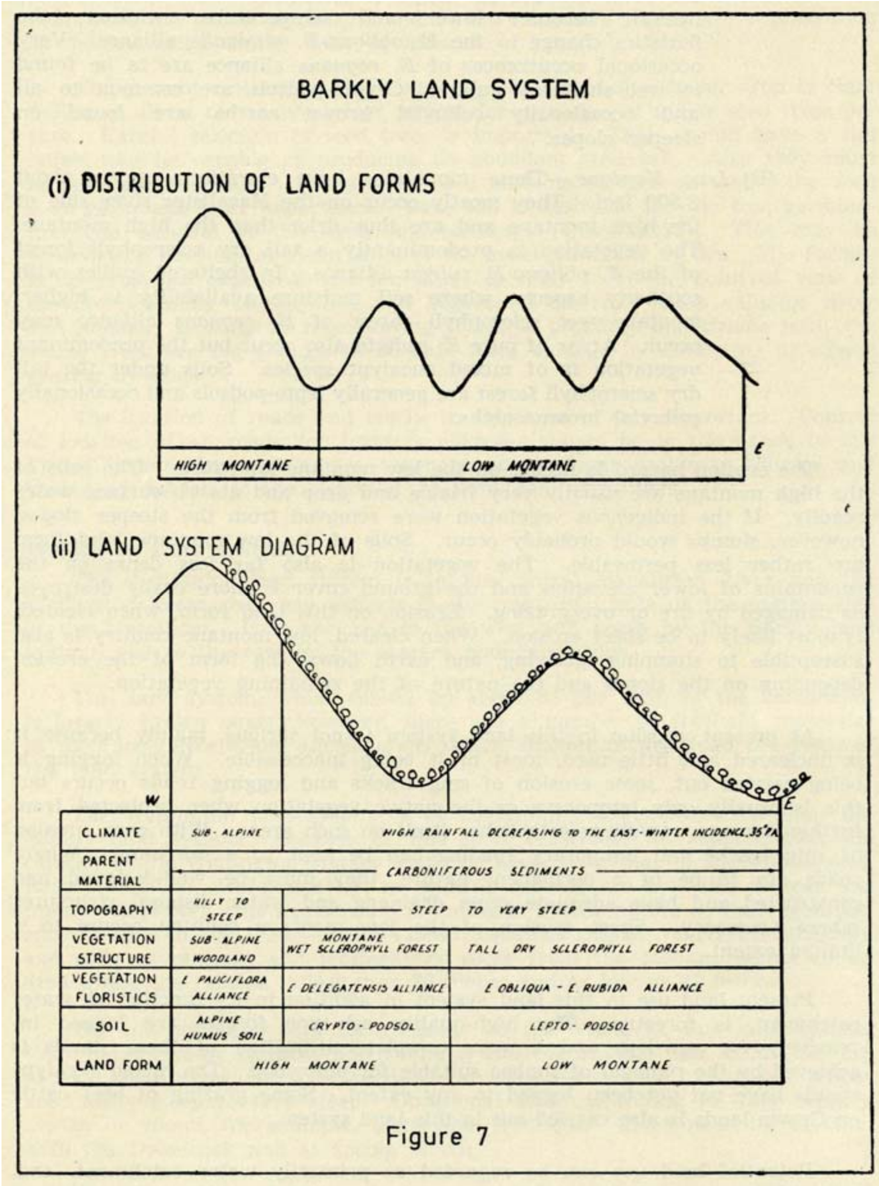


Figure 7 – Barkly Land System

The Barkly land system has a moderately high rainfall. It occurs as a strip around the western boundary of the catchment from The Springs, south of Mt. Useful to Mt. Howitt, and thence down the eastern side of the catchment, in a narrower strip, below the Snowy Plains land system. The adjacent land systems are the Snowy Plains land system of higher elevation and the Wellington unit located in the upper centre of the catchment, which is of generally lower elevation. The Wellington land system has an overall lower rainfall and a consequent drier type of vegetation and soil development than the Barkly unit.

The Barkly land system, which occupies about 33 per cent. of the catchment, is mainly Crown lands. An area of about 23 sq. miles to the south and east of Mt. Macdonald is State Forest and about 400 acres on Spring Hill is freehold land.

Two land forms make up this land system, high montane and low montane, the chief difference being based on elevation. Low montane land forms have elevations up to about 3,500 feet and high montane land forms generally have elevations over 4,000 feet. Slopes can be very steep but mostly they would be classed as steep. Small areas of rolling to hilly country are also found.

The relationships between the soils, vegetation, parent material, and climate are shown in the Barkly land system diagram (Fig. 7).

*(i) **High*** **Montane.**—Elevations of the tops of these mountains range from around 4,000 feet to over 5,500 feet. It is thus usual to find sub-alpine to alpine conditions prevailing on these peaks. In general, the vegetation of the peaks is a sub-alpine woodland of **E.** *pauciflora* alliance and the soils are alpine humus soils or lithosols. Below the sub-alpine woodland the vegetation is montane wet sclerophyll forest of *E. delegatensis* alliance and the soils are mainly crypto-podsols. Below this alliance, as rainfall becomes lower and temperatures warmer, the floristics change to the *E. obliqua-E. viminalis* alliance. Very occasional occurrences of *E. regnans* alliance are to be found in wet sheltered gullies. Crypto-podsols are common to all and occasionally colluvial brown earths are found on steeper slopes.

(ii) ***Low Montane**.*—These mountains have elevations up to about 3,500 feet. They mostly occur on the Macalister river side of the high montane and are thus drier than the high montane. The vegetation is predominantly a tall dry sclerophyll forest of the *E. obliqua-E. rubida* alliance. In sheltered gullies with southerly aspects, where soil moisture availability is higher, montane wet sclerophyll forest of *E. regnans* alliance may occur. Areas of pure *E. radiata* also occur but the predominant vegetation is of mixed eucalypt species. Soils under the tall dry sclerophyll forest are generally leptopodsols and occasionally colluvial brown earths.

The erosion hazard is higher on the low montane land form. The soils of the high montane are usually very friable and deep and absorb surface water readily. If the indigenous vegetation were removed from the steeper slopes, however, slumps would probably occur. Soils of the low montane land form are rather less permeable. The vegetation is also far less dense on the mountains of lower elevation and the ground cover is more easily destroyed or damaged by fire or overgrazing. Erosion on this land form, when cleared, is most likely to be sheet erosion. When cleared, low montane country is also susceptible to slumping, gullying, and earth flows, the form of the erosion depending on the slopes and the nature of the remaining vegetation.

At present, erosion in this land system is not serious, mainly because it is uncleared and little used, most of it being inaccessible. When logging is being carried out, some erosion of snig tracks and logging roads occurs but this is usually only temporary as the native vegetation when protected from further damage, rapidly re-establishes itself on such areas. With care, erosion of snig tracks and temporary roading can be kept to a minimum. Where roads are to be of a permanent nature, they must be well-designed and constructed and have adequate cross drainage and water disposal structures where necessary. Sheet erosion of the low montane country occurs to a limited extent.

Present land use in this land system in addition to its function as water catchment, is forestry. The high-quality ash-type forests are logged intensively for saw-logs and a more complete utilization of these stands is achieved by the removal of timber suitable for pulpwood. The mixed eucalypt stands have not yet been logged to any extent. Some grazing of beef cattle on Crown lands is also carried out in this land system.

Potential land use can be regarded as primarily water catchment, and, secondly, forestry. If forest grazing can be carried out without detriment to either of these functions then it could also be permissible as an additional land use. However, the case for or against grazing in these areas is not yet proven. The maintenance of a vigorous crop of trees is important from both the water catchment and forestry aspects. Adequate regeneration of the harvested timber must be assured.

The present method of obtaining regeneration of the timber crop is clear felling of all of the mature trees, except for retention of a few seed trees per acre. Careful selection of seed trees is important. They should have a full crown and be capable of producing an abundant seed fall. Also they must be suitable genetically. Preparation of a suitable surface on which the seed is to germinate is of importance. Bare soil is desirable for the best germination and survival of the seeds and seedlings (Grose 1957). This may be achieved by mechanical disturbance of the undergrowth or by fire. The former is desirable but expensive and the latter is risky from the point of view of the fire becoming uncontrolled and because it destroys much valuable litter and humus. Grazing in regenerating forest is probably undesirable until the young trees are big enough to be safe from damage by trampling or casual grazing by stock.

The location of roads and tracks in this area is very important. Control of location of all roads for forestry purposes should be in the hands of the Forest Commission with advice, when necessary, from Authority Officers, and should not be left to the discretion of individual sawmillers.

Wellington Land System.

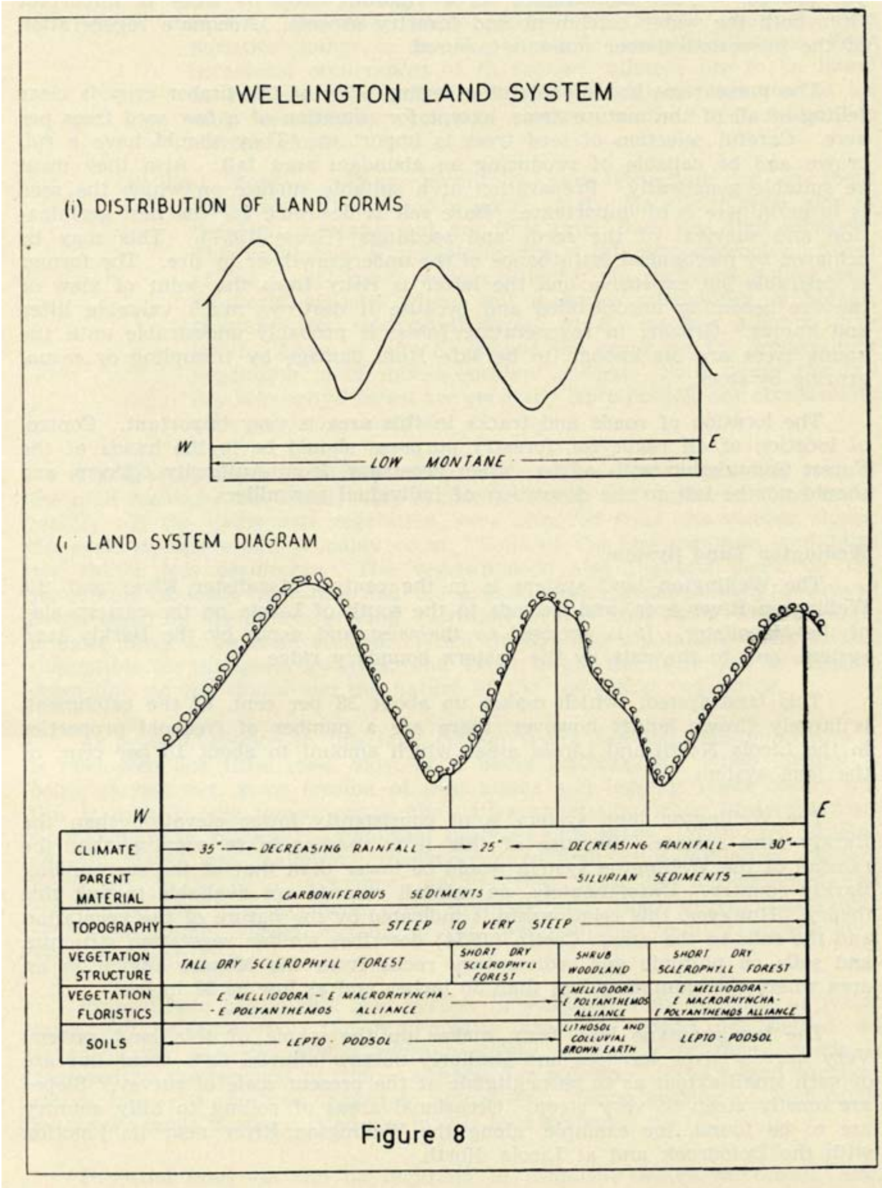


Figure 8 – Wellington Land System

The Wellington land system is in the central Macalister River and the Wellington River area, and extends to the south of Licola on the eastern side of the Macalister. It is enclosed to the west and north by the Barkly land system, and to the east by the eastern boundary ridge.

This land system, which makes up about 33 per cent of the catchment, is largely Crown lands ; however, there are a number of freehold properties in the Licola North and Licola areas which amount to about 10 per cent of the land system.

The Wellington land system is of consistently lower elevation than the Barkly land system. Because of this it is reasonable to suppose that the rainfall of the Wellington system would be lower than that of the surrounding Barkly country. Unfortunately, no rainfall records are available to test this theory. However, this relationship is indicated by the nature of the vegetation and the soils in the area. Costin (1954) describes similar vegetation structure and soils on plutonic and sedimentary rocks from the Monaro region in an area where the rainfall is less than 30 inches and as low as 22 inches.

The low montane land form makes up the whole of this land system. Very narrow river terraces and similarly narrow alluvial flats occur but are of such small extent as to be negligible at the present scale of survey. Slopes are mostly steep to very steep. Occasional areas of rolling to hilly country are to be found, for example, along the Wellington River near its junction with the Dolodrook and at Licola North.

The relationships between the factors of the environment are illustrated in the Wellington land system diagram (Fig. 8).

The vegetation varies from a tall dry sclerophyll forest through short dry sclerophyll forest to shrub woodland towards the centre of the land system, this latter being most frequent on steep slopes with northern aspects. This distribution is related to the availability of soil moisture. The species of the dry sclerophyll forest are contained in the *E. melliodora-E. macrorhyncha-E. polyanthemos* alliance and those of the shrub woodland are contained in the *E. melliodora-E. polyanthemos* alliance.

Soils are generally leptopodsols with colluvial brown earths and lithosols on steeper slopes.

The erosion hazard of this country is fairly high. Steep slopes and rather impermeable soils such as occur here can lead to serious erosion if care is not exercised in the use of the land. Removal of protective ground cover results in severe sheet erosion and even gullying. Removal of trees can result in slumps, earth flows and gullies if an alternative deep rooted vegetation is not rapidly established. In relation to the value of produce from this area, its potential contribution to the silt load of the streams is the highest of any land system in the catchment.

It seems that burning of the Crown lands in the past has led to the destruction of most of the accumulated litter on the forest floor and perhaps the replacement of many indigenous perennial species by annuals. Over-grazing could cause a similar change in vegetation of the forest floor. The present condition of the forest floor would allow extensive sheet erosion. The annuals die off when the soil starts to dry out in the summer, leaving the soil surface largely unprotected. Summer and autumn storms are probably the most serious in causing sheet erosion in this land system.

Where the land has been completely cleared and no attempt has been made to introduce improved pasture, slumps are common and are particularly severe on steeper country. Where slopes are less than 25 per cent gullies are common. Sheet erosion is probably quite widespread over the cleared country too, particularly during the summer and autumn months.

The present use of Crown land in this land system is for sporadic grazing by beef cattle and rarely sheep. This is more intensive in areas adjacent to freehold properties. There is no organized utilization of timber from these areas. The water yield is rather ineffective in that it contributes only to flood flows and would play only a very insignificant role in maintaining summer flows. Timbered freehold land is more intensively grazed than the Crown lands, but generally the same comments apply as for the Crown lands. The cleared country is used for grazing, primarily of beef cattle and sheep for wool. No cultivation is carried out and little evidence of pasture improvement was seen.

Because of the steepness of most of the cleared country in this land system, aerial topdressing offers the only means of improving present pastures, but on these steep slopes the desirability of this could be suspect. Some of the lesser slopes could be surface cultivated but these form only a small proportion of the cleared land.

Eradication of rabbits, and strict control of grazing by landholders is necessary to maintain an adequate vegetative cover. Establishment of trees may be necessary to stabilize areas where slumps are prevalent, and would also be desirable to provide shelter for stock.

The uncleared freehold and Crown lands should remain timbered. Prevention of fires should be aimed at, and careful control of forest grazing should be exercised to enable a build-up of litter and ground flora.


Plate 11.—Partly cleared low montane land-form—Target Creek area.

Yangoura Land System.

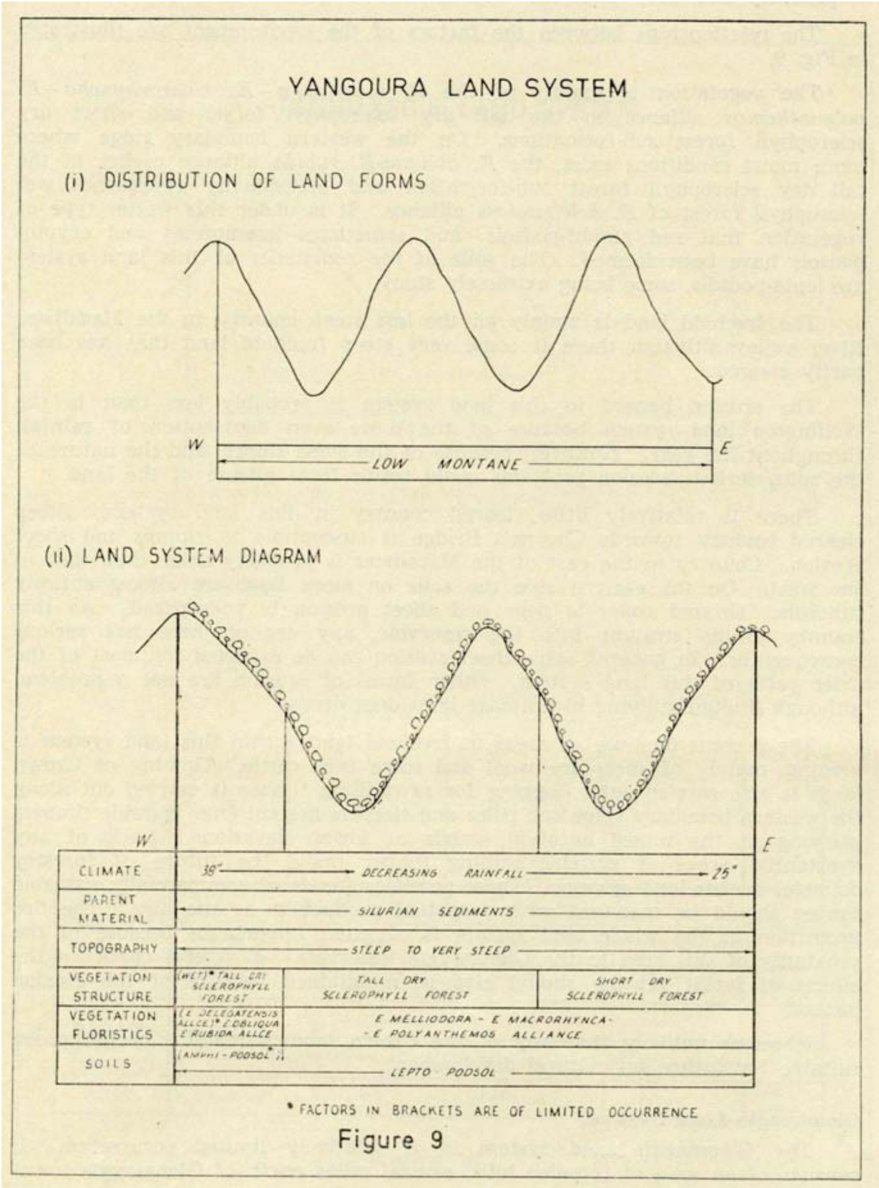


Figure 9 – Yangoura Land System

The Yangoura land system covers the majority of the country south of Cheyne's Bridge. It extends down to the flatter country around Glenmaggie Creek and the head of the reservoir.

In area, it represents about 16 per cent of the catchment. About 20 per cent of the land system is State Forest and 5 per cent freehold land, the remainder being Crown land.

The Yangoura land system is composed entirely of the low montane land form. It is differentiated from the Wellington land system, which is also composed entirely of the low montane land form, by the lack of the shrub-woodland form of vegetation and the more widespread occurrence of tall dry sclerophyll forest, as distinct from the short dry sclerophyll forest form. It is also thought to have a slightly higher annual rainfall but because of the lack of adequate records this cannot be used as a valid means of separation. Those records which are available indicate a more even distribution of rainfall throughout the year in this land system than in the Wellington unit, where the rainfall has a distinct winter maximum. The geology also differs considerably in that the whole of the Yangoura unit is of Silurian sediments, whereas the majority of the Wellington unit is of Carboniferous sediments with only a small section of Silurian rocks in the south-eastern corner.

Slopes are generally steep to very steep, however, in general this country is probably less steep than the Wellington land system.

The relationships between the factors of the environment are illustrated in Fig. 9.

The vegetation is mainly of the *E. melliodora – E. macrorhyncha– E. polyanthemos* alliance in the tall dry sclerophyll forest and short dry sclerophyll forest sub-formations. On the western boundary ridge where more moist conditions exist, the *E. obliqua-E. rubida* alliance occurs in the tall dry sclerophyll forest sub-formation and occasionally approaches wet sclerophyll forest of *E. delegatensis* alliance. It is under this wetter type of vegetation that red amphipodsols, and sometimes krasnozems and crypto-podsols have been formed. The soils of the remainder of this land system are leptopodsols, some being extremely stony.

The freehold land is mainly on the less steep country in the Macalister River valley although there is some very steep freehold land that has been partly cleared.

The erosion hazard in this land system is probably less than in the Wellington land system because of the more even distribution of rainfall throughout the year. However, because of the steep slopes, and the nature of the soils, serious erosion problems could result from misuse of the land.

There is relatively little cleared country in this land system. Steep cleared country towards Cheyne's Bridge is susceptible to slumps and sheet erosion. Country to the east of the Macalister is probably drier than that to the west. On the eastern side the soils on steep land are almost entirely lithosols. Ground cover is poor and sheet erosion is widespread. As this country drains straight into the reservoir, any erosion here has serious consequences. In general, some sheet erosion can be expected for most of the drier parts of this land system. Other forms of erosion are not a problem, although limited gullying in drainage lines does occur.

The present land-use of areas of freehold land within this land system is grazing, mainly of sheep for wool and some beef cattle. Grazing of Crown lands is also carried out. Logging for sawmilling timber is carried out along the western boundary ridge and poles and sleepers are cut from durable timbers growing in the mixed eucalypt stands at lower elevations. Lack of any substantial areas of suitable milling timber make the future of forestry doubtful in this land system. Where possible, stands of commercially valuable timber should be managed with perpetual production as the aim. The fire protection of the whole land system is of great importance because of the proximity of this area to the Glenmaggie Reservoir. A careful check on the effects of forest grazing should also be maintained because of the erosion hazard.

It seems unlikely that any of the Crown lands remaining would prove suitable for future agricultural development.

Glenmaggie Land System.

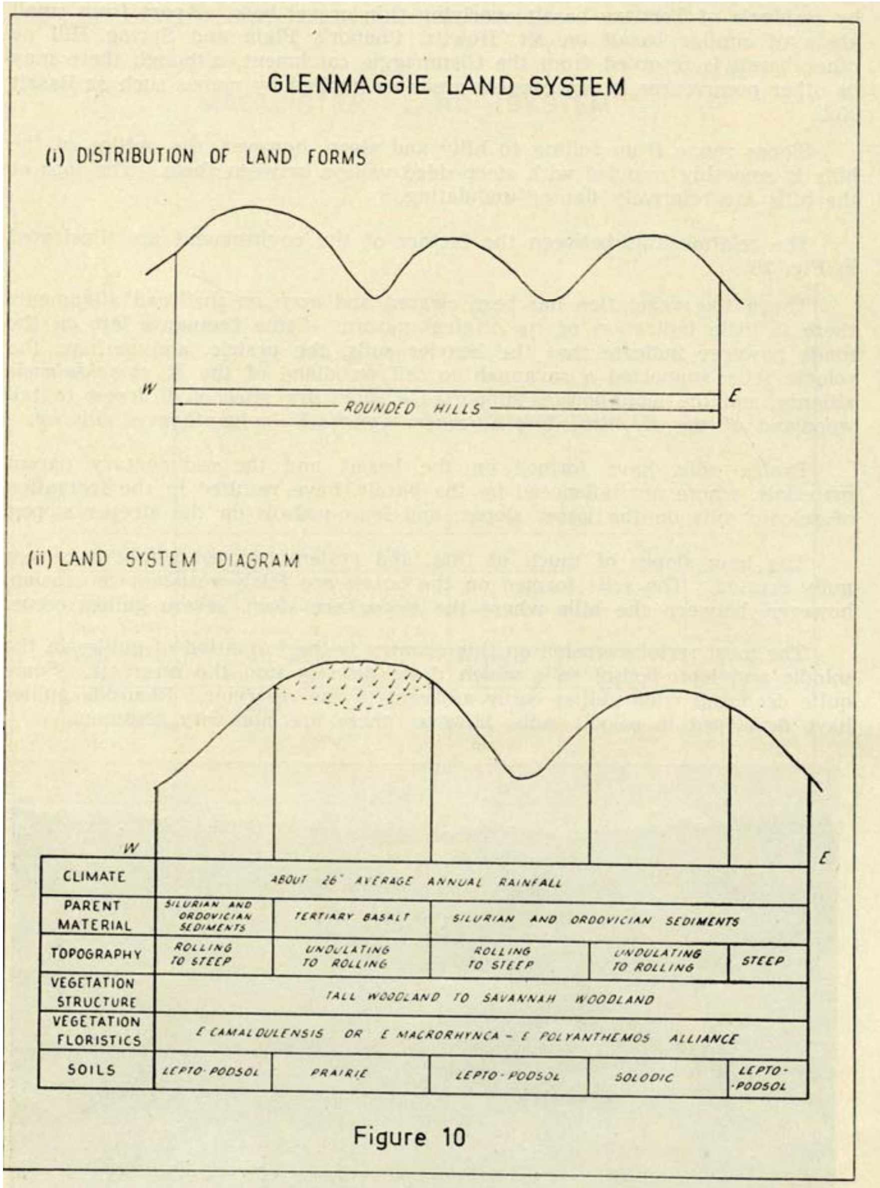


Figure 10 – Glenmaggie Land System

The Glenmaggie land system is of relatively limited occurrence. It consists of an area of rounded hills, several miles north of Glenmaggie town-ship and adjacent to the head of the reservoir. It makes up only two per cent. of the catchment area and is all freehold land.

The roundness of the hills makes this land system quite distinctive. Another important feature peculiar to it is that many of the hills are capped by residuals of Tertiary basalt overlying thin gravel beds. Apart from small areas of similar basalt on Mt. Howitt, Connor's Plain and Spring Hill no other basalt is recorded from the Glenmaggie catchment, although there may be other occurrences in inaccessible areas as implied by names such as Basalt Nob.

Slopes range from rolling to hilly and steep, however, the outline of the hills is smoothly rounded with steep-sided valleys between them. The tops of the hills are relatively flat or undulating.

The relationships between the factors of the environment are illustrated in Fig. 10.

The native vegetation has been cleared and even on the road alignments there is little indication of its original nature. Some remnants left on the roads however indicate that the heavier soils, the prairie, and perhaps the solodic soils, supported a savannah to tall woodland of the *E. camaldulensis* alliance, and the leptopodsols supported a short dry sclerophyll forest to tall woodland of the *E. melliodora-E. macrorhyncha-E. polyanthemos* alliance.

Prairie soils have formed on the basalt and the sedimentary parent materials, where not influenced by the basalt, have resulted in the formation of solodic soils on the lesser slopes, and leptopodsols on the steeper slopes.

The long slopes of much of this land system can contribute to severe gully erosion. The soils formed on the basalt are fairly resistant to erosion, however, between the hills where the slopes are steep, severe gullies occur.

The most serious erosion on this country is the formation of gullies in the solodic and leptopodsol soils which drain directly into the reservoir. Some quite deep and wide gullies occur adjacent to the reservoir. Roadside gullies have developed in solodic soils, however these are not very common.

Plate 12.—Glenmaggie land-system—gully erosion in prairie soils between the rounded hills.

The Glenmaggie and the Macalister land systems are the most intensively used in the catchment. The chief form of land-use is grazing of both beef cattle and sheep for wool. Some of the prairie soils on lesser slopes are cultivated to grow sunflowers for seed.

Macalister Land System.

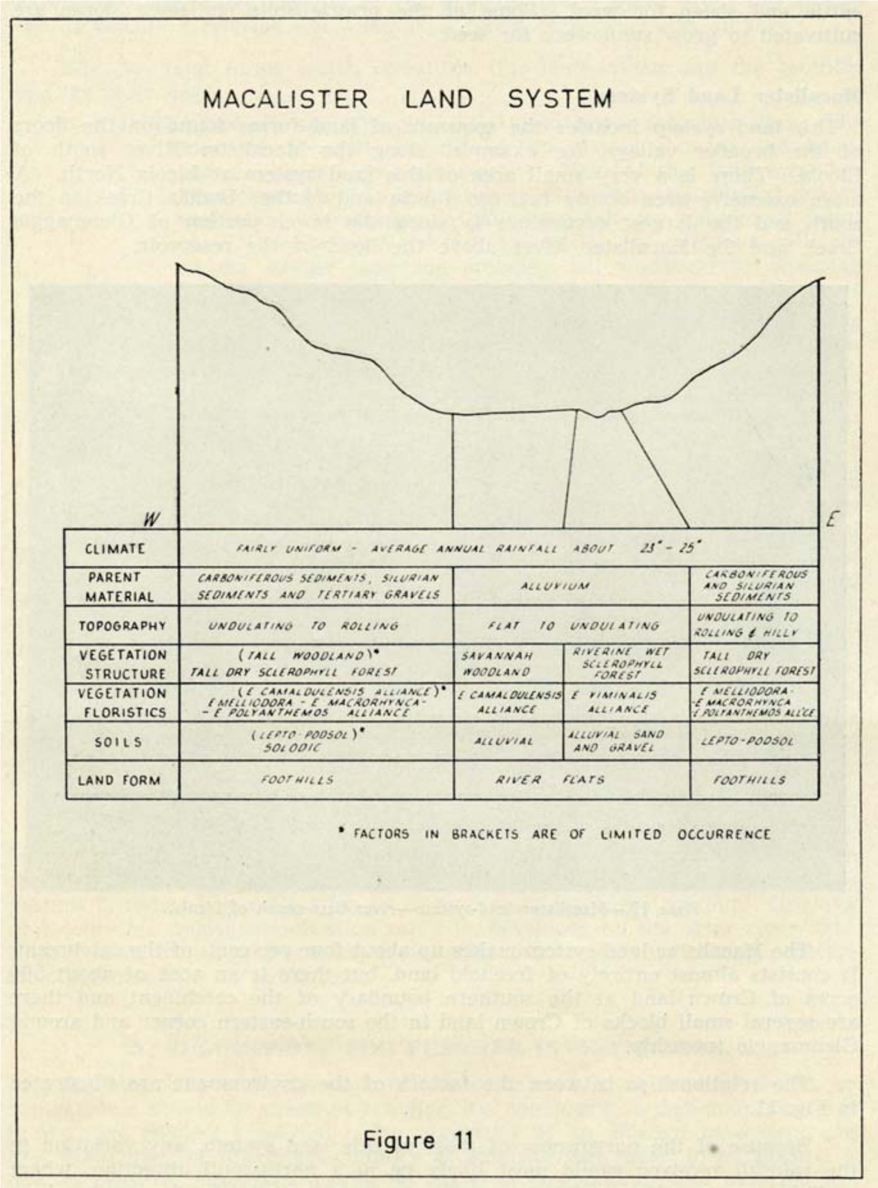


Figure 11 – Macalister Land System

This land system includes the sequence of land forms found on the floors of the broader valleys, for example, along the Macalister River south of Licola. There is a very small area of this land system at Licola North. A more extensive area occurs between Licola and Mother Budd's Creek to the south and the largest occurrence is along the lower portion of Glenmaggie Creek and the Macalister River above the head of the reservoir.

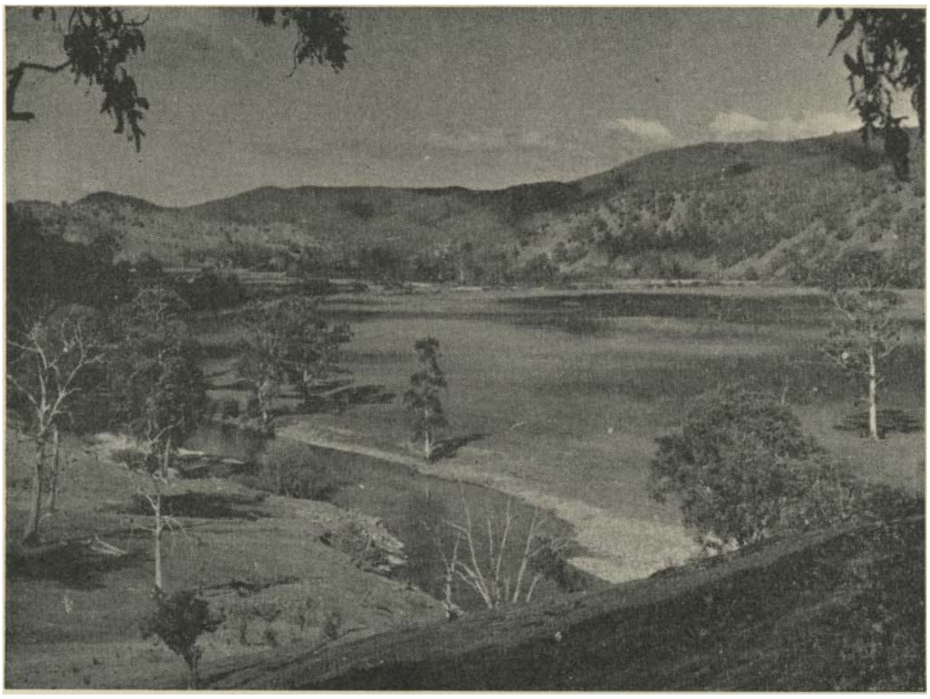


Plate 13.-Macalister land-system--river flats south of Licola.

The Macalister land system makes up about four per cent of the catchment. It consists almost entirely of freehold land, but there is an area of about 500 acres of Crown land at the southern boundary of the catchment and there are several small blocks of Crown land in the south-eastern corner and around Glenmaggie township.

The relationships between the factors of the environment are illustrated in Fig. 11.

Because of the narrowness of most of this land system, any variation in the rainfall received would most likely be in a north-south direction, where a slight increase from south to north may be expected. In the south where the land system is broader a drop of several inches in the average annual rainfall is known to exist from west to east. High levels of the river cause the river flats to have a wetter soil environment than the foothills. River-bank vegetation, because of the availability of water from the stream bed, is usually a riverine wet sclerophyll forest of *E. viminalis* alliance.

The two land forms which constitute this land system are the foothills and the river flats.

(i) The ***foothills*** are rolling to hilly areas above the river flats. The soils are generally solodic on the flatter country and leptopodsols where slopes are steeper. Most of this land form has been cleared and it is difficult to determine the original overall vegetation. It appears to have been tall dry sclerophyll forest of *E. melliodora-E. macrorhyncha-E. polyanthemos* alliance on the steeper land and probably tall woodland to savannah woodland of *E. camaldulensis* alliance on the flatter slopes.

(ii) The ***river flats*** land form consists of the level to gently undulating land which has been built up by deposition from the streams. Soils are usually deep sandy loams with no profile development. Gravel beds are common. The original vegetation which was probably savannah woodland of *E. camaldulensis* alliance has now been almost completely cleared.

The sloping foothills of this land system are gully eroded. Stream bank erosion of the river flats however, poses a most pressing problem. Many acres of valuable river flats have been destroyed and the eroded material deposited elsewhere—presumably in the reservoir. River improvement works such as diversion channels, brush mats and willow plantings have been carried out along these eroding flats in an effort to reduce or prevent loss of the soil. Some success is being met with. Roadside erosion occurs to a limited extent in the flatter country on solodic and leptopodsol soils.

The present land-use of the sloping foothills and most of the river flats is grazing of beef cattle and sheep for wool and some fat lamb raising. Some cultivation of the river flats for maize and sunflower seed growing is also carried out. Cultivation of river flats for pasture improvement has recently been carried out on a large scale.

The development of these river flats into high-carrying-capacity pasture or intensive cultivation for row crops would appear to be the best use to which they could be put. Much of the foothill country could also support improved pasture introduced by cultivation or surface working on the contour. Growing of lucerne for fodder conservation could be developed on the drier river flats. Improvement of pastures in these areas could help to ease the grazing pressure on other areas in the catchment.

X. SUGGESTIONS FOR FURTHER INVESTIGATION.

The most important function of the catchment is to produce water, so management should be aimed at bringing the catchment to and maintaining it in its most efficient condition. The properties of an efficient catchment are that it supplies the maximum quantity of sediment-free water in as uniform a flow as possible. Research should be aimed at determining how to bring the catchment to, or how to maintain it in a condition whereby this is achieved.

The high country is generally recognized as that part of the catchment which provides the most water and the most sustained flows. This would appear to be even more so in this catchment with its rain shadow extending over the lowlands and the centre. Thus, attention should be directed to the high country if increased and better sustained water yields are to be obtained. However, the third property, that of supplying sediment-free water, is the one which requires immediate attention and this necessitates that the catchment as a whole be considered.

The maintenance of adequate vegetative cover on all land in the catchment is needed. The questions then are: "What is regarded as adequate vegetative cover?" "What areas do not have an adequate cover?" and, "How can this be obtained where it is lacking?" Areas covered with wet sclerophyll forest can probably be regarded as having a quite adequate vegetative cover. The more open forests of the dry sclerophyll forests and shrub woodlands are in a much less satisfactory condition. Investigations into the soil losses from the areas should be made. If they are found to be of a serious nature, studies of how to build up and maintain a better vegetative cover on these areas should follow. Similar studies should be made on cleared land. However, the maintenance of adequate vegetative cover on freehold land may prove more difficult as a very close watch on grazing would have to be maintained by landholders.

Development of methods to control stream bank erosion along the Macalister River flats should be given urgent attention. It appears that much of the current silt load entering the reservoir is from this source.

Because it is most distant from the reservoir the Snowy Plains land system is placed low on priorities for soil loss experiments. It is doubtful whether soil movement here contributes very much to the silt load entering the reservoir. However, from the point of view of the long-range effect of erosion in the high country on water yield and sustained flows, investigations into these problems should not be neglected. Costin (1957a) has described the changes in vegetation which have occurred or are occurring and the extent of accelerated erosion in these areas. Studies should be made to determine the effect these changes are having on the catchment efficiency and, when the seriousness of the changes is evaluated, steps should be taken to find the causes of the changes in order to remedy the faults. Further investigations may be required to find methods of rehabilitating areas where this is necessary.

Also of importance to the State are the areas of high quality ash-type forests in the catchment. Recent estimations (Jacobs 1955) indicate that the total area of forest in Australia is not adequate to provide the timber requirements for future populations. It is of the utmost importance then, that all areas of productive forest are managed on the basis of perpetual yield. This entails removal of the crop of trees as it reaches maturity and its rapid replacement by an adequate stand of regeneration. Throughout its life the new crop should be so treated that it maintains a maximum rate of growth. These are, of course, not problems peculiar to this catchment and investigations could be carried out in any suitable area. Such investigations will necessarily take a long time because of the relatively slow growth of the trees and because of this it is important that investigations be commenced at an early date in order that the results can be put into operation as soon as possible.

In the field of research into improvement of land at present used for agriculture much can be done; however, co-operation of landholders is necessary. The first need is for a more detailed survey to delineate land-units. This should enable a better appraisal to be made of land-use potential and problems. Soil sampling and fertilizer and species plot-trials will probably be necessary to determine what action is required to correct nutrient deficiencies. Where slopes are too steep for conventional methods of pasture improvement, some alternative method may have to be developed. The economics of these improvements would have to be studied.

Investigations should be made into the possibility of more intensive utilization of river flats for row-crops or fodder crops.

Stabilization of many of the slumps which are prevalent on some of the cleared country will require investigation, together with means of controlling gullies in the solodic, leptopodsol and prairie soils.

XI. ACKNOWLEDGMENTS.

The authors wish to acknowledge the valuable assistance in the field and advice on preparation of this report given by Mr. F. R. Gibbons, Senior Research Officer of the Soil Conservation Authority. Mr. J. N. Rowan, Research Officer, and Messrs. G. T. Sibley and A. S. Rundle, Assistant Research Officers of the Authority, helped in discussion of problems arising from the survey. The editorial assistance of Mr. M. R. Swann, Publications Officer of the Authority, is also acknowledged. The staff of the National Herbarium Melbourne, have assisted in identification of a number of botanical specimens. Officers of the Forests Commission were very helpful in providing information on access and the vegetation of the catchment, and in arranging for accommodation in Commission camps.

APPENDIX I - Limits of detail for the environmental factors studied

Vegetation	(i) Structure the formation or sub-formation if consistent. (ii) Floristics—the alliance or sub-alliance if necessary.
Soils	Great soil group or sub-group.
Climate	(i) Rainfall inches per annum and incidence. (ii) Temperature—mean annual.
Geology	(i) Age in terms of eras. (ii) Lithology—in terms of rock type.

APPENDIX II - List of species mentioned in the text and their common names

Botanical Name	Common Name
Acacia dealbata	Silver Wattle
A. implexa	Lightwood
A. melanoxylon	Blackwood
A. penninervis	Hickory Wattle
A. pycnantha	Golden Wattle
Bursaria spinosa	Sweet Bursaria
Carex gaudichaudiana	Tufted Sedge
Cassinia aculeata	Common Cassinia
Casuarina stricta	Weeping Sheoak
Celmisia longifolia	Snow Daisy
Coprosma nitida	Shining Coprosma
Danthonia nudiflora	Rigid Wallaby Grass
Daviesia corymbosa var. laxiflora	Bitter Pea
D. latifolia	Hop Bitter Pea
Dodonaea cuneata	Hop Bush
Eucalyptus bridgesiana	Butt Butt
E. camaldulensis	Red Gum
E. delegatensis	Alpine Ash (Woollybutt)
E. dives	Broad-leaf Peppermint
E. elaeophora	Long-leaf Box
E. goniocalyx	Mountain Grey Gum
E. kybeanensis	Gippsland Mallee Ash
E. macrorhynclaa	Red Stringybark
E. maculosa	Brittle Gum
E. melliodora	Yellow Box
E. muelleriana	Yellow Stringybark
E. nitens	Shining Gum
E. obliqua	Messmate Stringybark
E. pauciflora	Snow Gum (White Sallee)
E. polyanthemos	Red Box

Botanical Name	Common Name
E. radiata	Narrow-leaf Peppermint
E. regnans	Mountain Ash
E. rubida	Candlebark
E. sideroxylon	Red Ironbark
E. sieberiana	Silvertop Ash
E. stellulata	Black Sallee
E. viminalis	Manna Gum
Exocarpos cupressiformis	Cherry Ballart (Wild Cherry)
Leptospermum ericoides	Burgan
Oxylobium alpestre	Golden Oxylobium
Platylobium formosum	Handsome Flat-pea
Poa australis	Snow Grass
Pomaderris apetala	Hazel Pomaderris
Pteridium esculentum	Bracken Fern
Stypandra glauca	Nodding Blue-Lily
Themeda australis	Kangaroo Grass
Veronica derwentia	Derwent Speedwell

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