INDICATORS OF LAND DETERIORATION IN SNOWY MOUNTAINS CATCHMENTS

BY

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PART II

Indicators of Deterioration

Several indicators are usually observable in any one area, and since few indicators have an absolute value which allows them to be used mechanically, an interpretation of catchment condition is likely to be more valid if a number of indicators provide complementary evidence. The recognition of any one or more of the following indicators in a particular area should be sufficient to suggest that catchment condition is unsatisfactory in some degree and that land use must be adjusted to prevent further downward trend.

Bare Soil Surface

Bare soil surface refers to soil surface that is not adequately protected by vegetation or litter against accelerated erosion. In many dryland vegetation types, small bare areas occur naturally in a well-dispersed mosaic with the vegetation. In such cases, stability of the soil surface is normally assured by dispersal of the aerial parts of the plants and possibly some litter.

Where snow grass is the dominant herb, and sod-tussock grassland or herbfield conditions pertain, bare areas are normally nonexistent or negligible (figure 16). In point of fact, bare soil surface is an unnatural phenomenon in almost all of the vegetational units of these catchments. Under ideal conditions, the forests have a relatively open floor dominated by snow grass and with some litter; the woodlands normally have a dense floor vegetation dominated by snow.
The grasslands and herbfields are composed of a dense carpet of snow grass and other associated or co-dominant herbs; the fens and bogs are dominated by species dependent on conditions of permanent wetness, which sustain soil formation rather than soil erosion. Only in the windswept fjeldmark communities (figure 9, Part I) is there any semblance of bare soil surface and even here it is doubtful whether soil has ever been formed, so that no problem arises from these confined areas.

Evidence of bare soil surface, under the climatic conditions which pertain in these catchments, must therefore be accepted as an unnatural phenomenon. That it is unnatural, is attested by the fact that accelerated erosion occurs wherever the vegetation is depleted or destroyed. Such an occurrence is clearly illustrated in figure 17. The woodland has been destroyed by fire and subsequent grazing; surface vegetation is seriously depleted and accelerated erosion is most active as indicated by soil remnants, pedestal plants and rill formation.

Under any circumstances, bare soil surface is thus an indicator of unsatisfactory catchment condition because of the constant threat of accelerated erosion due to frost, and wind and water action. The more widespread the condition of bare soil surface, the more serious is the deterioration that has occurred.

**Sheet and Gully Erosion**

Active gully formation is not a widespread phenomenon in the Snowy Mountains. This general absence of gullies is suggested as the main reason for a fairly common belief that there is little or no erosion in the catchments.
The exact reason for the restricted occurrence of gullies is somewhat uncertain. By virtue of their high organic matter content and fine grained structure, the alpine humus and transitional alpine humus soils are more prone to sheet erosion by wind and water following continual disturbance by frost. Apart from these soil characteristics, the vigorous frost action itself is a possible reason for the comparative lack of gullies, since constant heaving of the soil promotes the formation of broad, shallow depressions rather than deep narrow channels.

To date, almost all erosion damage is due to severe and extensive sheeting, but it is significant that rilling and gullying become more active once the top soil is stripped off, exposing the subsoil which contains less organic matter and greater quantities of larger particles and fine gravel.

An accurate assessment of erosion hazard and damage in these catchments is thus based essentially on recognising that, although erosion is different in kind to the extensive gully erosion observed in other regions, it is no less severe or disastrous in its effects. Both sheet and gully erosion indicate that the soil mantle is being destroyed and particularly where active gullying is concerned, a late stage in the process is indicated.

Gullies are said to be "active" when their sidewalls are unstable and when active cutting occurs at the head or in the bottom of the channel. They are caused by rapid surface flow and concentration of water, which under normal conditions, would enter and filter through the soil or be retarded by the vegetation. Active gullying is thus a strong indicator of deterioration on the catchment which promotes the gully.

Fig. 17.—This snow gum woodland, together with the ground vegetation, has been destroyed by burning and subsequent grazing. There is a wide occurrence of bare soil surface and accelerated erosion is most active as indicated by pedestalled plants, soil remnants and rill formation—Perisher Creek Valley.
Fig. 16.—Sod-tussock grassland of snow grass forms a complete ground cover in this snow gum woodland. There is no bare soil surface and hence there is no possibility of accelerated erosion—Pipers Gap.

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Sheet erosion is more insidious in its effect and may reach an advanced stage before being recognised. In the initial stages, the rate of soil loss is generally relatively slow, so that vegetative development may tend to keep pace with this loss and mask its effects. Where the vegetation is further depleted, soil loss increases and results in reduced soil fertility, alteration of micro-climate and ultimately in the isolation and death of individual plants.

Under these conditions, increased run-off predisposes active rilling and gullying, so that any signs of sheet erosion indicate deterioration and thus unsatisfactory catchment condition.

**Erosion Pavement**

Erosion pavement is the name given to the concentration of gravel and rocks at the soil surface following the removal of the fine soil particles by accelerated wind and water erosion.

The accumulation of gravel on the surface is not, in itself, conclusive evidence that the soil has been washed or blown away. Gravel may be moved downslope as erosional debris by excess run-off from eroded areas above, or it may be the result of normal processes of scree movement if the area has not been stabilised by vegetation.

Evidence that the pavement has been produced by accelerated erosion is normally found in other indicators such as small alluvial deposits, soil remnants and pedestalled plants. Erosion pavement produced by accelerated erosion indicates that the soil mantle, or a large part of it, has been lost and that the site has deteriorated greatly from its original condition (figure 20). The micro-climate is drier, and subject to greater extremes of heat and cold. Usually, infiltration capacity is lower and the rate of run-off...
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A well-developed erosion pavement indicates an advanced stage in erosion damage, since all or part of the original soil mantle has been destroyed and removed. Additionally, the effect of increased run-off on lower slopes and on stream hydrology involves the possibility of deterioration extending over a larger area.

Soil Remnants

Soil remnants are relics of a soil surface and occur as islands of soil elevated above a common level of erosion pavement. They owe their presence to the protection of the remaining vegetation, which is said to be “pedestalled” because of its position on top of the soil remnants. They are strong indicators of accelerated erosion for a number of reasons.

A soil mantle is normally built up as a continuous body, the type of soil which develops depending on local topographic and climatic conditions. Erosion of this soil body results in soil loss, and soil remnants are what remains after part of the mantle has been eroded away.

The existence of soil remnants with vertical sides, and with plant roots exposed, indicates recent erosion and probably that erosion is still active. If the sides of the remnants are sloped and occupied by vegetation, a return to more stable conditions may be indicated. For all practical purposes however, soil remnants indicate that the soil mantle has been damaged comparatively recently. An examination of the remnants, together with the presence or absence of other indicators, will confirm whether erosion is still taking place.

Fig. 19.—Although the vegetation has been completely destroyed and this area is severely sheet-eroded there is, as yet, little evidence of gully formation. It is necessary to recognise this factor in the erosion process to assess correctly the extent of erosion damage in these catchments—Carruthers Peak-Mt. Twynam.
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![Fig. 19.](image-url) Although the vegetation has been completely destroyed and this area is severely sheet-eroded there is, as yet, little evidence of gully formation. It is necessary to recognise this factor in the erosion process to assess correctly the extent of erosion damage in these catchments—Carruthers Peak-Mt. Twynam.
Fig. 18.—Active gullies such as these do not occur commonly in the area. In this instance their formation was due to destruction of vegetation and concentration of water by a track leading across the severely eroded slope—Carruthers Peak.

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Fig. 20.—The almost complete destruction of the soil mantle on this area is indicated by soil remnants with pedestalled plants and by the formation of an erosion pavement—Carruthers Peak-Mt. Twynam.

**Observed Soil Movement**

Observed movement of soil indicates that accelerated erosion is still active. The actual displacement of soil may be caused by wind, water, gravity or the trampling effect of animals on slopes with exposed soil.

Soil displacement is most obvious in the discoloured and muddy appearance of streams but this condition may not relate to damage on the catchment itself. Such discolouration can be due to road drainage, engineering works, natural landslides and caving of the stream banks. Observed movement of soil on the catchment proper is, however, a definite sign of accelerated erosion.

The most obvious agent of displacement in this area is surface run-off derived from rainfall or melting snow. Figure 21 illustrates a severe, but not uncommon, case of soil movement where soil, gravel and rocks have been deposited on snow as a result of excessive run-off and soil loss from the slope above. The local conditions on the water-shed which lead to soil movements of this order are extensive areas of bare soil surface, with active sheet and gully erosion (see figure 2, Part I).

Fortunately, soil movement is not always so obvious as in this instance, for soil movements of this magnitude indeed indicate a very late stage in accelerated erosion. We may be quite certain that if soil movements of this nature occur regularly it will not be long before the whole soil mantle is destroyed over extensive areas.

The development of small rills, small alluvial deposits and burial of vegetation downslope are early indications of soil movement and therefore that deterioration is taking place.
Lichen Lines

Lichens are flower-less fungus-like plants which grow above ground level on fixed rocks. Their value as an indicator of soil stability is that they grow very slowly. If soil is eroded, the original level of the soil surface can often be traced on rocks by a sudden change from a zone of dense lichen growth to a zone of relative scarcity or absence of lichens.

Although little is known of the exact rate of growth of lichens, it is certain that their development is sufficiently rapid to keep pace with normal erosion and perhaps with even moderately accelerated erosion. The existence of clearly defined lichen lines (figure 22) thus indicates that the rate of soil removal has been rapid. Soil loss adjacent to the rock in figure 22 varies between 9 and 12 inches. Further evidence that the original soil level coincided with the well-marked lichen line is also illustrated by the remnant of vegetation and soil in the rock crevice.

Lichen lines are not always so pronounced as in this instance, but in practice, the clear evidence of soil loss demonstrated here allows the general use of lichen lines as indicators of accelerated erosion.

Soil and Vegetation Lines

Lines which correspond to the former level of vegetation and soil on fixed rocks are more limited in their occurrence and hence in their application as indicators than are lichen lines. However, their occurrence under some conditions in this area warrants description.

In general, they are associated with severely eroded areas which were formerly wet places and which supported fen or bog

Fig. 21.—Soil movements of this order, highlighted here by deposition on snow, indicate an advanced stage in acceleration erosion—Carruthers Peak.
plant communities. The soils developed under these conditions of free ground water and a constant return of humus material, are peaty in nature and very dark-brown to black in colour.

In addition to a well-defined lichen line in many cases, the rocks which have been exposed by erosion of these soils now exhibit two other well defined zones. The general level of the vegetation and soil nearby, suggest that these lines coincide with the original soil level and the zone occupied by vegetation.

The rock indicated by the person in figure 23 carries these three distinct zones. Other evidence which indicates the original soil and vegetation levels and which shows that considerable soil loss has occurred at this site, are the soil remnants and pedestalled plants in the right centre of the photograph and erosion pavement in the right foreground. Soil surface is bare, with no indication of invasion by vegetation, and hence it is concluded that accelerated erosion is still taking place.

**Exposed Plant Roots**

Plant roots which are exposed by soil displacement indicate recent erosion. The younger the plant, the more recent the erosion is likely to have been.

Figure 24 shows a young tree with roots already exposed by soil loss to a depth of six inches. The small roots, and the fact that they grew in the soil, indicates that the soil must have been removed quite recently. Deterioration in other vegetation close by, due to the loss of soil from around the plant crowns and roots, also indicates that erosion is recent.
Fig. 23.—In addition to a clearly defined lichen line, some of these rocks show two other clearly marked zones which probably correspond to the zones originally occupied by the soil and vegetation—Gungartan area.

Fig. 24.—The roots of this young tree have been exposed by soil removal, shown also by soil remnants and pedestalled plants in the adjacent herbaceous vegetation—Daner's Gap.
Exposed roots of small herbaceous plants are an even stronger indicator than the large roots of trees. Trees normally have an extensive root system which extends well down into the soil and subsoil, so that the exposure of surface roots is generally not sufficient to damage the tree. Exposed root systems of smaller herbaceous plants, normally means that the tenure of the plants on an eroding site is only temporary (see figure II-D, Part I). As the soil is removed and the plant roots are exposed, the environment, to which the plant was formerly accustomed, changes considerably. Death of the plant can normally be anticipated within a relatively short time.

Humification and Erosion of Peat

Under natural conditions, large areas of peat and peat soils have developed in these mountains. The accumulation of peat is dependent on three main factors, namely, a constant supply of organic matter, an excess of water and a very slow process of decay. The most common factors which limit decay are an excess of water and low temperatures.

The development of peat, often to considerable depths, is evidence of stability in the environment over a very long period of time. Signs that peat is being eroded (figure 25) are indisputable evidence of marked changes in the vegetation-water relationships in the former bog or swamp, and probably in the higher parts of the catchment as well.

Erosion of peat may be initiated by fire, grazing or stock trampling (often all three combined), each of which may alter the water regime in the bog. As a result, water

Fig. 25.—A close study of the above stream channel shows that the original peat deposits are being actively eroded following drying out of the bog and humification of the peat—

Carruthers Peak.

Photo: A. B. Costin.
Fig. 26.—An entrenched and eroding stream channel, now a common occurrence in the broad valleys found in these catchments. Old meanders, typical of those which conform to the natural hummock and hollow pattern in a healthy bog community, can be seen in the centre—Johnnies Plain.

Flow is concentrated in single streamlines instead of being dispersed as free water over the whole of the bog area (figure 26). As the stream channel deepens, the water table is lowered and the bog begins to dry out. As the bog dries out, the peat dries and is humified through contact with the air. The peat dust, or loose fibrous material, which results from this humification is then readily removed by wind or water.

Once peat dries out it is very difficult to rewet, so that when erosion begins it is virtually an irreversible process. For this reason particularly, evidence of the humification and erosion of peat deposits is a powerful indicator of deterioration.

Entrenched Streams

When water is concentrated in a defined channel, in contrast to an equal volume of water in a broad shallow flow, its velocity of flow is greatly increased together with its power to erode and transport soil.

Although not completely proven by objective studies, there are many reasons for suspecting as unnatural phenomena the entrenched streams which now occur widely throughout these catchments (figure 26). Foremost among these reasons are the type of soil and vegetation naturally associated with the broad swamp-like valley floors.

The soils which normally occupy these sites are distinctly ground-water soils such as peats and silty bog soils. Such soils are only laid down under conditions of permanent wetness and complete stability in the environment. The vegetation associated with these wet conditions is largely dominated by sphagnum moss (Sphagnum cristatum). The fact that some of these soils are now
exposed and that alternating soil characteristics can be traced at similar levels on each side of the entrenched channels, can only mean that some change has occurred in the environment since the soils were laid down. Active stream bank erosion, gravel deposition and an apparent change towards vegetation able to tolerate drier conditions, all suggest that the changes are recent in origin.

Under normal conditions, the vegetation in these wet places, mainly as a result of moss development, displays a typical hummock and hollow pattern. Throughout this system there occur tiny meandering channels which carry excess water and which remain well vegetated provided there is no disturbance. Following damage by fire or stock, these small streams carry greater amounts of water and gradually enlarge due to the death of protecting vegetation and erosion of the channel. As the channels enlarge, greater amounts of water are carried, velocity of flow increases and successive meanders in the channel are cut through and by-passed to provide a more direct stream-line. Very often, the earlier meandering course can be seen to conform to the original hummock and hollow pattern. The dynamics of this process can be seen in figure 26.

Once delineated, the main stream gradually deepens, lowering the water table still further, active stream bank erosion occurs, and a bed load of gravel is alternately transported and deposited by fluctuating stream flow (see figure 27).

Sedimentation

The existence of alluvial flats along the middle and lower reaches of streams generally, is evidence that a natural process of transportation and deposition of soil and soil forming materials has proceeded for a very long period of time. Under normal conditions of stability in the catchment, and of equilibrium between the processes of normal erosion (i.e., transportation and deposition),

Fig. 27.—The extent of sedimentation in local streams is shown in the sand and gravel shoals in the bends of this entrenched stream channel. Blocking of stream channels by sediment encourages streambank erosion, adding further to sedimentation problems.

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these sedimentary deposits are mainly silt, clay, very fine sand, and organic matter. Generally, these deposits yield some of the most fertile soils and support highly-developed systems of agriculture.

If erosion is accelerated on the catchment however, this normal process of deposition is greatly altered. Increased run-off erodes the soil more rapidly and transports larger soil particles in greater quantities. As a result, stream channels become choked with erosional debris, active stream bank erosion occurs, and at times of high stream flow, inert sand, gravel, and other debris may spill over and bury the original, fertile alluvial soil. On the larger scale, and as sedimentation increases, reservoirs, navigation channels and harbour facilities may be threatened. Such problems are now manifest in many of our major streams and in every instance, sedimentation must be regarded as the significant and final expression of damage in the higher parts of the catchment.

Because the Snowy Mountains rise steeply above the surrounding land, the streams which flow out from the area are all youthful in character and normally, any sediments yielded by erosion would be deposited ultimately in the stream channels at lower levels or on the adjacent lands. The inherent value of this land, and of these catchments as a water producing resource, has been, and will always remain sufficient reason for not allowing any erosion problem to endure in the catchments. However, in spite of the evidence which has accumulated over a number of years to show that erosion has been greatly accelerated, the problems of erosion and sedimentation were not recognised effectively until comparatively recently, when they assumed greater significance with the planned installation of a number of dams in the current hydro-electric scheme.

Although the evidence available from one small pondage, installed five years ago, suggests that the rate of sedimentation is insignificant, the fact that part of its catchment is severely eroded casts some doubt as to whether such a low rate will obtain for all time if the eroded area is not stabilised. At the present time, it is apparent that a substantial part of the surface soil is being removed by wind action, but inevitably, as the coarser materials found at lower levels in the soil mantle are exposed, increased run-off and active gullying begin to contribute much greater quantities of sediment to the streams. For a number of years, these sediments are withheld by the natural barriers formed by the vegetation and other features in the headwaters of the smaller streams, but eventually the time must come when this is no longer possible. If erosion continues on the damaged part of the catchment and increases the area which acts as a flood and sediment source, the pressure applied to the streams becomes greater and the sediment begins to move much more rapidly.

The early signs of this process are apparent throughout these catchments (figure 27) and whilst it is conceded that sedimentation is not likely to become catastrophic in its effects in the immediate future, it must be acknowledged that an eroded catchment always involves the threat of sedimentation at lower levels. Normally, this threat is proportional to the seriousness of erosion in the catchment.

Fire Damage

Damage due to fire, and the subsequent pattern of rehabilitation in the vegetation, can be considered in two categories—that where all other disturbance is excluded following fire and that where disturbance continues.

Fires in the mountains have originated from two main sources, the major bushfire entering the area from outside and the deliberate fires lit by stockmen as part of normal grazing practice. Regardless of the origin of fire, it has been normal practice to graze as soon as possible after fire, that is, as soon as new growth has appeared. Having been normal practice for the greater part of the last century, the damage due to fire has to a large extent become accepted as “normal”.

But permanent damage in the woodlands and forests, particularly with the genus Eucalyptus, is not normal. If all other disturbance is excluded, recovery soon occurs by means of new growth from seedlings, epicormic shoots or basal lignotubers depending on the species. Snow gum, the main species which has been consistently
attacked and damaged by human interference, regenerates both by seedlings and new shoots from basal lignotubers. This new growth is readily grazed by stock and if grazing pressure is maintained, regeneration is soon prevented altogether.

The fenceline study in figure 33 illustrates this degeneration. This particular fence encloses an area dedicated as a water reserve and, together with surrounding areas, it was burnt over during the major fires of 1939. The area to the left of the fence have been grazed since that time, whereas the area to the right of the fence and within the reserve has been excluded from grazing. Vegetation studies carried out along this fence (Anon. 1958) have revealed a striking contrast between the vegetation of the two areas as shown in Table I.

**Table I. The effect of protection from grazing on the recovery of vegetation in fire-damaged snow-gum woodland.**

<table>
<thead>
<tr>
<th>Vegetation Cover</th>
<th>Ungrazed Reserve</th>
<th>Grazed Lease</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(per cent. cover)</td>
<td>(per cent. cover)</td>
</tr>
<tr>
<td>Snow Gum ... ...</td>
<td>39</td>
<td>2</td>
</tr>
<tr>
<td>Snow Grass ... ...</td>
<td>34</td>
<td>42</td>
</tr>
<tr>
<td>Shrubs ... ...</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>Bare spaces and inter-tussock areas ... ...</td>
<td>12</td>
<td>36</td>
</tr>
</tbody>
</table>

The dense regeneration which occurs after fire is not without problems. In addition to the sapling regrowth of the dominant snow gum a dense understorey of shrubs soon develop and forms a severe fire hazard. A lengthy period must elapse before the shrubs first die and, later, by natural thinning and death of the weaker saplings a more open stand of trees, approaching the original condition, is attained.

In the past, the answer to this problem of fire hazard and the reduction in grazing due to unpalatable shrub growth, was to undertake further deliberate burning. However, this provided only temporary relief as, in the long run, fires encouraged shrubs at the expenses of grasses and also bared the soil, resulting in erosion.

The control of deliberate burning has been fairly effective since 1954 and a fire protection scheme is now in operation. Both the scope and intensity of protection measures are being increased from year to year, and although it is unlikely that the threat of a major bushfire will ever be removed, the likelihood of outbreaks being controlled before they reach major proportions has already been greatly increased.

The wholesale destruction of tree cover has many effects. Within the Kosciusko State Park it destroys the aesthetic appeal provided by a healthy vegetation. Where catchment stability is concerned, it goes much further.

One of the main effects is the alteration of local and microclimate. If the ground vegetation, adapted to conditions in the environment dependent on tree cover, is suddenly bereft of the protection of the overstorey vegetation the conditions for normal plant growth and regeneration are greatly altered. If grazing pressure further damages the herbaceous ground vegetation, the natural repair of fire damage is prolonged. In almost all cases, this prolonged state of depletion in the surface cover has led to some degree of accelerated erosion. Complete destruction of the tree cover over widespread areas also means loss of the seed source and, even though grazing may cease at a later stage, regeneration is prevented.

Considered in relation to overall conservation requirements, particularly where hydro-electric development is concerned, destruction of the woodlands in the subalpine tract can involve serious loss of snow by wind and hence water yield is affected.

Snow is affected by windscour in much the same way as exposed sand or soil, and where it is not protected by tree cover, considerable loss of snow may occur from higher to lower elevations. For efficient hydro-electric development, the maximum head of water is required at the highest possible elevation, so that loss of snow to lower elevations involves economic loss in power generation.
Fig. 28.—A fire damaged woodland showing dense pyric regrowth of snow gum and associated shrub species. In this condition the area is a serious fire hazard and to allow for further grazing would need to be burnt again—Round Mountain.

Fig. 29.—The forests have been extensively damaged by fire and in many cases they are now scrubbed-up by a dense pyric regrowth. Following an earlier fire, indicated by regrowth from epicormic shoots on some trees, this area has been burnt again—Nimmo.
Fig. 30.—The accumulation and retention of a snowpack is greatly influenced by a healthy woodland. Here a small group of snow gums protects the snowpack, whilst on adjacent areas exposed to wind, the snow has melted—Daner's Gap.

Photo: A. B. Costin.

Under natural conditions in the woodlands, trees have a marked effect on the accumulation and retention of snow (figure 30). The effect on the snowpack of an even, sparse cover of timber is amply demonstrated in figure 31, where fire-damage in the woodland is highlighted against the snow.

Fire has been responsible for damage in all vegetational units—the forests, woodlands, grassland, herbfld and bog communities. The occurrence of individual or occasional fires may not in themselves indicate serious deterioration, but the widespread effects of recurring fire as used to benefit grazing, are evidence of deterioration in catchment condition and stability.

Stock Trampling

The effects of trampling on slopes subjected to heavy stock utilisation, where damage to the vegetation and disturbance of soil result in the formation of small bench-like structures variously referred to as "terracing", stock trails, and stock terraces, are commonly described in publications which deal with techniques or range management and which assess watershed or catchment deterioration. Such damage has its counterpart in these catchments, where the most widespread and readily observed form of damage which results from excessive or prolonged stock trampling, is contour terracing. The typical development of these terraces, which occur generally on slopes throughout the tussock grasslands of the subalpine tract, is shown in figure 32.

In a previous article (Durham 1956), which reviewed the overall problem of erosion in these catchments and referred broadly to the information then existing on various
types of soil movement thought to occur, the main role in the development of terracettes was ascribed to frost activity. Subsequent studies in the area, however, notably by Raeder-Roitzsch and Phillips (1959), point clearly to the fact that animals are primarily responsible for the occurrence of these structures.

It is significant that terracettes caused by stock trampling occur under a wide range of environmental conditions varying from those which are generally warmer and drier, to those which are experienced in these catchments where frost activity is severe for a large part of the year. The effect of frost activity, which greatly assists the process of soil movement on all bare areas, is thus more correctly, one of assisting the formation of terracettes once the vegetation cover has been opened up and the soil surface has become exposed.

In the formation of terracettes in the tussock grasslands of these catchments, it is implicit that burning, grazing and trampling are responsible for the initial opening up of the vegetative cover and for the enlargement of the inter-tussock spaces. Soil that is subsequently dislodged by trampling, or the agencies of erosion, is then carried or forced downslope and, as a temporary measure, it assumes the form of a more or less level terracette supported by the vegetation immediately below.

Further grazing and trailing on these damaged areas hastens the process of soil movement and ultimately individual areas at, or near the same level on the slope, coalesce to produce a continuous terracette which may persist for some distance across the slope or conjoin with another one above or below. If the process continues, the terracettes gradually become wider or deeper.

Fig. 31.—Even a sparse cover such as this protects the snowpack and delays snow melt, which helps to sustain stream flow in the summer months. In this instance fire has killed the sapling regrowth from an earlier fire in the woodland—Wilson's Valley.

Photo.: A. B. Costin.
depending on the degree of slope. On very steep slopes, terracettes and the intervening vegetation often become so unstable that slumping occurs. The essential problem associated with the formation of terracettes is thus an increase in the incidence of bare soil surface and an extension of erosion hazard.

Stock trampling is also responsible for damage in wet places; on unstable slopes where trampling hastens normal scree and soil movement; and on areas already damaged through loss of the vegetation. Its effect in wet situations—the bogs and fens—is expressed in mechanical damage to the vegetation; in pulverising the peat and bog soils causing changes in microtopography; in alterations of water flow characteristics; and, in conjunction with grazing and burning, in the ultimate desiccation and erosion of soils which were formerly waterlogged and stable. On unstable or damaged areas they are responsible for further soil displacement by mechanical damage to an already depleted vegetation, and in further retarding vegetative development already made very difficult by an unfavourable micro-climatic environment.

The detrimental effect of grazing is generally considered only in relation to the removal of vegetation. Although this is a major factor in baring the soil to the eroding agents the effect of stock trampling in compacting, pulverizing and displacing the soil cannot be lightly dismissed. The widespread evidence of terracette formation and other disturbance to the soil indicates a real erosion hazard from this source, and a factor contributing to unsatisfactory catchment condition.

Fenceline Studies

Fenceline studies are mainly of value in demonstrating the effects of various types of land use, and in adding weight to other
indicators which suggest continued deterioration as a result of grazing or some improvement as a result of release from grazing.

In recent years, a number of fences have been constructed to provide enclosures for regeneration studies, and already much valuable information has been obtained regarding current grazing utilisation and the rate of rehabilitation in different type-areas once grazing ceases. If maintained for a sufficient length of time, these enclosures can provide valuable information on which attempts may be made to visualise or reconstruct conditions as they were prior to human interference.

The fenceline study in figure 33, showing marked regeneration of snow gum in the area protected from grazing, provides us with evidence of the effect of grazing after fire in contrast to the effect of excluding stock. While detailed ecological studies reveal the same evidence, which satisfies the ecologist or conservationist, a fenceline study such as this displays the evidence in bold relief and is there for all to see.

Figure 34 shows some obvious difference between utilisation to the left of the fence in contrast to that on the right. In this instance, the area to the right of the fence is part of a stock route which serves the leases in part of these catchments. Along any stock route it is normal to expect heavy utilisation both from grazing and trampling, but apart from the fact that a stock route is thus an extreme case, several things may be deduced from this study. The soil surface to the right of the fence is obviously in an unstable condition. There is no surface vegetation, the soil is compacted and we could expect infiltration capacity to be low and run-off to be excessive. To this extent,
Fig. 34.—The effect of heavy stock concentrations is clearly shown on the area to the right of this fence. Earlier fire damage is indicated by fire scars on the trees and by pyric regrowth to the left of the fence—Nimmo.

The section of the catchment in which this area occurs is unstable. Previous fire damage is evident from the fire scars at the base of the trees and also in the pyric regrowth to the left of the fence. Although not ideal, catchment condition to the left of the fence is far superior to that on the right.

Figure 35 shows the accumulation of litter and erosional debris against a fence due to excessive run-off from the slope on the right. This indicates that the slope is unstable and this may be judged in several ways. Surface vegetation is sparse and litter accumulation is not dense enough to retard surface water flow. The woodland is comprised of mature trees, showing that regeneration has been prevented, probably by constant grazing of young seedlings.

Another example of the value of fence line studies is shown in Table II, which summarises the results of a study carried out in recent years to assess the effect of grazing on the regeneration of snow gum. The figures represent the number of seedlings in an area one yard wide along either side of the eastern fence of a regeneration area which was established in 1954. These figures show a marked increase in the number of seedlings in the protected area and a gradual decline in the seedlings on the unprotected area. The fall in numbers in 1958 is due primarily to the preceding extremely dry summer.

**Table II. The effect of protection from grazing on the regeneration of snow gum seedlings.**

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of Snow Gum Seedlings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grazed Lease</td>
</tr>
<tr>
<td>1954</td>
<td>...</td>
</tr>
<tr>
<td>1955</td>
<td>37</td>
</tr>
<tr>
<td>1956</td>
<td>26</td>
</tr>
<tr>
<td>1957</td>
<td>16</td>
</tr>
<tr>
<td>1958</td>
<td>15</td>
</tr>
</tbody>
</table>
Throughout these catchments there are a number of relatively small areas which have been used consistently as stockyards or mustering and holding paddocks over a long number of years. Owing to the effect of heavy concentrations of stock, the original vegetation has been replaced in most cases by a dense sward of introduced grasses and clovers. Grazing interests constantly quote this effect, and the resultant soil stability, as an example of the benefits of grazing and to sustain their arguments in favour of a continuance of grazing.

The fenceline study in figure 36 shows a typical example of the conversion from sod-tussock grassland to a disclimax grassland of introduced species seen to the left of the fence. Stock have certainly been responsible for this change, but not in the manner suggested above.

Such areas normally served a number of surrounding snow leases and were often used for mustering, or holding stock as they are brought into or taken out of the mountains. The change in the vegetation is thus due to much more than the effect of intensive grazing. The beneficial effect is due to the introduction of numerous plant species and a constant build-up of the soil nutrient level by concentrated dunging, as a result of heavy concentrations of stock on these areas from surrounding leases. Chief among these introduced species are white clover (*Trifolium repens*), Kentucky blue grass (*Poa pratensis*) and brown top bent grass (*Agrostis tenuis*).

In contrast to the native species, all the introduced species demand a much higher soil nutrient level and their persistence is thus dependent on the constant replenishment of soil nutrients. The formation of a dense sward is effected by the extreme grazing pressures to which the areas are subjected for a few days in each year.

The arguments advanced by grazing interests imply that further grazing in the

*Fig. 35.—The unstable nature of this slope is indicated by the accumulation of soil and litter on the fence, due to depleted surface cover and excessive run-off—Nimmo.*
catchments would have the same effect over much greater areas. The fact that this has not occurred during the past century, however, is surely significant. The reason is, of course, that extensive open-range grazing will never produce such a system.

Another factor which has operated favourably during these conversions to improved pasture species, is that the majority of the areas are located on level to gently undulating land, so that there is no real problem from erosion while the areas are in a largely bare condition following heavy grazing and trampling. It is doubtful whether attempts at similar conversions on steeper slopes would be so successful, owing to the effect of increased run-off in transporting soil and plant nutrients to lower levels.

Any attempt to convert larger areas to this form of introduced pasture, or to bring about rapid conversions to justify a continuance of grazing, must face the real problem of supplying and maintaining the required soil nutrient level. Additionally, those areas most vulnerable to stock damage, namely, the bogs, fens, snow patch sites, very steep slopes and areas already damaged, would need to be fenced to exclude stock. The areas considered suitable for conversion would need subdivisional fencing to gain the required stocking rates.

Fig. 36.—The dense sward of introduced species on the left of the fence contrasts strongly with the existing conditions in the native vegetation, which has been grazed on the normal extensive basis—Tibiaude Creek.

Photo: S.M.H.E.A.
to maintain the system and to justify the capital outlay involved. The economic aspects of fencing, application of fertilisers and the possible effects of increased run-off, from a closely grazed sward, on stream hydrology have been described in greater detail elsewhere by the Australian Academy of Science (1957) and Costin (1958).

Judged by the examples described above, fenceline studies are thus of considerable value in providing information regarding the changes which occur as a result of grazing, or as a result from grazing. Other indicators which are normally present in the area, enable an assessment to be made as to whether there is a trend towards improvement or further deterioration in catchment condition.

THE APPLICATION OF INDICATORS

The general absence of gullies, and of other outstanding evidence of accelerated erosion over much of the area, has been stated as the main reason for a fairly common belief that there is little or no erosion in these catchments. Usually, this belief is based on casual observance or a lack of appreciation for the type of erosion which occurs, and thus it may be readily understood but not readily excused.

The area shown in figure 37 will help to illustrate this point. Except for fire damage which is evident in the woodland on the slopes, the general condition of the area appears satisfactory for catchment purposes. Ground cover appears adequate with no discernible evidence of accelerated erosion. A detailed, but not intensive, examination of the area however proves that this assessment is quite incorrect.

Beginning from point A, and by referring to the subsidiary figures which are identified with the sites A—D, a considerable amount of evidence may be assembled which shows that, although the area is not yet extensively eroded, it is already seriously deteriorated with several indications that erosion hazard and damage are increasing.

Site A (figure 37A) comprises an area of sod-tussock grassland providing a complete ground cover. Recalling the general principles that bare soil surface is not naturally a component of this plant community, and that erosion is accelerated only when the vegetative cover is depleted, it is therefore readily determined that Site A is in a satisfactory condition, so far as catchment purposes are concerned. If, on the other hand, the grazing value or potential of the site were being determined, the knowledge that vegetation in this condition does not yield attractive grazing, would permit of other equally valid but entirely different conclusions being drawn. For example, it would follow that to obtain attractive grazing, fresh grass shoots must be substituted for the older, unpalatable growth by such means as regular burning, or that the dominant snowgrass must be reduced to at least co-dominant status by encouraging the invasion and growth of more palatable species. Because these motives have been implicit in past grazing practices and because it is now recognised that such practices ultimately create bare soil surface, the incompatibility of grazing and catchment requirements is thus readily established. The general condition on Site A however, suggests that these influences have never operated to any great extent and on this basis it might easily be concluded that the remaining area is in an equally sound condition.

An inspection at Site B however, quickly dispels this latter conclusion because the circumstances are very much different. Here, the complete sward of snowgrass is missing and in its stead there is a mosaic of enlarged inter-tussock spaces and pedestalled plants. Remembering the pattern followed by erosion when the inter-tussock spaces are kept bare (figure 37B), it is thus possible to conclude that grazing, as the only factor capable of maintaining the vegetation in a constantly depleted state, has been the prime cause in the loss of a considerable part of the soil mantle by frost, wind and water action.

On Site C, (figure 37C) the position is worse. Accelerated erosion has reached an advanced stage as indicated by the loss of the surface soil and also by the presence of a well-developed erosion pavement. A close examination of the edges of Site C show
that erosion is still active, and that the damaged area is most likely to extend in size. Here needle-ice activity is severe and soil is continually being loosened and removed from around the base of the tussocks. This results in exposure of more of the plant root system and further weakening of plant vigour. The effects of the erosion, for the time being, are thus a lateral extension of the damaged area through the continued loss of vegetation and soil.

Examples of deterioration are evident from closer inspection of other parts of the area shown in figure 37. At Site D, a fen community has been disturbed by grazing and also at some previous stage by fire. There is also a tendency here towards single stream line formation, and the fact that some soil loss has occurred is indicated by lichen and soil lines on rocks.

Additionally on this site it was noted that one of the principal fen plants, tufted sedge (Carex gaudichaudiana), had been grazed to water level. This is evidence that animals do invade such wet places, and apart from the removal of vegetation, considerable damage may be expected by trampling in these situations. There was also a heavy concentration of fine gravel at this site, which was tending to engulf the vegetation and which was being transported at a fairly rapid rate by water flow concentrated in a single stream.

Even such a brief examination as this, therefore, results in an entirely different interpretation of the real condition of the area in question, which contrasts markedly with an opinion that might be formed on casual observance or perhaps on examination of Site A alone. As the evidence shows, the condition of the area as a whole is far from satisfactory. Unless the deterioration which is evident can be arrested, it is quite certain that further deterioration will occur, with

Fig. 37.—Except for some fire damage to the woodland on the slopes of this area in the subalpine tract, there is little evidence of deterioration when viewed from a distance. Examination of sites A-D (see figure 37A-C) however shows that there is considerable evidence of accelerated erosion—Plains of Heaven.
Fig. 37A.—Sod-tussock grassland in relatively good condition, but showing early signs of the effect of grazing in enlarging the inter-tussock spaces.

Fig. 37B.—Following further depletion of the inter-tussock vegetation, the small spaces have coalesced to form larger bare areas. Some soil loss has occurred as indicated by pedestalled plants.

Fig. 37C.—Destruction of the vegetation has resulted in the loss of the soil mantle and development of erosion pavement. As erosion proceeds the chances the vegetation surviving around the edges of these areas become increasingly remote.
the distinct probability that erosion will become more serious.

Although the foregoing discussion relates mainly to condition within a sod-tussock grassland environment, the same basic principles in applying indicators may be adopted for all other vegetational units, once the main indicators for the particular site are determined.

For example, three areas based on subalpine woodland, having similar environments but displaying obvious differences in condition, might be considered. The first area, where condition may be termed good, comprises a relatively open stand of mature trees with a sprinkling of seedlings and suppressed younger growth. Ground vegetation provides a complete surface cover and varies with site according to soil-water relationships. Such condition bespeaks a natural balance between plant and environment, affording optimum conditions in plant growth and regeneration, in the accumulation of snow, in the infiltration and retention of water, and ultimately, in the stream flow characteristics of the area.

The second area carries a similar stand of mature trees but seedlings and other young growth are largely absent. Such seedlings as do occur have been consistently grazed and are in danger of being killed out. The understorey of grasses and other herbs has been partially depleted, resulting in the proportion of perennial vegetation being reduced and the inter-tussock spaces being enlarged. Although erosion hazard is not really evident at this stage, the existing depletion in the vegetation must be recognised as indicating a trend towards the creation of erosion hazard. It follows then that grazing pressures must be greatly reduced if the area is to be safeguarded against further deterioration, or that grazing should cease if a return to natural conditions is regarded as the minimum requirement.

The third area presents a different appearance altogether. The woodland has been destroyed by fire and trees have failed

Fig. 38.—The indiscriminate influence of man operates in many ways. The establishment of this gravel borrow area, within one mile of the Summit of Mt. Kosciusko, is a complete negation of all that is desirable in the management of public lands—Main Road 286, Kosciusko.
to regenerate where in fact they should. Because of the attractiveness of snowgum regrowth to livestock for grazing and because the evidence illustrated in the fence-line study in figure 33 applies in this instance, it is fairly certain that regeneration occurred after the fire but that subsequent grazing ultimately resulted in the death of individual trees. Shrub species have invaded a considerable part of the area as a natural consequence in secondary succession, whereas normally they are confined to the steeper, rougher and drier situations. The original snowgrass sward of the grassland has been broken up into the typical mosaic of pedestalled plants and bare areas, either of which establishes that deterioration and erosion have reached an advanced stage. The lower valley sites, which were formerly water-saturated and occupied by fen or bog plant communities have dried out to a great extent. The existence of entrenched stream channels, active streambank erosion, and the humification and erosion of bog peat which accumulated under the formerly wet and stable conditions in the environment, all attest to the fact that fire, grazing and trampling have been instrumental in so changing the environment that accelerated erosion now largely dominates the scene.

An example such as this latter one might appear to overstate the position, except that the several indicators described above show clearly that some or all of these degrading influences are now manifest in particular areas. But the existence of lesser evidence of deterioration over the majority of the area should not be a reason for complacency. Unfortunately however, this general situation has been adopted by some as a false argument and has been taken as an unconditional assumption that the area as a whole is not, and is not likely to be, seriously threatened by erosion hazard and damage. By virtue of the weight of evidence against these arguments however, the existence of any sign of deterioration, even though it may be a very early stage, should be recognised as a warning of what could follow on more extensive areas if the deterioration is allowed to continue. Stated more simply, it should thus be clearly understood that the present larger and more seriously eroded areas, unquestionably, have developed from smaller ones and that the present small areas are equally liable to develop into larger ones, unless the factors responsible for this deterioration are brought under rigid control.

**INFLUENCE OF OTHER ACTIVITIES**

Because the grazing industry, as an historical fact, is the oldest established activity in these catchments, and because also, there is no valid explanation other than grazing for the degree of deterioration which is now evident over the area as a whole, the discussion so far has centred on the many changes brought about by past grazing practices. Apart from the grazing industry however, there are other activities which must be referred to because each of them has contributed in some way to the overall problem of damage in the area.

In the discussion which follows it will be shown that there is a relationship between all activities which, in any way, deplete the vegetative cover and expose the soil surface to the agencies of erosion. The full extent of the exploitation for which man has been responsible, and perhaps more importantly his capacity for exploitation, is thus readily demonstrated.

These activities, other than grazing, relate mainly to the engineering works of the Snowy Mountains Hydro-Electric Scheme and to the provision of skiing facilities by various clubs and organisations. To these may be added a number of lesser activities which are necessary in the provision of general services, and which will undoubtedly increase in extent with the growing popularity of the area for tourism and recreation.

The scope of the engineering works involved in the hydro-electric scheme which was commenced in 1949, has been referred to briefly in an earlier section of this article. Some of the problems created by these works were described in greater detail in a previous article (Durham, 1956) wherein it was shown that the destruction of vegetation, the creation of bare soil surface, and the alteration of the natural drainage pattern on steep slopes, had all contributed to a greatly increased erosion hazard on many sites. At the same time, a number of techniques which were then being employed in the repair of
erosion damage were described. In subsequent years these techniques (and newly developed ones) have been used in the successful control of erosion hazard and damage on a number of sites disturbed during construction works.

In the years since the scheme commenced, conservationists have referred constantly to the need for caution in the initial stages of individual projects and to the need for early application of remedial measures once those projects were finalised. Unfortunately, this has not always been done but it is now more widely recognised that considerable damage can be avoided by greater care in the initial stages of the works. Although much remains to be done before stability is achieved on many sites, the Snowy Mountains Authority has given an undertaking that all erosion hazard and damage arising from its works will ultimately be controlled. To give added significance to this undertaking however, and to reduce to a minimum the need for costly remedial measures, better co-ordination in the separate stages of planning, design and construction is desirable.

Skiing has been established as a sport in this area for a long number of years but it has enjoyed an immense growth in popularity during the post-war years. This has been due in part to the provision of better facilities, but more importantly, the rapid increase in interest has meant the need for constant additions to the facilities already in existence. At the present time the erection of new lodges, the installation of ski-tows, and the clearing of ski-trails is proceeding at an unprecedented rate.

As a result of many of these works, particularly some of the earlier ones, which were unwisely sited and inadequately supervised because of the lack in overall planning and control, serious erosion hazard has been created and damage caused on a number of sites. In supplying and maintaining lodges situated some distance from made roads,
motor vehicles and tractors have been used during the summer months in the past to transport and store winter requirements. The indiscriminate use of these vehicles, without any regard to the environmental conditions, now has as its legacy a considerable mileage of seriously eroded and unserviceable tracks. In the past, as one track eroded to a depth where it became unusable, it was common practice to select another one nearby, thus aggravating the general problem (figure 39).

Road construction is another activity which creates erosion problems, and which accordingly must be carried out with due caution if extreme erosion damage is to be avoided. In particular the haphazard borrowing of gravel for road maintenance purposes from sites adjacent to main roads is to be avoided, as the bare surface exposed encourages rapid run-off, and soil loss both from the borrow area and from areas below. Additionally, such borrow areas cause serious disfigurement in an area reserved as a public park for its scenic and recreational attractions.

To date these problems have not been dealt with effectively, either through education or the institution of controls to prevent their recurrence. Regardless of the type of activity, it should not be difficult to understand that such practices cannot be allowed to continue if catchment condition and scenic values are to be preserved intact on a lasting basis. For the same reasons that grazing has been prohibited above the 4,500 feet level and an undertaking given that engineering damage will be repaired, it is logical that skiers, road-building authorities and others should accept some form of control in the overall need to exchange exploitation for conservation.

It is unfortunate, and probably the reason for many of these problems, that the acceptance of such controls is not always easy, for man, by nature, largely conducts his individual pursuits through sectional interest and is apathetic towards the needs of the

Fig. 40.—The scattered development of ski lodges requires many miles of tracks, most of which are soon eroded—Back Perisher Range.
community at large. Because this area however is of such vital importance as a water-producing resource and because lately more serious account has been taken of its unique recreational qualities—and hence a trend established in its inevitable pattern of development—some form of self discipline or statutory control must therefore be accepted as a fundamental principle in guaranteeing perpetual stability in the environment.

CONCLUSION

This article attempts to emphasise the significant fact that man—whether a grazier, an engineer, a road maintenance employee, or an enthusiastic skier bent on providing access to his lodge can exercise, and has exercised, an indiscriminate influence in a multiplicity of ways on the original land systems of these catchments. There can no longer be any question that the natural system has suffered extraordinary damage since the entry of white man, as the many illustrations in this article clearly show. Because it was only 130 years ago that the area was discovered, it is therefore imperative that we look to the future.

In drawing attention to all these unfavourable influences, the conservationist has no intention or desire to retard progress. Rather does he attempt to guarantee progress by ensuring that the resources in any area shall be conserved for the future benefit of the greatest number within the community. In discharging these responsibilities, his prime duty is to recognise, investigate, and draw attention to any aspect of land use which threatens the stability of a particular environment and which therefore involves the possibility of land wastage through accelerated erosion. From this standpoint it is now recognised that grazing, in conjunction with deliberate burning and naturally occurring fires, has greatly depleted the vegetative cover and initiated accelerated erosion. But the construction of roads and tracks, the clearing of ski-trails and a host of other human occupations, also make their own characteristic demands in particular environments and involve, in far too many instances, the destruction of vegetation and the creation of bare soil surface.

The relationship between the various activities which have been referred to, together with their separate relationships to many of the indicators of deterioration which have been described, is thus sustained in the knowledge that the destruction of vegetation, by whatever means, in the climatic environments of these catchments will always involve the threat of accelerated erosion and hence the loss of the basic resource—SOIL.

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References


