PART III
THE INFLUENCE OF SETTLEMENT

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF PLATES

TIME ACTIVITIES OF MAN

The aboriginals are considered to have been a part of the natural ecosystem and their activities as being in harmony with the ecological balance of the area.

European settlement has had a considerable effect on the ecology of the area. Settlement was naturally accompanied by such activities as ring-barking and clearing of trees, and the burning of vegetation to prepare the land for agriculture or to encourage fresh grass on bush country. The settler brought with him new species of animals and plants some of which were able to adapt themselves to the environment so well that they competed with the native fauna and flora, sometimes to their exclusion.

All these activities altered the fine ecological balance which had been maintained during the centuries before settlement. The stability of the vegetation and the soil were affected and the hydrologic properties of the catchment were altered. No conscious effort was made to preserve or re-establish an equilibrium between the factors of the environment, which is essential for the maintenance of a healthy and stable agriculture.

Ringbarking And Clearing

The land was cleared without the aid of machinery in the pioneering days ; the axe and saw, the horse or bullock team and fire were tools with which clearing was achieved. Steepness of land proved to be no barrier to these methods, with the result that, often, slopes beyond the clearing limits safe for soil stability were stripped of trees and subjected to grazing. The indigenous herbaceous vegetation of this area was poorly adapted to intensive grazing. The clearing of large areas of woody vegetation permitted the native grasses to be more productive than they were able to be when in competition with trees and shrubs, but they were still not adapted to heavy, continuous grazing and trampling by hard-hooved animals. Furthermore, these introduced animals were confined and were not free to search for new grazing when the old became inadequate. Thus, overgrazing was prevalent when native grass pastures were relied upon and much erosion was started.

Burning

Evidence collected by Fawcett (1955, unpublished report to S.C.A.) indicates that although the country was frequently burned by the aboriginals prior to settlement, these fires were not of large extent nor did they seriously damage the vegetation. They were used in hunting certain types of game. She concludes that the aboriginal was apparently very cautious about the use of fire as he had very much to lose and nothing to gain by burning large areas.

However, King (undated, roneoed report of C.S.I.R.O. Div. Phys. Chem. Melb.) after studying many of the reports of the early explorers and the earliest settlers, concludes " that the aborigines were not careful with fire and must have repeatedly started bushfires ". The extracts quoted by King indicated that fire was used by the aboriginals for cooking, signalling, as a weapon, and that they burned to promote new grass to attract game, or to hunt game.

Nevertheless, many of the references to extensive fires or recently burned areas encountered by the explorers would seem to be in the category of defensive fires. It is not hard to imagine the alarm created in the aboriginal population by the first appearance of white men and their animals and equipment. They could be expected to try to destroy the intruders with their most effective broad-scale weapon, fire, or to starve them by destroying the native game in their vicinity. Such fires as recorded by the explorers may not have been a normal feature of the environment as is sometimes inferred, and indeed, some of the extracts in King's report indicate that the aboriginal was quite skilful in restricting the spread of fire when he wanted to be.

Therefore, despite the aboriginals' caution, because of the apparent reliance on fire for many of their activities, it may be assumed that some extensive uncontrolled fires were started, and together with fires caused by lightning, probably resulted in at least the occasional burning of large areas.

Most of the records of early fires are from the plains or riverine country. There is little information on the periodicity of burning in the mountainous areas prior to settlement.

The first record of a disastrous fire in the new colony of New South Wales was in February, 1851. It seems that the Omeo district escaped this fire but the northern part of the catchment may have been burned.

The great fire of 1939 was probably the most serious ever known in this catchment. It was caused through the lighting of numerous fires by different people all ignorant of the danger. These fires linked up under extreme conditions and raged through the country causing immense damage and loss of life.

Wild fires occur every summer. Some become serious and some are put out by rain or by the efforts of fire fighters. In 1952 large areas in the Koetong-Shelley and Burrowye-Cudgewa areas were burned.
Fawcett (op. cit.) states that until about 1890 very few fires were deliberately lit by graziers, but miners were responsible for many fires in the 1850-60's. Cattlemen used fires to remove coarse, dry grass from their runs. This encouraged the new growth of grass and provided better grazing in the forests, for a while. However, the fires also encouraged the growth of scrub, and the forests, which were once park like (Andrew 1920), are now so dense with scrub, that in many places it is almost impossible to push through on foot. It may take many years of protection from fire and perhaps from grazing too, to allow the processes of natural Succession to re-establish the open grassy nature of these forests.

Fire was apparently used only as an aid to clearing on the freehold land subsequent burning was regarded as a disaster.

Animal Introduction

The early settlers grazed cattle and to a limited extent horses. Sheep were not favoured because dingoes were a constant menace and the long, coarse grass, typical of the area in those times, was not favourable for sheep. Gradually the settlers introduced all the domestic animals common to agriculture including, of course, cats and dogs.

Some of the animals introduced to this country in the early days were for the purpose of providing game for shooting. Rabbits, hares, foxes and deer were all introduced for this reason. Although the deer and the hare are not generally serious pests in this country they did become established-the deer in more specialised places other than in this catchment. The introduction of the rabbit has proved to be one of the most costly mistakes made by the early settlers. This animal, because of its adaptability, its rapid breeding and close grazing soon developed into a major pest. It competed successfully for grazing with both the domestic stock and the indigenous herbivorous animals. Many people blame the rabbit for the near extinction of some of the native animals. Fawcett (op. cit.) suggests that much of the serious erosion in the Omeo and Hinno Munjie country was initiated largely by a combination of drought and a rabbit plague.

The introduction of myxomatosis and well-organised poisoning and fumigating campaigns have gone a long way towards controlling the rabbit population.

Domestic animals which have gone wild cause some concern to graziers to this day. Wild dogs are a constant menace to sheep. Brumbies in the mountains have been blamed for damaging the vegetation associations regarded as important in regulating stream-flow. The domesticated cat and those which have gone wild cause much destruction in the population of native birds which had not previously been exposed to predators of this type.

All these introductions have caused changes in the balance between the biological components of the environment. Many other introductions of fauna have also occurred, some causing obvious changes, others seemingly causing none.

It is appropriate here to mention the slaughter of many of the native animals by the white man. The kangaroo, wallaby, possum and koala have each been hunted for their skins. Some species of possum, the rock wallaby and the koala have been near extinction, largely as a result of their slaughter by the early settlers.

Plant Introduction

Many of the early settlers found the Australian bush inhospitable. The trees and shrubs lacked the bright greens and colourful flowers of the vegetation of their native lands, so they frequently brought with them some of the plants to which they were accustomed in their old homes. The introduction of the weeping willow which graces the banks of so many of the streams in the north of the catchment has already been mentioned.

Some of the most economically important plant pests such as the blackberry *(Rubus fruticosus),* St. John's Wort *(Hypericum perforatum)* and Paterson's Curse *(Echium plantagineum)* were introduced as garden plants.

On the credit side, are introductions of pasture species which provide grazing of better quality and quantity, and are better able to stand trampling and intensive grazing than the native species.

Subterranean clover *(Trifolium subterraneum)* and white clover *repens)* are two of the more valuable introduced species which readily become established when levels of soil phosphate are suitable.

Use of Chemicals

The use of chemicals to improve plant growth and control or destroy plant pests has increased greatly in recent years.

The use of superphosphate to encourage the growth of pasture species, particularly legumes, is a recommended practice. However, the increased nitrogen made available by the increased growth of legumes is in many cases poorly utilised, particularly on steep hill country where the introduction of improved types of pasture grass is difficult. Annual weeds, such as cape weed and a variety of thistles become dominant oil such nitrogen-rich areas to the exclusion of perennial species. These weeds are not generally favoured by grazing stock so that the grazing value of the area declines. The death of the weeds as summer approaches leaves the soil with poor protection against the high-intensity summer and autumn storms, and wind action also may lead to considerable loss of top-soil. This is an example of the creation of an imbalance in the ecology of an area through lack of understanding of the full consequences of the initial action.

The widespread use of insecticides to control pasture pests may be criticised on the same grounds. The insecticides may effectively control the pest but could also destroy beneficial soil fauna. Some soil animals are responsible for the breakdown of plant residues, thus making the nutrients they contain available again for plant use. Destruction of these beneficial creatures could result in the locking up of nutrients in plant remains with a consequent drop in soil fertility. The soil fauna is also capable of improving soil structure, permeability and aeration, all of which are beneficial to the growth of plants.

Pesticides used without an understanding of their total effect on the complex soil fauna may lead to more serious problems than they cure.

PRESENT USE OF THE LAND

The principle forms of land-use in the catchment are water conservation, forestry, grazing and agriculture. In a country where both the best commercial forests and much of the most productive non-irrigated land occur in the higher-rainfall catchments, a policy of multiple use appears to be desirable wherever possible.

It is becoming more widely accepted that shortage of water is a major limitation in the development of Australia. Because of the value of water for irrigation, large water storages such as the Lake Hume, have been built at a considerable cost, to conserve the winter and spring flows for release to irrigation farmers during the summer. Thus, the catchment to Lake Hume should be considered primarily as a water-supply area. Other forms of land-use may be acceptable if they do not appreciably reduce the efficiency of the area for water-supply purposes. In general, commercial forestry, grazing and agriculture are compatable with catchment efficiency, but certain aspects of these forms of land-use may lead to undesirable catchment conditions.

Water Conservation

A water-supply catchment is dependent on a number of environmental factors for its satisfactory functioning. Sufficient water must be available to justify storage and distribution works. The higher-rainfall and snowfall areas provide the greatest proportion of usable water. The quantity and distribution of the precipitation cannot, as yet, be influenced to any extent by man, but the rate of delivery of the water can be greatly modified by human activities.

All precipitation should be absorbed by the soil and move slowly down through it to the streams. This would result in a leveling out of stream-flows so that damaging peak flows would not develop, and water would be supplied to the streams over a prolonged period.

Unless soil particles are well aggregated, the surface of bare soil can become sealed by dispersion of the finest particles by raindrop action, with the result that the surface soon becomes impermeable and high run-off results. Soil which has a cover of litter and vegetation is not subjected to raindrop action, and the micro-environment created by the cover is favourable to the development of soil micro-organisms which help to maintain the surface in a permeable condition. Vegetation and litter provide a barrier which slows the overland movement of water and allows it more time to soak into the soil. A well-vegetated catchment provides the best conditions for water conservation and flood mitigation and should be the aim of all land-use in the area.

Snow, which may lie well into the spring and even into the early summer in some years, provides a valuable additional means of holding winter precipitation in the catchment. A late thaw may provide sufficient water to maintain substantial flows well into the summer. Any means by which snow-fall or accumulation can be increased and snow-melt retarded would increase catchment efficiency.

The alpine and sub-alpine areas, which provide the greatest quantities of snow and have the highest rainfalls, are mainly located in the south-west of the catchment. Parts of the catchment which receive somewhat lower rainfall and less snow, but which comprise a greater area, are mainly in the south-cast. The drier areas in the north and the rain-shadow areas in the south contribute little to sustained flows, but these are the areas from which the greatest sediment yield comes. Estimates of the contribution to total water yield by various parts of the catchment have been made and are set out in Table 10. Because of the relatively small contribution to stream-flow made by the drier areas, soil conservation measures designed to reduce surface run-off will have little effect on total water yield.

Moss beds form deep permeable deposits in most of the alpine and sub-alpine drainage lines and are capable of absorbing large quantities of water. Water from winter and spring rains and snow-melt passing through the bogs saturate the mass and continue to seep out long after the supply has ceased. Many bogs have been considerably reduced in size, and some are nearing extinction (Plate 15). This damage is attributed to trampling of the bogs by cattle in their search for water and palatable vegetation. Trampling allows freer drainage and leads to lowering of the water-table. As the bog dries out it becomes more accessible to the cattle and the process continues. Fires will burn readily in the dried-out peats beneath the bog vegetation and many bogs have probably suffered in this way.

Fire has also greatly modified the nature of the sub-alpine woodland vegetation. Low, dense coppice shoots now cover considerable areas which once supported the large-crowned, open woodland of *E. pauciflora*. The woodland vegetation provided suitable conditions for the accumulation of numerous, deep snow drifts in the gaps between trees. Costin et. al. (1961) have demonstrated this in the Kosciusko area. Much of the potential water storage of the snow drifts is now lacking because the coppice growth is not tall enough, or lacks suitable gaps, for drift accumulation. The snow which would accumulate in these drifts is now blown on to lower elevations, melts and contributes mainly to peak flows.

The effect of ground vegetation on infiltration and retardation of surface flows has been mentioned previously. Fire is by far the most serious cause of destruction of ground cover. Wild fires and "protection" fires may both have the same effect on ground cover, and although the latter may not have such lasting effects on the woody vegetation as wild fire, it can cause complete destruction of the protective litter layer. Fire protection, as an aspect of catchment protection, is of vital importance.

Grazing also can result in serious depletion of ground cover. Over-grazing of pasture lands generally results in fairly uniform depletion of ground cover and is usually obvious, even to the casual observer. However, grazing of the snow-grass plains in the alpine and sub-alpine country presents special problems in that the dominant species, Poa australis, is not generally favoured by the cattle, and selective grazing of inter-tussock vegetation usually occurs (Costin 1958). Furthermore, if the grazing pressure is too high, destruction of this part of the vegetation results.

The initial effect is a slight opening up of the sward and the appearance of more-or-less connected patches of bare soil. These danger signs are not very obvious, particularly to the casual observer. With continued over-grazing, the inter-tussock spaces enlarge, and bare soil becomes dominant. Small, discontinuous areas of bare soil may not cause a serious reduction in catchment efficiency, but large or continuous areas, particularly in areas of high rainfall, result in rapid, overland flows of water which usually carry sediment stripped from the bare soil, thus contributing to peak flows and possibly to sedimentation of streams.

It appears from fencing experiments (Carr and Turner 1959) that prior to modification by grazing, the alpine herbfield vegetation was more extensive than at present, and that shrubs had a much more restricted distribution in the alpine areas. The fact that shrubs are the most successful colonisers of bare soil at these elevations (Carr, 1962) indicates that the present extensive shrub distribution in the alpine areas is a consequence of the opening up of the grassland and herbfield sward, mainly by grazing and fire. The existence of dense plant material, such as shrubs, within the snow pack appears to lead to earlier and more rapid snow-melt (A. S. Rundle, pers. comm.). If this is so, the replacement of grassland or herbfield by shrubs produces undesirable hydrologic effects.

As a result of good seasons and better pasture and range management, serious over-grazing is no longer common. However, the grazier should always be alert for signs of over-stocking. Pasture improvement and fodder conservation should be encouraged.

Improvement of stream-flow regime which would result from an improvement in the condition of the upper part of the catchment could lead to a marked reduction in stream-bank erosion which is a serious problem in some of the lower valleys.

Forestry

Sawmilling, involving production of both seasoning and scantling grades of timber, is an important industry in the catchment. One of the aims of properly controlled forestry is the orderly removal of mature trees, in such a manner that the site is left in a suitable condition for rapid regeneration by the timber species.

The largely even-aged forests of *E. delegatensis* are extensively logged for seasoning-quality timber. The utilization usually involves clear felling with retention of some seed trees or artificial reseeding of the area. On the less-steep country, tractor logging usually results in considerable damage to the ground vegetation, and bare soil is exposed over relatively large areas. Under these conditions seedling regeneration is usually satisfactory and re-establishment of ground cover takes only one to two years. The soils in these areas are well structured and permeable and little or no surface flow occurs from logged areas. On the steeper slopes, tractor logging does not result in such extensive site disturbance and regeneration may not be as satisfactory. Also, there is a tendency to haul logs up well-defined tracks which may become drainage channels. When logging is completed, rehabilitation would be assisted by blocking the channels at frequent intervals, and thus ensuring that any drainage water is well dispersed. The most satisfactory regeneration follows the burning of logged areas (Grose 1961). Although fire is not generally favoured in the catchment, such burning involves relatively small areas annually, and as it occurs only once in 60 to 100 years of any one area, it probably has little adverse effect on ground cover.

In the forests of mixed eucalypt species in higher-rainfall areas, logging of scantling-quality timber is usually more selective because of the uneven-aged character of these forests and the varying suitability of the species. There is not the widespread site disturbance which occurs in the logging of the even-aged *E. delegatensis* forests. Regeneration may be attained by seedlings or coppice.

The quality of much of the timber being cut from both the *E. delegatensis* and mixed-species forests has been reduced by occasional ground fires which have caused fire scars in the butts of standing trees, and through which insect and fungal attack have frequently been initiated. Complete protection from fire is necessary to ensure that the subsequent crops of trees do not suffer similarly.

The mixed-species eucalypt forests of the lower-rainfall areas are of poorer quality, and usually contain more durable species than the forests of higher-rainfall areas. The main produce from these drier forests is firewood, fencing timbers and small quantities of telephone and shed poles, all for local use. Vegetative ground cover is generally poor and the litter layer is important in protecting the soil. Re-establishment of ground cover after fire is slow.

The Forests Commission is establishing extensive plantations of *Pinus radiata* on the Shelley-Koetong plateau. This is resulting in the replacement of the relatively low-productivity indigenous eucalypt forest by high-productivity softwood forest.

Roads are essential for access for the farming community, trade generally and tourist activities. An adequate road system is also needed for both commercial forestry and for rapid access for fire protection. Road making poses special problems in a mountainous catchment because it usually involves a side-cutting which cuts across natural drainage lines and seepage. Frequent cross drainage is needed to prevent accumulation of excessive flows in the table drains, and provision may have to be made for re-spreading the water after it emerges from the culverts. The steeper the grade of the road, the more frequent should be the culverts. Regular maintenance is essential to ensure that the drains and culverts are kept clear of debris.

Grazing and Agriculture

Where the average annual rainfall is relatively low, grazing is the chief form of agricultural land-use. On the southern tablelands, where the rainfall is about 25 inches per annum, grazing of fine-wool Merino sheep and Hereford beef cattle is the most important agricultural land-use. The cool winters experienced in this area make supplementary feeding desirable in most years.

Another area of relatively dry climate occurs in the north-western corner of the catchment and particularly on the northerly-facing slopes of the Murray River valley. Here, wool and fat lamb production from crossbred sheep and fattening of beef cattle are Practised. Flatter land in this area is also suitable for dairying. However, the steeper country has shallow and light-textured soils and freer drainage, and pastures dry out earlier, so that the steeper country is not generally favoured for dairy farming.

Dairy farming is largely confined to the rolling hills and undulating terraces of the northern valleys, where rainfall is about 30 inches or more per annum. These areas should present few problems for pasture improvement with perennial species. Stream flats are also valuable for summer and autumn grazing, but because of flooding and water-logging in winter and spring, they are frequently unavailable for several months. Also, because the stream flats are the lowest part of the topography, they receive cold-air drainage from higher land and are thus colder than the adjacent terraces or hills. Grazing of sheep on the flats is not popular because it is claimed by some farmers that sheep contract more disease there than on higher land. Alluvial flats are usually best farmed in association with terrace or hill country.

Dairying on the northern plateaux has not been successful in the past. The high cost of establishing pasture on virgin land is probably a major factor. Spring growth of pastures starts later than at lower elevations, and peak production is reached during early summer. This could be a great advantage to the butter factories in the vicinity, as peak production from valley farms is usually in spring. Wool production and the fattening of sheep and cattle have proved successful on these plateaux.

In dairying areas it is usual to find some farms on which grazing is the main land-use. Breeding, and the fattening of beef cattle and the breeding of sheep for wool and fat lamb production may be combined. The size of the holding is a consideration in the type of land-use chosen. Small farms of 100 acres to 150 acres usually cannot be Profitably worked as grazing properties, so that dairy farming is an economic necessity. Beyond this, personal preference for one form of land-use is usually the deciding factor.

Many dairy farms contain a fairly high proportion of steep, and sometimes stony, hill country. Small flocks of sheep are often fun to utilise this land and to provide a supplementary income.

In the remote areas, particularly cast of Benambra, wild dogs make sheep grazing hazardous and usually only beef cattle are grazed.

In the northern valleys, where rail transport is available, superphosphate is widely used on native and sown pastures. Subterranean clover readily volunteers in the native pastures when phosphate levels are raised. Rates of application range from about one bag per acre in three years over large properties, to one bag per acre per annum on smaller, more intensively managed farms. Molybdated superphosphate has been used on many farms in the north, apparently with mixed success. The drier, shallow soils on northern aspects seem to provide the best response to molybdenum. The cost of molybdated superphosphate is only little more than " straight " superphosphate and the small additional cost is well worthwhile.

On the southern tablelands, superphosphate has not been extensively used. The main argument put forward for non-use is economics. The nearest rail head is Bruthen, some 70 road miles to the south, so that handling and transport costs are relatively high. The subsidy on superphosphate, introduced in 1963, greatly increased its use in these areas (R. E. Kelly pers. comm).

Aerial application of superphosphate is becoming more popular with farmers generally, and particularly where large or hilly areas are involved. Bulk handling in conjunction with aerial application is also finding favour. With easier handling the tendency is to spread more superphosphate.

Excessive top-dressing of native pastures on steep country can have undesirable consequences. A substantial build up of soil nitrogen following stimulation of volunteer legumes can lead to elimination of the native perennials by competition from high-fertility annual weeds. These die off in summer and leave the soil poorly protected from the severe summer and early autumn storms. On less-steep country, improved perennial species can be introduced to utilise the increased fertility, but the steep slopes, which are inaccessible to farm implements, cannot be treated.

Dunin (1965), experimenting on undulating country near Bacchus Marsh, has demonstrated that the conversion of native perennial pasture to annual pasture can, under some conditions, result in increased run-off in summer because of the deterioration in ground cover as the annual species die off. This effect may be expected to be exaggerated on the steeper slopes under discussion.

In general, not enough is known about the fertiliser requirements, the best species combinations and management practices on the grazing and agricultural lands of the catchment.

It would seem that many areas in the northern valleys could be successfully irrigated, some by flood irrigation. Experimental work on these problems, followed by vigorous extension work, could lead too much higher production.

Isolation and high transport costs of both in-coming farming necessities and out-going produce, are important problems in the southern tablelands of the catchment.

The assessment of safe and economical stock carrying capacities of pastures is a controversial subject. However, there seems to be little doubt that increased stocking rates, which would be possible with better pastures over much of the agricultural land in the catchment, would result in higher net returns.

Although fruit-growing is at present only a minor form of land-use, it has been demonstrated that on the well-drained soils of the Georges Creek valley and the Shelley plateau, orchards, mainly of apples, can thrive. There are considerable areas of undeveloped freehold land in the Shelley area which could be developed for apple orchards.

Gold mining was a thriving industry in parts of the catchment from the 1850's to the early 1900's. Resurgence of interest in gold mining occurs from time to time. At present gold is being sought in some remote areas of the catchment and the "Maude and Yellow Girl" mine at Glen Wills was operated until recently. Tin mines are being developed in the Walwa area, on the plateau north of Mt. Lawson, and near Koetong.

Plate 21. Wind-sorted pebbles on an erosion pavement on Mt Loch; the prevailing winds blow from the right.
The *Poa australis* tussocks degenerate from the windward side and the gap is enlarged down-wind. Frost heave is severe on bare soil at these elevations. Natural regeneration is extremely difficult under these conditions.

PRESENT CONDITION OF THE LAND

Erosion
Erosion caused by the action of both wind and water and by mass movement of soil occurs in the catchment.

Areas where the various forms of erosion occur are indicated in Figure 19.

Wind Erosion

The most serious wind erosion occurs on the exposed tops of the highest peaks where the grassland and herbfield vegetation is discontinuous. The main occurrences of wind erosion are on Mt. Hotham and Mt. Loch, where the thin layer of organic soil has been stripped to an erosion pavement of pebbles and shingle (Plate 21). Patches of snow grass and low shrubs form a mosaic with the bare erosion pavement. Mt. Bogong, Mt. Nels and to a lesser extent, other peaks in the Bogong land system, are also affected (Plate 22). Less-obvious wind erosion occurs extensively over the Bogong land system where grazing stock, vehicular traffic or earth works have caused damage to the grassland and herbfield vegetation.

It has been suggested (Costin 1957b, Carr and Turner 1959) that the original vegetative cover was continuous, and that it has deteriorated to the present condition under the influence of uncontrolled grazing and fires. Carr and Turner (op. cit.) have demonstrated that the total exclusion of grazing animals results in a gradual improvement in ground cover, provided that deterioration is not too far advanced. However, some of the more seriously affected ridge tops may require protective works, such as straw mulching and sowing down to bring about revegetation. Costin and Wimbush (1963) have reported success in hastening secondary succession on badly eroded and exposed areas in the Snowy Mountains, by the use of naturally occurring herbaceous mulch.

Water Erosion

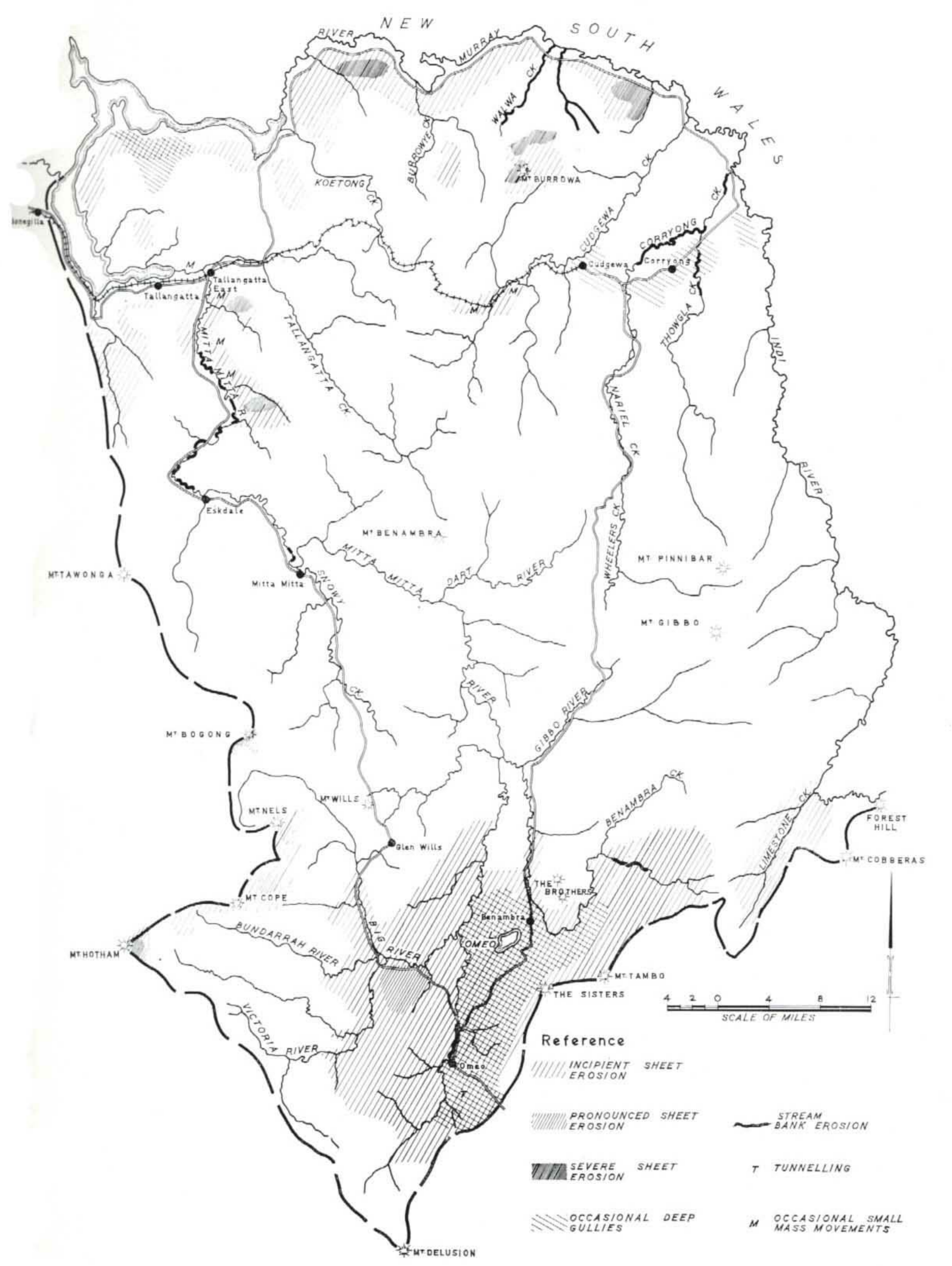
Gully erosion, is the most spectacular form of erosion in the catchment (Plate 23). It is most serious in the southern tablelands and to a less extent in the north-eastern corner of the catchment. Gullies, up to 40 feet deep and many chains in length occur on the southern tablelands. Although the floors and lower reaches of many of these gullies seem to be fairly stable, the heads are generally still active. In the north-cast, Sandy Gully has caused much trouble by sitting up the main Corryong-Cudgewa road.

Erosion-control works have reduced this problem for the present. Both these areas have relatively low rainfall (less than 30 inches per annum) and receive heavy thunderstorms in the summer and late autumn.

It has been suggested (Fawcett 1955, unpublished report to S.C.A.) that much of the gully erosion in the southern tablelands originated early in the century and was caused by a combination of drought and a rabbit plague. Another suggestion is that the early graziers had few fences and watering places, and stock used to follow the drainage lines on their way to water. Poor ground cover, even in recent years, has aggravated the problem. An extensive programme of pasture improvement and subdivisional fencing to provide better control of grazing stock would result in an improvement in the condition of these areas. Mechanical works and structures may be needed in some places to arrest the gully heads, although some have cut back to the tops of their catchments.

Plate 22. A patch of severely sheet-eroded alpine herbfield near the summit of Mt Bogong. Note the entrenchment of the cattle track at left centre.

Fig. 19 Map of erosion incidence



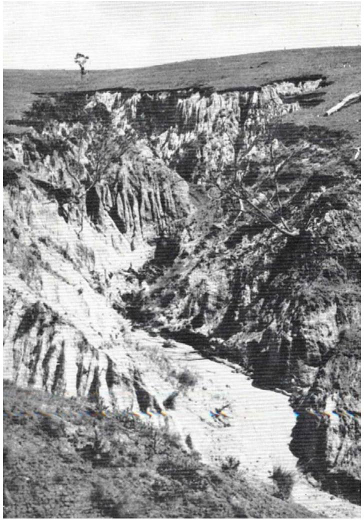


Plate 23. A large gully with many active heads, in the catchment of Black Camp Creek south of Omeo.

Tunnel erosion (Downes 1946) is sometimes associated with the severe gully erosion existing in the southern tablelands. Old plough lines running down the slope are frequently the points of origin of tunnels (Plate 24). The soil in these tunnelled areas is always solodic. Fortunately this form of erosion is not very extensive, but wherever the combination of low rainfall and solodic soils is found, there is a danger of tunnel erosion resulting from improper land-use. Pasture improvement would help to alleviate this danger.

Sheet erosion, although not always very obvious, occurs over extensive areas. Uncleared, steep, granitic hills in the lower-rainfall areas usually have an open, scrubby vegetation with poor ground cover. Destruction of the accumulated litter and sparse ground flora, for example by fire, results in accelerated sheet erosion.

In the lower-rainfall areas, great care must be taken to ensure that over-grazing does not leave the soil exposed to summer and autumn storms, which usually produce high-intensity rain. Particular care must be taken on northern aspects where the vegetation dries off earliest and where stock prefer to graze.

Severe sheet erosion on cleared hill country occurs commonly around Omeo and Benambra in the south, and around Talgarno in the north. Generally, where steep slopes in low-rainfall areas are grazed by sheep, a sheet-erosion hazard will exist. Improvement of pastures and better control of grazing by the landholders would help considerably to overcome these problems.

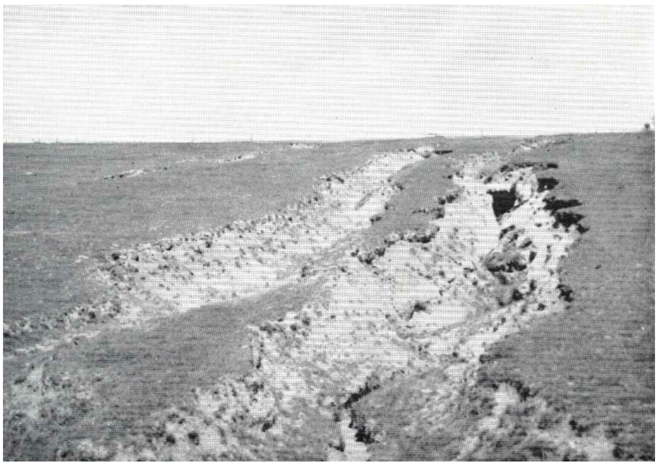


Plate 24. Gully erosion, initiated by tunnel erosion in the catchment of Black Camp Creek, south of Omeo.

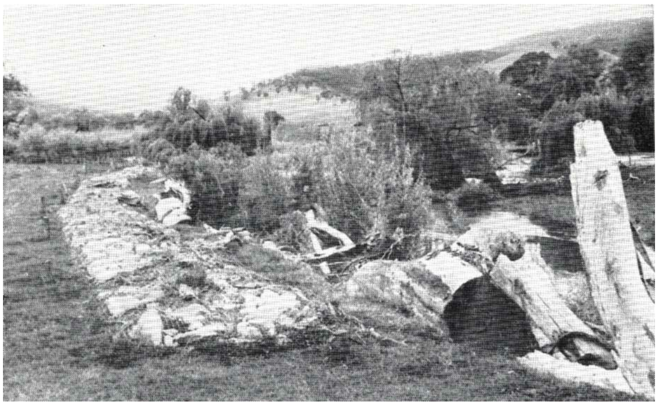


Plate 25. Erosion prevention works on the Mitta Mitta River.
The bank has been protected with logs and willos and a stone-in-wire-mesh barrier prevents back-cutting when the log barrier is over-topped.

Stream-bank erosion has resulted in the loss of substantial areas of good agricultural land on some farms along major streams. A survey of the problem by the Soil Conservation Authority in 1953 (unpublished) showed that the Murray was reasonably stable for a few miles above the back-water of the reservoir, and again in the upper reaches of the Indi River. Tributary creeks such as the Jeremal, Corryong and Cudgewa Creeks were actively eroding. The Mitta Mitta River was eroding from Tallandoon to Mitta Mitta township. The present position is much the same except that on the Mitta Mitta River, a River Improvement Trust has carried out extensive protective works with some success (Plate 25). In the south of the catchment, permanent streams such as Mt. Leinster and Livingstone Creeks are also actively eroding their banks (Plate 26).

Prevention, or at least reduction, of the damage caused through stream-bank erosion would be aided by extensive improvements in vegetative cover in the upper catchments. The effects of this would be to reduce surface run-off and damaging peak flows.

Erosion caused by *wave action is* occurring around the margins of Lake Hume when the water is near full-supply level (Plate 27). Much of the land now inundated when the water level is high is relatively steep. The waves which build up when strong winds blow cause under-cutting and caving of the soil on the steeper slopes. Soil from above full-supply level which enters the reservoir by this means reduces the storage capacity. It is inevitable that a certain amount of this type of foreshore erosion will occur on such a large water storage. The resultant loss of storage may be insignificant, but control of this form of erosion may become necessary on some steeper parts of the foreshore. Probably when a beach has been produced by wave action, little additional soil movement will occur, but the small beach-cliffs may act as gullyheads and cause gully erosion in adjacent land.

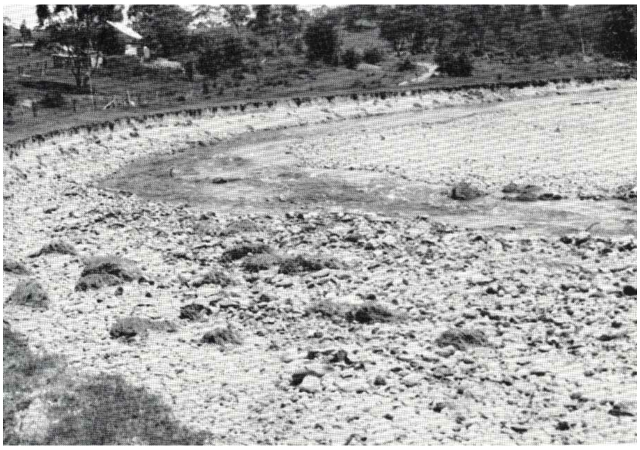


**Plate 26. Stream-bank erosion on the Livingstone Creek north of Omeo.
Most of the erosion to the left of the stream was caused by run-off from a single storm.**

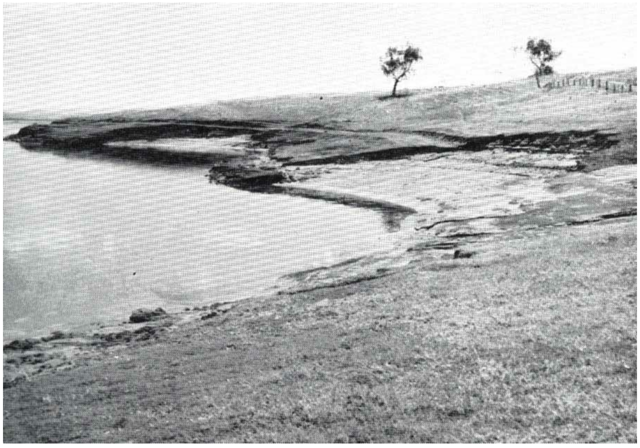


**Plate 27. Wave-action which occurred whilst the Reservoir was near fully supply level in 1959.
The road in the background was abandoned prior to the increase in storage capacity.**

Roadside erosion and *track erosion* are special forms of rilling or of gullying and sometimes of sheet erosion. Where roads lack adequate drainage, run-off water accumulates in the depressions or wheel tracks (Plate 28). Even where grades are moderate, high water speeds can develop and cause severe erosion, because of the continuous nature of the road. A drain along the inner edge of the road and frequent culverts are needed to prevent damaging flows from developing. Continual maintenance is required to keep the drains and culverts clear of debris, which in forest country, accumulates rapidly. Some consideration should also be given to safe disposal of the water which issues from the culverts. This is particularly important in the snow country where, during the thaw, culverts may carry large quantities of water for a considerable time.

Some examples of badly eroded public roads which have been abandoned are to be seen in the Omeo area. Many farmers have recently constructed small-width, side-cut tracks around the steeper parts of their properties. The objective is to produce access for farm vehicles at a low cost. If expensive drainage and culvert works are not to be used on such roads, they should be given a slight grade to the outside edge so that water is readily shed and does not accumulate in channels. Frequent maintenance is necessary during the first few years. Ridge-top roads should have frequent cut-offs to divert water off the road.

Plate 28. Road erosion caused by inadequate drainage.
Sound design and construction is essential and regular maintenance is necessary to minimise erosion of roads. Batters should be cut to a low angle wherever possible, and revegetated. Particular attention should be paid to the revegetating of large fill batters.

Stock tracks pose another erosion problem which, although not usually of the magnitude of gully erosion, can become serious. Sheep and cattle tend to follow definite tracks when moving from one area to another. The heavy trampling causes destruction of the vegetation on the track and powders the soil, which is then readily eroded by wind or water. Continuation of this process can lead to deep entrenchment of the tracks. This is often seen in the high plains area where cattle have abandoned tracks when they became too deep, and have created new ones. Sometimes there are several tracks within half a chain width. Apart from the loss of soil, these tracks cause the soil in their vicinity, to dry more rapidly, and the vegetation suffers accordingly. Stock tracks which converge at openings in down-slope boundary fences of hilly paddocks may result in concentration of sufficient water to produce gully erosion.

Mass Movement of Soil

The term mass movement embraces the movement of large volumes of soil without the detachment and transportation of the individual particles (Gibbons and Downes 1964). Certain forms of mass movement may be classed as geological erosion and are not considered here.

Slumping results from the discontinuous movement of a mass of earth over a slip plane. Although not as severe in this catchment as in some other parts of Victoria, slumping does occur on the steeper hill slopes, particularly on southerly aspects and in years of above average rainfall. Accumulation of water in the subsoil, usually above an impeding horizon such as rock or clay, creates a semi-fluid slip plane. Slumping may occur if there is a fair depth of firm soil above the slip plane and the slope is sufficient. Slumping of newly cut road batters is often a problem.

Plate 29. An earth flow near Berringama. Accumulation of subsurface water liquified the subsoil and allowed the soil mass to flow.

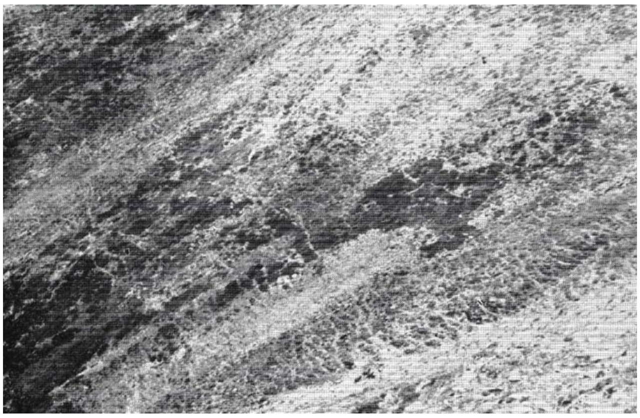


Plate 30. Stock terracettes on steep slopes of Mt Bogong.
These appear to be caused by minor mass movements of the soil produced by stock trafficking when the subsoil is extensively wet. The sheet erosion shown in the plate is the result of over-grazing of snow-patch vegetation.

A mass of earth which has moved down-slope in a laterally elongated form is termed earth flow results from a greater proportion of the earth mass being in a semi-fluid condition than is the case with slumping. *Mudflows* result when the soil is almost all in a semi-fluid condition. In this area, these forms of mass movement do not occur as frequently as slumps.

Solifluction is the almost imperceptible movement of soil under the influence of gravity. It is assisted by processes which loosen the soil, such as freezing and thawing. *Stock terracettes* (Plate 30) appear to be produced by a combination of solifluction and stock trafficking. They are very common on steep grazed slopes along the major valleys and on the steep treeless slopes of the sub-alpine areas.

Frost heave occurs at low elevations, although it is more common and more severe at high elevations. Bare soil is a pre-requisite for this form of soil movement. The unvegetated batters of roads at high elevations may suffer severely from frost action. Frost heave is also a powerful factor in preventing seedling regeneration on bare, unprotected soil in the snow country.

Hydrology

Because of the lack of hydrologic studies in the catchment or in similar areas elsewhere, there is little quantitative information available to indicate the trends in hydrologic condition. Attempts have been made to estimate the potential contributions to total stream-flow of various parts of the catchment by theoretical means (Table 10). Costin, Wimbush and Kerr (1960) and Costin et al. (1960) have studied vegetation and soil changes, and the effect of different types of ground cover and vegetation on the water balance and soil loss in the alpine area of Mt. Kosciusko.

Assessment of the trends in hydrologic features attributable to changes in vegetation or soil have been made elsewhere in this study. Only a general consideration of the present condition of the catchment as a water supply area is given here ; much of it is based on personal observations and lacks experimental backing.

The conversion of *E. pauciflora* woodlands to dense coppice regrowth has an adverse effect on snow-drift accumulation and snow-melt (Costin et. al. 1961). It seems likely that the increased area of shrub community in the snow country leads to more rapid snow-melt (A. S. Rundle, pers. comm.). The opening up of the alpine herbfield and tussock grassland sward may increase surface run-off. Decrease in the effective depth and in the area of the moss beds probably has resulted in the more rapid movement of peak run-off downstream.

The higher-rainfall forest country has a generally good soil cover and seems to be satisfactory hydrologically. Roads contribute to peak flows and to sediment in streams during high-intensity rain. Much of this could be overcome if more attention was given to safe disposal of road-drainage water.

Logging temporarily increases total water yield from small areas, and may increase surface flow to, and the sediment load of, adjacent streams. It is generally limited in frequency to once in 60 to 100 years in the most intensively logged forests, and the area involved annually is relatively small.

The drier forest areas have poorer ground conditions. Litter and small shrubs are often the only soil cover and the soil surface may be hard and impermeable. This condition may have resulted from repeated burning and uncontrolled grazing. The proportion of surface run-off to infiltration is probably relatively high in these areas and little contribution to base flow can be expected from them.

Extensive grazing of unimproved native pastures in drier areas may result in excessive removal of ground cover, and compaction of the soil surface by trampling is inevitable. Areas which have better climate and less-steep slopes may suffer similarly, but the less-steep land generally carries improved pastures which produce better ground cover. The problem of soil compaction also exists in these areas but can be overcome by ripping or chisel ploughing where tractor-drawn implements can be used.

The condition of the snow country requires careful consideration as it is from these areas of higher precipitation that most of the streams' base flows originate. Rapid surface flows from these areas reduce the base flow and increase the flooding hazards in the lower valleys.

Much could be done in grazing areas to improve the ground cover and the infiltration rate of the soils. High surface run-off from any of these areas, and particularly from the snow country and cleared land, could lead to increased flooding, more severe stream-bank erosion and increased sedimentation of stream flats and the reservoir.

Changes caused by burning

In the absence of any experimental evidence on the effects of fire, reliance must be placed on observations and inference. Although fire has been, and is still used extensively as an aid to clearing land for agriculture and in the establishment of forest plantations, any subsequent fire in these developed areas is widely regarded as undesirable or even disastrous. The same does not apply to the forested land, and numerous fires, some of which are deliberately lit, occur each summer. Large areas are sometimes burned before they are put out.

Fire is used by foresters as an aid to regenerating logged *E. delegatensis* forests and to remove excessive accumulations of inflammable material, either natural of caused by logging or road making. The autumn or spring "protective burn" is a feature of most forested areas in Victoria.

In the past, cattlemen with licences to graze forested country, frequently burned their areas to induce a fresh growth of grass.

It seems that repeated fires have been the cause of the development of dense scrub in the higher-rainfall forests. The most abundant species of shrub in the dense scrub are legumes, or species with renewal buds below the soil surface. *(Daviesia latifolia, D. ulicina. D. corymbosa* var. *laxiflora, Acacia dealbata, A. penninervis, Platylobium formosum, Bossiaea foliosa, Oxylobium alpestre, Hovea longifolia* are the most common). It is inferred that the regeneration of the legumes is aided by fire, and those shrubs with subterranean renewal buds have a strong competitive advantage over other species.

The destruction of the mature *E. pauciflora* woodland, and its replacement by coppice over much of the snow country, has been caused by fire. Also, the invasion of the tussock grassland and alpine herbfield by shrubs in the snow country has probably been assisted by fire (Costin 1957b; Carr and Turner 1959 ; Carr 1962). Fire has probably contributed to the decrease in area and depth of the moss beds.

Wild fire in *E. delegatensis* forests may kill the trees as this species is fire-sensitive. However, the fire usually induces abundant seedling regeneration of the trees. A light ground fire in the *E. delegatensis* forests, although not killing the trees, may cause considerable damage by forming fire scars in the butts of the trees. These scars provide ready access to the heart-wood for wood-destroying fungi and termites. Much of the unsound heart-wood so common in the mixed-species forests is probably initiated in this way.

Much of the plant nutrients, particularly in the soils of higher-rainfall areas, is concentrated in the litter and the surface soil. Re-circulation of nutrients from soil to plant and back to the soil is an important feature of the ecology of these communities. When the litter and humus are burnt, the nutrients in the ash are more available. Some may be removed by surface run-off. In the higher-rainfall areas, where soils are deep and permeable, significant quantities of nutrients may be lost by leaching. The erosion of nutrients from the soil surface after fire, may be the cause of the lack of herbaceous ground flora on some of the steeper slopes in the drier parts of the catchment.

Fire has affected all forms of land-use in the catchment. Those which have suffered most seriously are water conservation, commercial forestry and forest grazing.