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Review 39

Tussock Grasslands & Mountain Lands Institute – December 1980

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Research report

Debris flows

An important process in high country gully erosion

T. C. Pierson

Introduction

Many steep hillslopes in the New Zealand high country, especially in the South Island, are prominently dissected by "gullies" or "guts", ranging in size from narrow, shallow chutes to deeply eroded ravines. Although these erosional features differ considerably in form from gullies developed on agricultural land of lower relief (Heede, 1976), concentrated runoff of water has long been held to be the sole agent of erosion responsible for both kinds of gullies in New Zealand (Department of Science and Industrial Research, 1939; Gibbs and Raeside *et al.*, 1945; Cotton, 1949). Campbell (1951) recognised that slips and mudflows (debris flows) could also play a part in cutting gullies, but his broader grasp of the interrelationship of processes has not been applied to later published considerations of the gully problem. Recent symposia on the control of erosion in general (N.Z. Association of Soil Conservators, 1978) and gully erosion specifically (Ministry of Works, 1973) made no connection between gullies and the process of debris flow. Yet a connection does indeed exist in the high country. Parallel ridges of coarse-grained debris (levees) along many gully margins and very poorly sorted, lobe-shaped deposits on numerous debris fans below gullies attest to this connection.

Distinguishing between water flow and debris flow is not just an academic exercise; it is important because of the difference in erosive force between these two geomorphic processes. Recognition of this difference should permit more effective erosion control in gullies where debris flows are recognised to be an active process.

DEBRIS FLOW – A SPECIFIC EROSION PROCESS

What are Debris Flows?

Water is not necessarily the only fluid that flows down slopes or channels during rainstorms. Whenever well-graded soil and rock debris (i.e. material having an even distribution of particle sizes) is mixed with a critical amount of water, a structurally coherent slurry forms (very much resembling fresh, wet concrete), which is capable of flowing rapidly downhill and transporting even large boulders in suspension. Flowage of such a mixture is termed a debris flow. If too much water is added, the coarse solids separate out and the structural integrity of the mixture is lost. If too little water is present, internal friction prevents flowage.

The mixing of water with solid debris can take place when landsliding or bank collapse dumps soil and rock into a stream or when the stream incorporates loose debris from the channel bottom into the flow. Alternatively, jostling and dilation of a saturated soil mass in a landslide can induce liquefaction of the material, creating a debris flow without additional water. Fluid debris is about twice as dense as the muddy water that normally flows in gullies and stream channels during floods (2.0 to 2.4 g/cm^3 as compared to 1.1 to 1.2 g/cm^3) and contains between 60 per cent and 90 per cent (by weight) solid particles. The solid fraction of recent debris flows from Mt Thomas, North Canterbury (Pierson, 1980) averaged 80 per cent gravel, 20 per cent sand, 6 per cent silt and 4 per cent clay.

Debris flows may be confined to a channel or may flow overland. When confined to a channel, sufficient fluid depth may be achieved to allow flows to move at high velocity and cover great distances. In Bullock Creek at Mount Thomas, debris flows travelled over 3 kilometres at speeds up to 5 m/s (18 km/h), whereas streamflow in the same channel did not exceed 1 m/s. Larger debris flows have been observed travelling over 10 km at velocities up to 12 m/s (43 km/h) (Niyazov and Degovets, 1975). There may also be a tendency for flows in channels to move in surges, either as single pulses or in multiple surges. Surge fronts may be several metres high, and usually carry some of the largest boulders available (perhaps as much as several metres in diameter). Such a surge front moving at several metres per second can exert large impact and shear forces on any structure in its path. Channel-confined debris flows do, in fact, cause a number of the bridge "wash-outs" along our mountain roads, but because depositional evidence of their activity is often obliterated by subsequent streamflow, their role is not commonly recognised.

When debris flows are not confined by already existing channel boundaries, they produce their own levees, which are parallel ridges of coarse particles formed by internal sorting processes within the flows. Levees confine a flow laterally, thus helping to maintain flow mobility by ensuring adequate flow depth. Unconfined flows will continue downslope until they deposit most of their mass in the formation of levees or until increased internal friction (caused either by decrease in slope or water loss) brings them to a halt. On steep slopes, such unconfined flows are capable of rapid gully cutting.

Erosive Power of Debris Flows

Flowing debris can be much more erosive than flowing water. This can be seen by examining the equation that defines the total shear stress applied to a channel bed by a fluid:

$$\tau = \rho g R S$$

where τ is total sheer stress, ρ is the density of the fluid, g is the acceleration of gravity R is the hydraulic radius of the channel (approximately equal to flow depth in wide channels), and S is friction slope (which, in uniform flow, is equal to the channel gradient). For channels steeper than 15°, S should be replaced by sin α, where α is the slope angle of the channel. Not only is ρ greater for debris flows, but flow depth is also greater during surges. Along a 6° reach of Bullock Creek in 1978, Pierson (1980) observed that surges were about 1 metre deep, whereas streamflow between surges did not exceed 0.3 metre in depth. Plugging this information into the equation reveals that these debris flow surges exerted a shear stress on the channel bed approximately 6 times greater than that exerted by streamflow between surges. The increased amount of eroded material can easily be carried away because of the greater flow velocity and much greater transport efficiency of debris flows.

The greater erosive force of debris flows was verified in the field when those in the Bullock Creek catchment caused channel entrenchment of up to 4 metres in sheared bedrock and up to 11 metres in unconsolidated gravels in less than 24 hours. An adjacent, nearly identical catchment (viz. slope, catchment area, percent bare ground) produced no debris flows, only muddy streamflow. Downcutting in unconsolidated gravel there was limited to less than 1 metre during the same storm.

However, debris flows will not always erode. As the equation indicates, slope and depth of flow are controlling variables of bed shear stress. If their values fall below critical levels, debris will flow over the ground surface without causing erosion.

Examples of Debris-flow Gullies

At three localities in the South Island (Figure 1), gully erosion by debris flows has been observed or inferred from morphologic evidence. Here, as in most cases, debris-flow gullies have developed on unforested slopes. Debris flows do occur on forested slopes, but enlargement of the resulting eroded tracks

Figure 1. Location of examples of debris-flow gullies.

into gullies is not common. This observation supports the argument that interlocking tree roots impart a significant binding strength to forest soils, and that the removal of forest trees and the subsequent decay of roots on steep slopes make the soil more vulnerable to erosion (O'Loughlin, 1974).

Mount Thomas

Mount Thomas is an upfaulted block of tectonically crushed greywacke and argillite on the north edge of the Canterbury Plains. The contributing factors of steep slopes (30° to 40°), thin silt-rich soil, very weak bedrock,

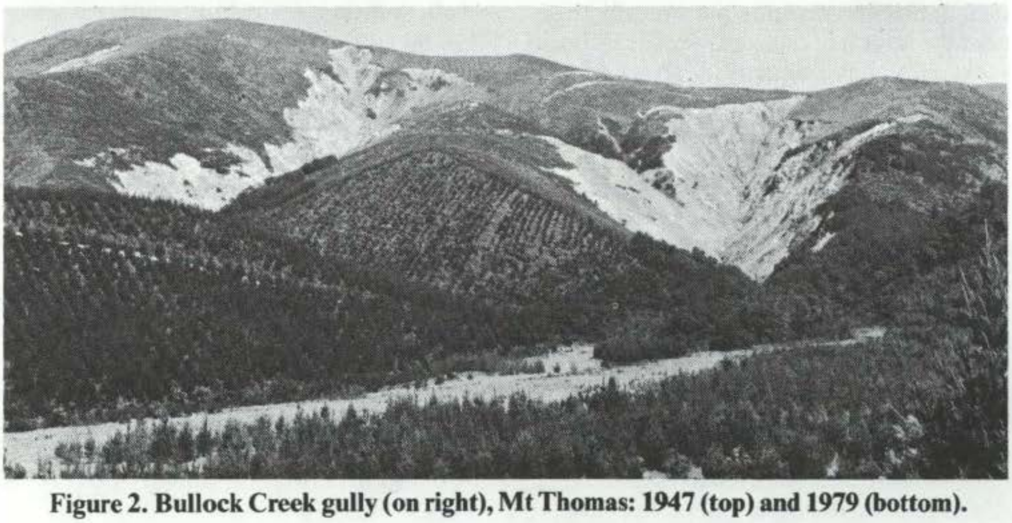

Figure 2. Bullock Creek gully (on right), Mt Thomas: 1947 (top) and 1979 (bottom).

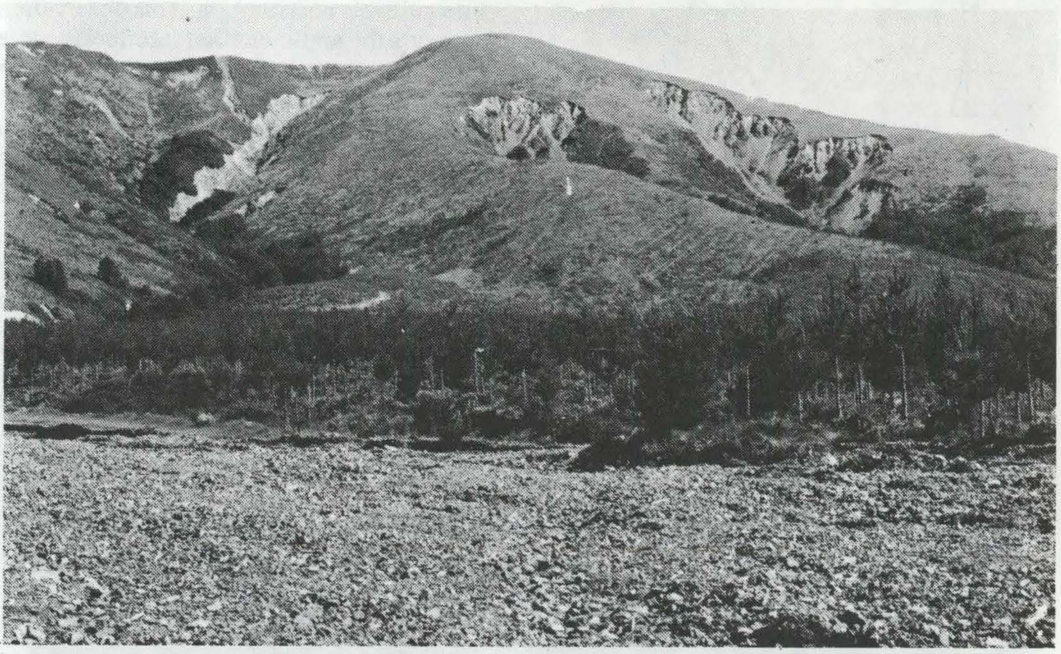

Figure 3. Other debris-flow gullies, Mt Thomas.

and lack of forest cover have allowed spectacular debris-flow gullies to develop (Figures 2 and 3). There thirteen active or recently active gullies range from small scars 30 metres long, 5 to 10 metres wide, and less than 2 metres deep, to gaping chasms nearly a kilometre long, 200 to 300 metres wide, and over 100 metres deep. In a little over two years, debris flows issuing periodically from one of the largest of these gullies, the Bullock Creek gully, have destroyed about $7,000 worth of reafforestation plantings, caused over $15,000 worth of damage to forestry roads, polluted a farm water supply, and inundated part of a paddock with gravel.

At five sites where the evidence is still preserved, the gullies appear to have been initiated by liquefaction of soil at the moment of slope failure. These sites are steep and topographically concave, and at each one a narrow, shallowly incised gully emanates from a spoon-shaped soil-slip scar, above which no rilling or gullying has occurred. Immediate flowage of and erosion by the slip debris best explains the eroded tracks.

Enlargement of these gullies appears to occur principally by (1) downcutting into the weak, sheared bedrock, (2) consequent oversteeping of the gully sides and head, and (3) mass failure of these oversteepened slopes. Frost action, wind and surface erosion by water also aid in wearing back the gully sides and depositing loose debris in the gully bottom. Shear stresses are greatest on the headwall section of the gully margins where lateral support has been almost completely removed (Figure 4). Headward extension of four gullies between 1960 and 1970 averaged between 3 and 4 metres a year. Between 1923 and 1970, the headwall of the Bullock Creek gully retreated at an average rate of 2.7 metres a year.

Mount Fitzwilliam

The steep slopes (30°–40°) of Mount Fitzwilliam in western Canterbury are characterised by thin, silt-rich soil (sometimes overlying bedded scree deposits) and the absence of forest cover. But, unlike Mount Thomas, the underlying greywacke bedrock is hard and firm, although fractured. Forty-seven gullies of predominantly debris-flow origin are recognisable.

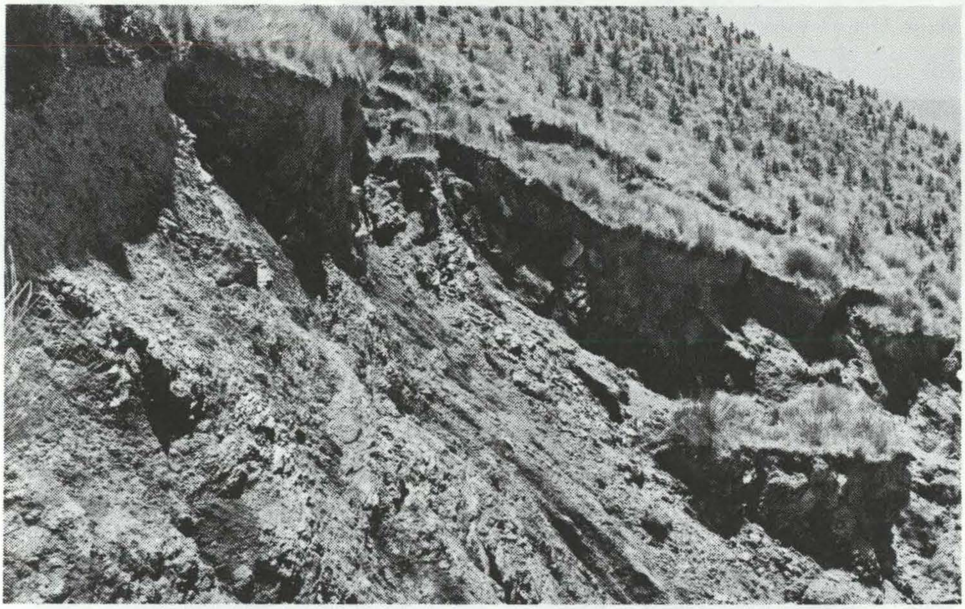

Figure 4. Failure of headwall in Bullock Creek gully, Mt Thomas.

Figure 5. Numerous debris-flow gullies on Mt Fitzwilliam.
Photo: J. H. Johns, N.Z. Forest Service.

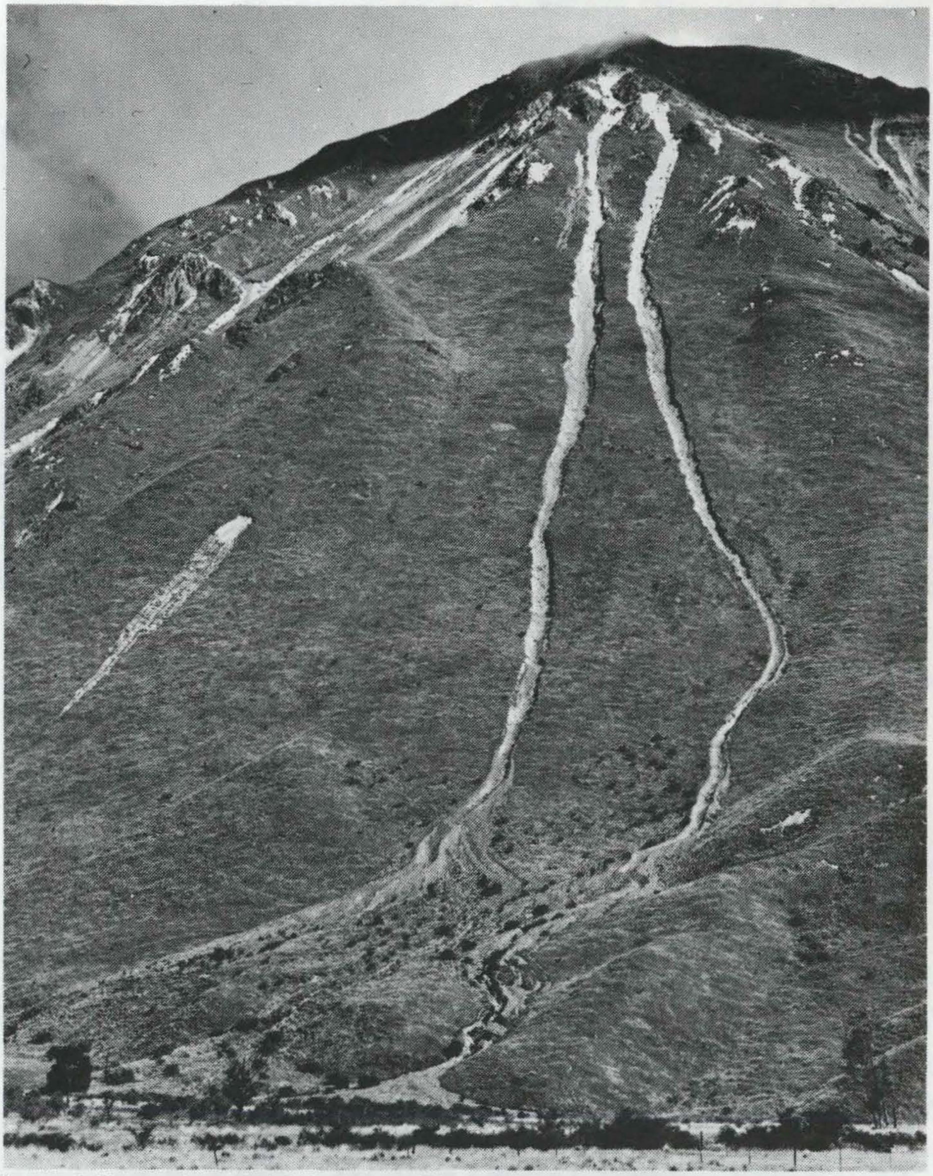

Figure 6. Two enlarged debris flow gullies on Mt Fitzwilliam following major storm in December 1957 (note shallow slip in left centre showing soil flowage).
Photo: J. H. Johns, N.Z. Forest Service.

In contrast to the Mount Thomas gullies, these are very narrow, only shallowly incised (down to the bedrock surface at most), and commonly extend from near the top of the slope to the base, where they terminate in lobate tongues of poorly sorted debris or in steep debris cones (Figures 5 and 6). In cross section, the gullies are 'U'-shaped when fresh (characteristic of debris-flow channels), becoming broader with age due to infilling and lateral retreat of the side walls (Figure 7).

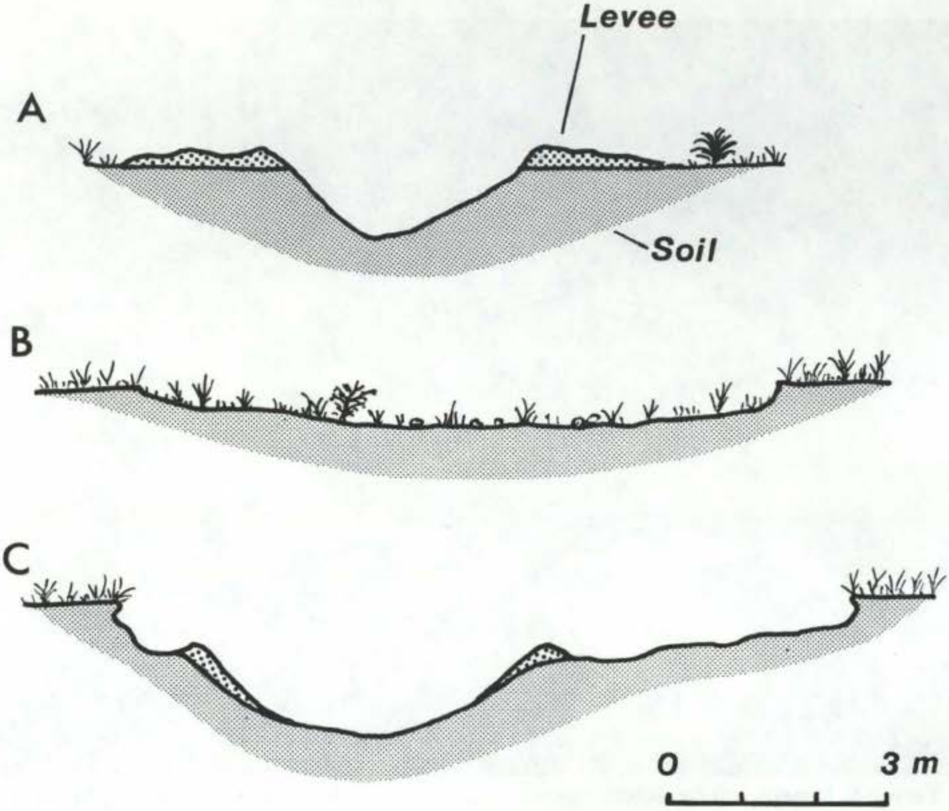

Figure 7. Cross sections of three separate Mt Fitzwilliam debris-flow gullies, which depict sequence from initial gully cutting (a), to infilling and "healing over" by revegetation (b), to reinitiation of active downcutting (c).

Levees left by passing debris flows characteristically bound the gullies on either side and fresh levees sometimes overlap older levee deposits (Figure 8). The largest gullies observed at Mount Fitzwilliam were approximately 20 m wide and 8 to 10 m deep.

Some of these gullies originated from soil slips, as at Mount Thomas. The narrow gully on the right in Figure 6 appears to have been formed in this way, and the debris from the small slip scar in the left centre of Figure 6 definitely appears to have flowed at the moment of failure, although it did not erode.

Other gullies start on or immediately below unvegetated fine-grained screes, bare patches of soil, or extens[illegible] areas of bare rock (e.g. Figure 5). The debris flows that curve these gullies appear to be caused by the topographic concentration of storm runoff. This conclusion is based on observations made on a number of bare soil patches where surface erosion by water has formed coalescing rills that have joined to form single small water-cut gullies about 20 to 30 centimetres wide and 10 to 20 centimetres deep. At some distance further downslope, usually only 5 to 10 metres, levees of poorly sorted debris have appeared along the gully margins. At this point the gullies' dimensions, especially depth, have increased abruptly. This transition in morphology must mark the point at which flowing water, which was progressively picking up loose soil, was transformed into debris flows. The sudden deepening of

Figure 8. Levees left by debris flows in a gully at Mt Fitzwilliam. Overlapping levees from successive flows can be seen.

the gully in each case attests to the increased erosive power of the flowing debris, while the preserved levees are a clear indication that the threshold from water flow to debris flow had been crossed.

Enlargement of these gullies is carried out by both water flow and by debris flow, but downcutting has been limited by the depth to bedrock. As long as entrenchment continues, side wall failure and widening keeps pace. But once a gully has cut down to bedrock, further widening is curtailed. For this reason the Mt Fitzwilliam gullies have not been able to enlarge in the manner of those on Mount Thomas.

Liebig Range

Like Mount Fitzwilliam, the Liebig Range near Mt Cook is underlain by hard, fractured greywacke. Debris-flow gullies have developed on a steep, unforested northwest-facing slope near Jolly Peak that is characterised by a very steep upper segment of bare rock slope with a patchy thin mantle of colluvial soil, and a lower straight segment made up of coalescing debris cones.

In February 1975, a fresh, narrow, roughly linear quality gully was photographed on an old revegetated debris cone (Figure 9, upper left). It was less than two metres across, exhibited debris-flow levees along the lower margins of the track, and terminated in a lobe of coarse unsorted debris at the toe of the slope. One year later (February 1976) the same reach of gully was over 4 times wider and an unknown amount deeper (Figure 9, upper right, gully on right). Above the old debris cone the gully remained narrow and shallow, but it maintained its characteristic 'U' shape in cross section. It appears to have originated from a soil-slip further upslope. Flow levees just above the debris cone and

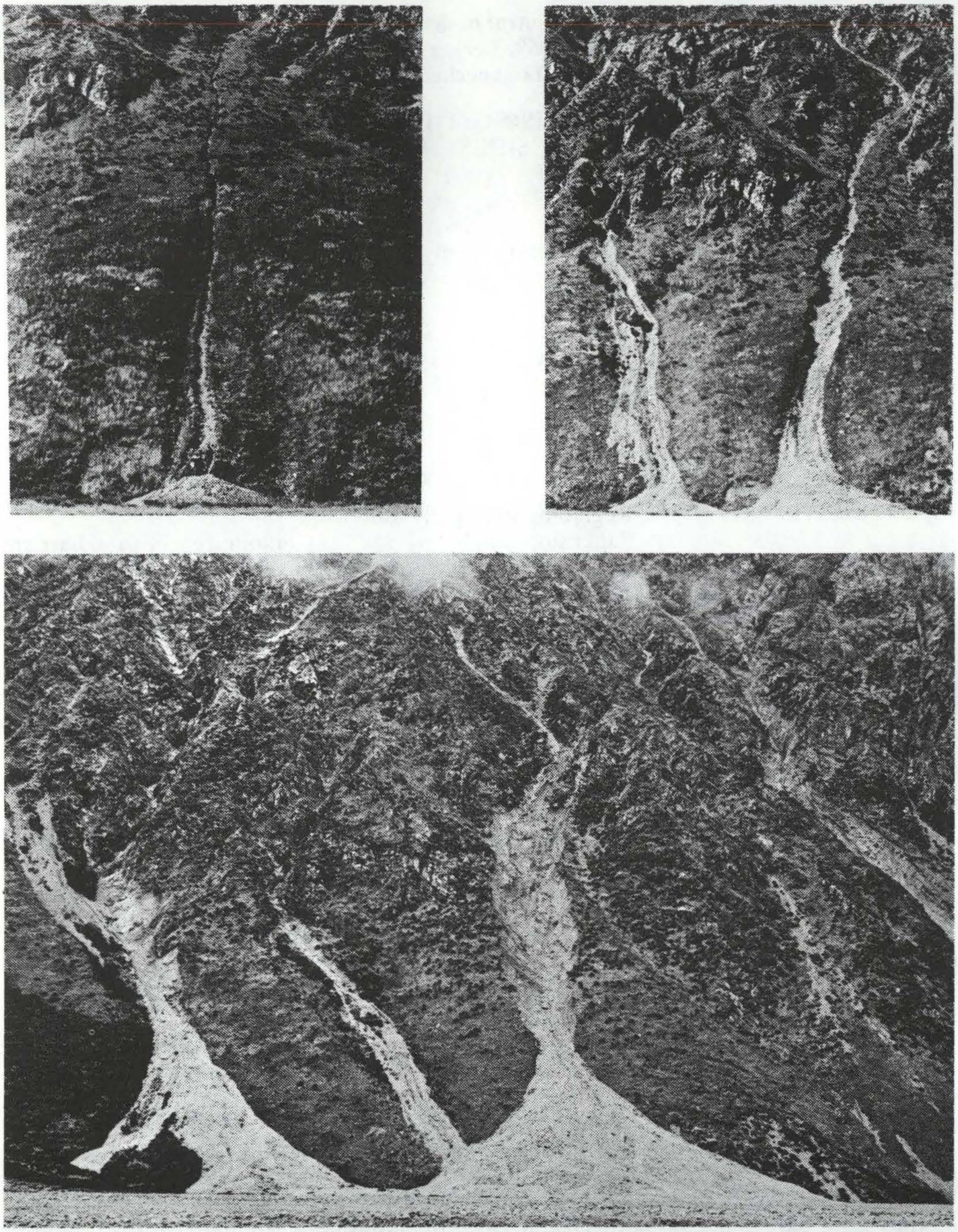

Figure 9. Development of debris-flow gully on northwest flank of Liebig Range: Upper left, February 1975; upper right, February 1976; bottom, February 1980.

Photos: B. Field, N.Z. Geological Survey.

TABLE 1. Techniques applicable for control of debris-flow gully erosion (cf. Norcross, 1936; Strom, 1937; Gagoshidze, 1969; Becker and Mills, 1972; Ministry of Works, 1973; Heede, 1976; Schouten and Hambuechen, 1978).

STABILISING THE GULLY FLOOR	STABILISING THE GULLY SIDES	PREVENTING UPSLOPE WATER AND DEBRIS FROM REACHING GULLY
Channel linings (small gullies only)	Revegetation (only in relatively small gullies)	Oversowing and topdressing
– Hydraulically rough linings: Rubber tyres, coarse rock, etc. secured by wire ties or netting	– Oversowing and topdressing	Tree planting
	– Tree planting	Mulching
– Hydraulically smooth linings: Fibreglass matting, asphalt, concrete	Regrading steep gully walls to flatter slope angles (followed by revegetation)	Contour trenches and barriers
		Diversion dikes and ditches
Weirs	Internal drainage of rock and soil masses in gully walls with horizontal or vertical drains	Filter berms
Spillways	Reinforcement of sites with terraces, concrete facing, or retaining walls	Gully bypass chutes and flumes
Chutes		
Sills		
Openwork sediment – trapping dams (interlocking concrete cribbing)		
Cable net dams		
Debris dams (check dams) – earth, rock, gabion, concrete cribbing filled with rock		
Sabo dams		

lobed deposits on the cone itself are clear evidence of debris-flow action. By summer 1980 (Figure 9, bottom, large gully in centre), the gully and its debris cone had enlarged still further. This followed a very severe rainstorm in December 1979 (537 mm/24 h at Mt Cook Village), which must have played an important part in enlarging this feature through the action of both running water and debris flows. Erosion on the upper slope segment is constrained by the shallow, hard bedrock surface, whereas erosion on the old debris cone is not so constrained.

Controlling Debris-flow Gully Erosion

Many cases of erosion in the high country can be controlled, but ultimately it cannot be prevented. Whether or not it is aggravated by introduced animals or poor land-use practices, erosion is the inevitable consequence of the action of water, wind, frost and gravity upon mountain slopes. The term "control" implies the regulation of natural processes in such a way that the catastrophic element (usually responsible for the greatest damage) is removed as far as possible. This is feasible for debris-flow gullies.

The need for control, however, must be judged on the basis of:

1. Definition of Acting Processes. What combination of processes is acting and at what frequency? How large and steep is the gully? Are debris flows likely to occur, and if so, how large and how erosive are they likely to be?
2. Projected Benefits of Control. Will control eliminate the threat to land, buildings, roads, water supplies, etc? Will control improve the scenic value of the area? Will serious loss of topsoil be prevented?
3. Exploration of Options. Having determined which geomorphic processes are acting and with what frequency and magnitude, what programs can be realistically expected to bring the problem under control?
4. Projected Costs of Control. How accessible is the site? What will labour, machine time, and materials cost? What costs might be involved for the land owner (e.g. loss of access or productive land)?

It may be that the control of every active gully in an area cannot be justified. If however it can be justified, effective control may not be possible within the allowed budget.

If a realistic assessment shows that control is viable its effective accomplishment in debris-flow gullies will depend on (1) stabilisation of the gully floor to prevent further downcutting and either (2) stabilisation of the gully headwall and sidewalls where mass failure is the main enlargement mechanism, or (3) diversion of surface runoff away from the gully head where flowing water is the debris-flow triggering mechanism. Table 1 is a summary of methods which can be employed to achieve these three objectives. The methods are arranged roughly in order of increasing effectiveness and cost. Most of the in-channel techniques listed have been widely and successfully used for controlling debris-flow erosion on a much larger scale in Europe, Japan, and Indonesia. The gully control techniques usually used in New Zealand – topdressing and oversowing, tree planting, and pole and netting check dams (cf. Ministry of Works, 1973) – will probably not be effective alone in controlling debris-flow gullies.

High country gullies do stabilise of their own accord; numerous well vegetated debris fans below old gullies bear witness to this. Stabilisation occurs when downcutting is inhibited by a resistant substrate, when a supply of loose debris is no longer available, or when a new, more stable slope configuration is reached. It may therefore be possible to treat individual gullies by changing the pattern of land use to achieve maximum slope stability (e.g. a change from pastoral use to forestry) and allow the gullies to stabilise naturally. This could, however, take a long time.

Ultimately, the best control is prevention of gully initiation by recognising potential problem areas and adapting the land use accordingly. Slopes that are potential sites for gullying can often be recognised on the basis of slope angle, soil conditions, vegetation cover, and evidence of previous or incipient instability and gullying. The stability of such slopes can be improved by retiring them from grazing, not burning or clearing existing vegetation, and planting wind resistant trees at close spacings.

Conclusion

Although debris flows are not generally recognised as an important erosion mechanism in the high country, they are a potent force in the erosion of gullies on steep slopes. Triggered by heavy rains, debris flows are more erosive than the water that runs off the land's surface. With sufficient slope angle and depth of flow, they are capable of eroding great volumes of soil and rock literally overnight. When erosion control efforts are directed at debris-flow erosion, the greater erosive forces of this natural geomorphic process must be taken into account.

Acknowledgements

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Dating your scree

I. E. Whitehouse, M. J. McSaveney and T. J. Chinn

Introduction

Throughout the Southern Alps, particularly in Canterbury and Marlborough, there are widespread accumulations of loose, coarse, broken rock called screes, talus or shingle slides. Some believe that screes are more common now than when settlers first arrived in the South Island and have blamed their widespread occurrence in the eastern Alps on early European burning and overgrazing, or on fires about 600–900 years ago which removed much of the beech forest of the area. Others maintain that they are natural deposition forms. Since the first settlers were too busy to record how much scree existed on their arrival, determining the age of scree surfaces is one method used to clarify the cause of many screes.

When rocks are left out in the weather, they rust a bit, like old iron, although the process takes a little longer. The rot of physical and chemical decay sets in, alters the rock's surface colour and slowly chews inwards, forming an ever thickening rind of discolouration. The longer a rock lies about in the weather, the thicker is its weathering layer. This weathering-rind grows thicker with time at a predictable rate, giving a means of determining the age of all sorts of exposed rock surfaces such as boulders on screes.

As is the perverse wont of nature's laws, this method of guessing how long rocks have been lying around is not completely foolproof. There are a few tricks to the trade in dating rusty rocks. The first thing the novice scree scratcher discovers is that different rock types rot at different rates. Some, like schists, are completely useless because the rinds fall off as they form, or grow at a variety of different rates (and they do not chip too well either). In this regard the Canterbury high country is fortunate in being blessed with the right kind of rocks in the ubiquitious greywacke sandstones spread throughout the hills.

For the estimation of rock ages, using rind thickness, a calibration curve of how fast the rot sets in is required. A calibration curve is not something bought off the shelf or made at home in the shed. Rock weathering is a very slow process, and one has to hunt for rock rinds of known age, or find those that can be dated by other means.

Method

With such information we drew our own calibration graph of rind thickness versus age. This is shown in Figure 1. This calibration has been achieved by a quest for rocky landslides and such things that have buried and preserved forests or other plant remains, the age of which can be estimated by carbon dating. To these we have added several sites whose ages are known because someone saw or felt them form. This provides the so-called known age.

Colour changes

Observations on moraines and landslides, dated by radiocarbon ages of buried wood, lichenometry or historical records, indicate that, while colour varies from individual rock to rock, the overall surface colour provides an index of surface age.

Calibrating the rate of colour change simply involved graphing rock surface colour against surface age (Figure 2). The most widely used system of colour identification is that of Munsell. This system is based

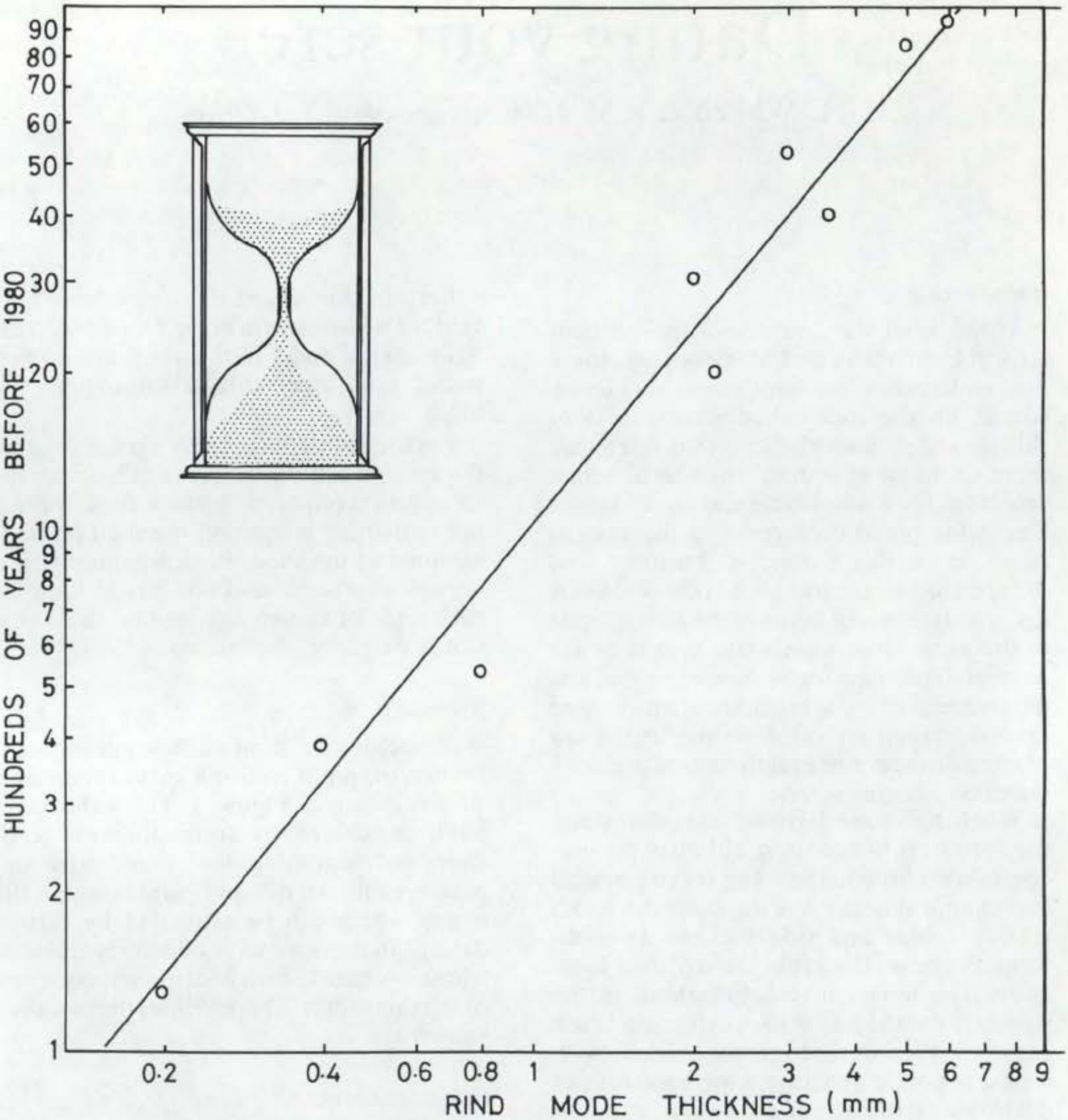

Figure 1. Weathering rind aging curve. Data obtained by sampling surface rocks in radiocarbon and historically dated landslides and moraines in the eastern Southern Alps. From Chinn (in press).

on a colour sphere which has a neutral grey axis grading from white at the top to black at the bottom (Figure 3). This property of lightness is called 'value'. Around the circumference or equator of the sphere are the 10 major hues, each of which is divided into 10 numbered divisions, so that five marks the middle of a hue and 10 marks the boundary between one hue and the next. Thus any particular hue can be designated by a number and a letter such as 5R or 10YR. Any single vertical section through the neutral grey axis and a particular hue constitutes a colour chart, on which the colours grade in value from light at the top to dark at the bottom and in chroma (degree of saturation) from grey at the left to the most vivid colours at the right. Both value and chroma are numbered so that any particular colour can be given a numerical designation representing hue, value and chroma such as 5R 6/4 or 10YR 8/2.

However, despite this ability to accurately describe any colour, the variation on a rock surface makes it difficult to assign a single colour to any surface. The colours given in Figure 2 (colour vs age) are only "average" colours, since the variation of surface colour with time is relatively imprecise. Rocks, young and not-so-young, and old and very

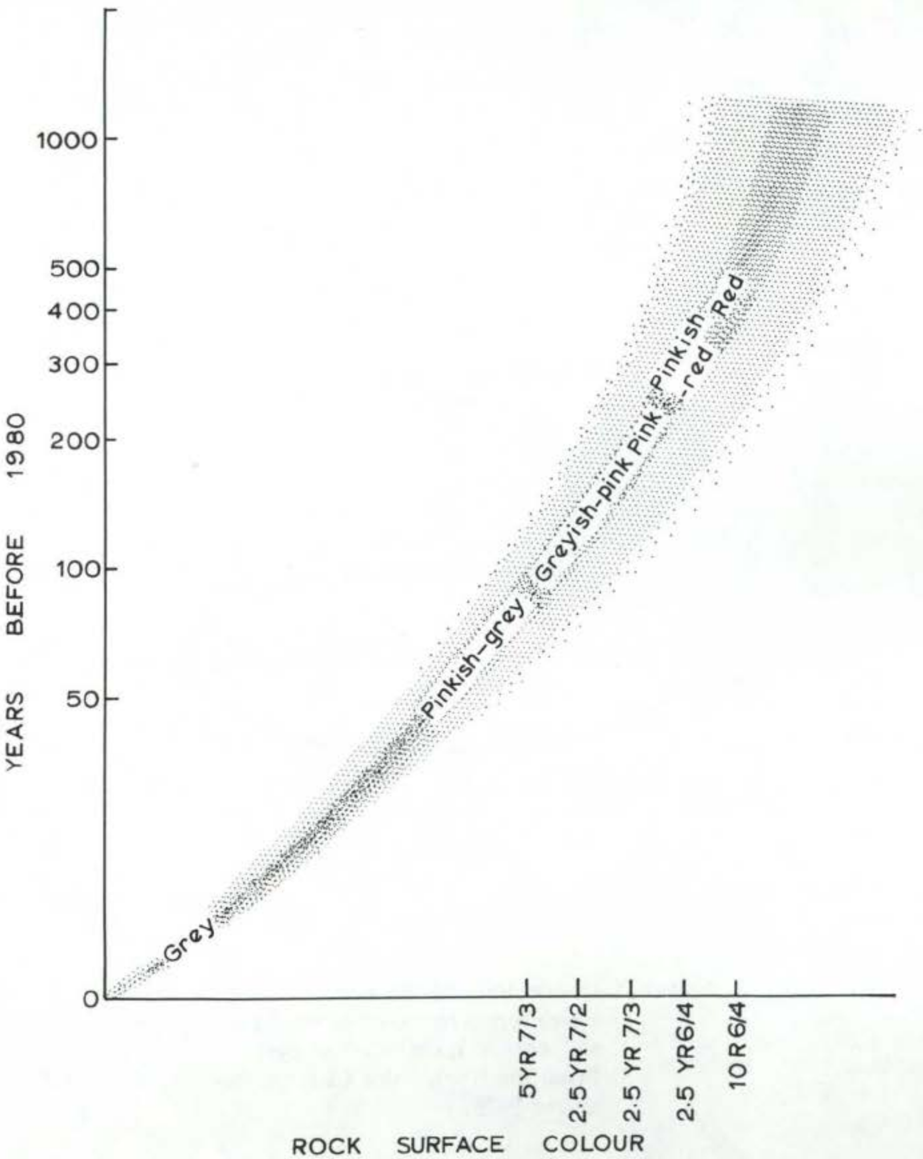

Figure 2. Variation of rock surface colour with age. Based on data presented in Table 1.

Table 1. Surface colour on dated moraines and landslides.

Location	Feature	Age	Dating method	Surface colour	Modal weathering rind thickness (mm)
Cameron Valley	moraine	1890	Historical record +	Pinkish-grey 5YR 7/3	rind discernable but not measurable
Cameron Valley	moraine	1850	Historical record and lichenometry +	Greyish-pink 2.5YR 7/2	0.2
Cameron Valley	moraine	1750	Lichenometry +	Pink 2.5YR 7/3	0.2
Clyde Valley	landslide	1596 ± 28	Radiocarbon*	Red 2.5YR 6/4	0.4
Acheron Valley	landslide	1418 ± 66	Radiocarbon°	Red 10R 6/4	0.6

+ Burrows (1975a)
* N.Z. Radiocarbon number 4901
° Burrows (1975b)

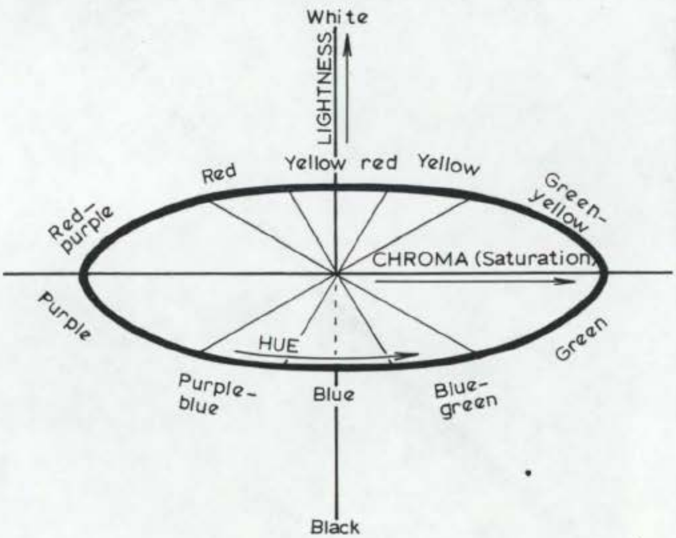

Figure 3. Dimensions of the colour sphere which forms the basis of the Munsell colour identification system. From the Rock-color Chart Committee 1975.

old can, however, be quickly distinguished. An all-grey scree, for example, like a river bed after a flood, is a young scree. Sometimes only a part of a scree is grey – a small grey patch at the top or a long thin grey stripe down the middle. These are the recently active portions of the scree. The beginning of a pinkish hue is discernible after about 90 years of stability; the rocks turn pink by 200 years, and after being left undisturbed in the weather for 400 years the rocks have a red hue. Beyond 400 years, all screes look very similar from a distance.

Rind thickness

Estimating the age of rocks by measuring the weathering-rind thickness requires a little more expertise, more effort, and more sophisticated equipment than the non-colourblind eye. Greywacke rocks can be reliably dated up to 8000 to 10,000 years. Basalt rock in Bohemia has been dated at a million years, using a similar method (Cernohouz and Solc, 1966).

Basically, age dating by weathering rinds is a simple process. A chip is knocked off a rock and the thickness of the coloured rind measured. However, over half of the rocks measured give an unreliable reading. Some very coarse-grained sandstones appear on the basis of rind thickness to be older than they really are, while measurements of black shales or argillites tend to under-estimate their true age. To overcome the effects of "untruthful" rocks, many have to be cracked and the measurements scored on a histogram. When all the chips have been measured, the thickness with the most chips is taken to be the true one. We have found that with less than 40 chips, the indicated age could be unreliable, while 60 chips usually provide an unambiguous answer. We have actually used a blitz of a few hundred or so for single dates on the calibration curve.

The basic tool used is the geologists' hammer which is most suitable for the more angular rocks. For the big ones, a sledgehammer is required. (Personal protection is a necessity; it is advisable to wear protective glasses and a pair of shin pads (Figure 4).

In the inner boundary of the rind, there is a whitish fuzzy layer, under the pinkish rock surface. The thickness of this layer is variable, so we class the rind thickness as being as far into the rock as a whitish discolouration can be discerned. Despite this indefinite boundary, we have been able to measure calibration rinds to the nearest 0.2 mm using a graduated lupé (magnifying glass). This gives consistent results for any particular observer, but there is some variation between individuals.

We have cracked thousands of rocks and have come up with enough variations in rind thickness to gain an understanding of what they all mean. Histograms shaped like that in Figure 5 (a) indicate rocks coming from surfaces formed over a very brief period of time, such as a large rockfall. Surfaces that develop over a long period often give weird distribution patterns with very broad-crested histograms (Figure 5 (b)). Many screes give this sort of pattern.

We have looked at the colour of many more screes than we have cracked (it is easier, and can be done using colour slides and colour aerial photographs). Many screes are steel grey from top to bottom, with no weathering rind. This indicates surface instability, and while not indicating when the scree formed, it clearly shows that such screes are not about to stop.

Sometimes, the origins of these fresh young screes can be gleaned from geomorphic evidence: times of deglaciation, periods of cold climate or removal of some of the scree toe. We suspect that many active screes, underneath their disguise, are just as old as the stable screes we can age by rinds and surface colour, but we have yet to prove it. The problem, is that a scree really is as old as the oldest rock deep inside the scree pile, while we only scratch the surface, so to speak. In a sense, we are merely determining how young screes are, but the knowledge can still be put to good use.

The majority of the screes examined have patches of predominantly red or pink coloured rocks with thin rinds, usually 0.2 to 0.4 mm thick. These patches usually occur

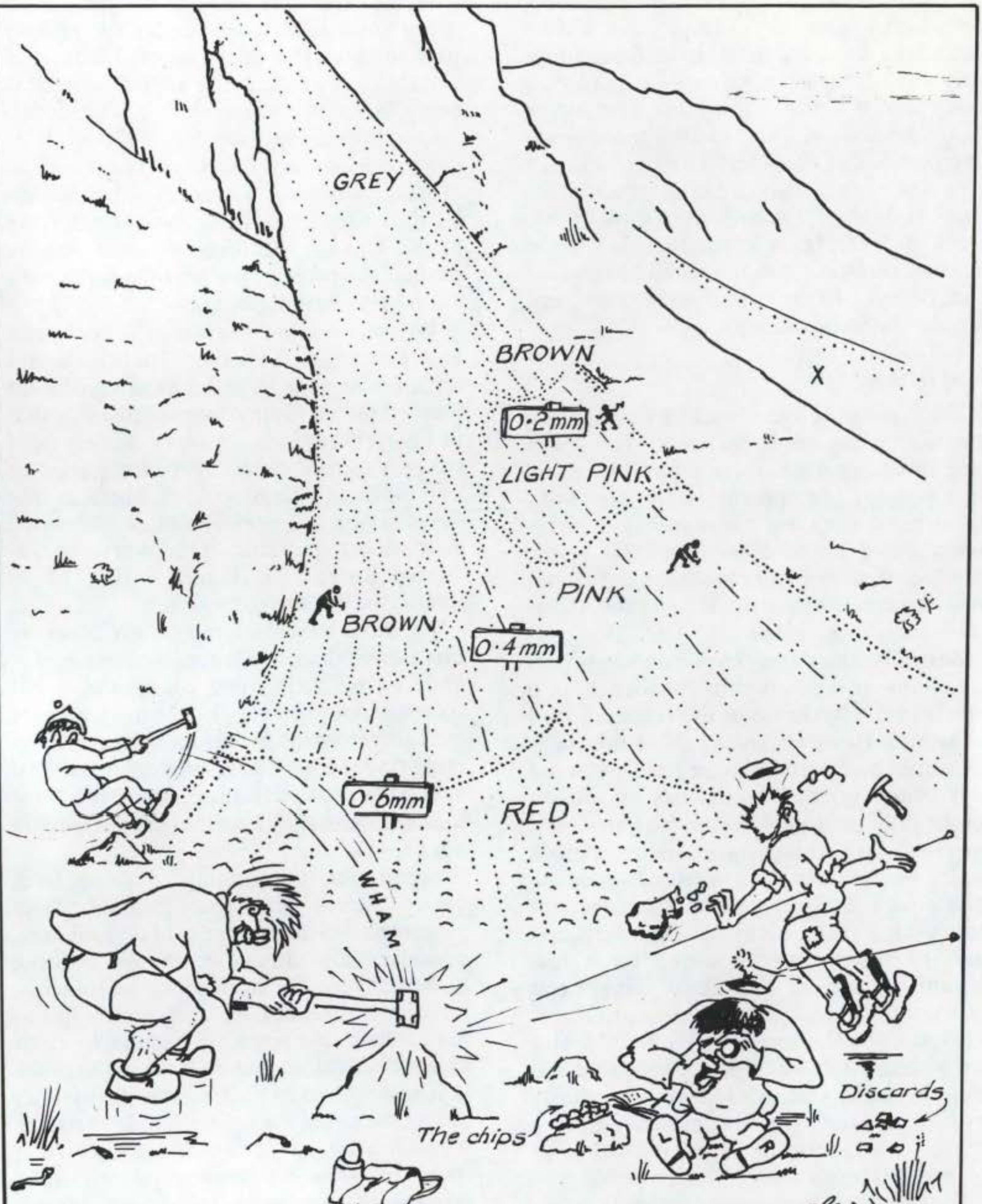

Figure 4. Scientists at work on a scree.

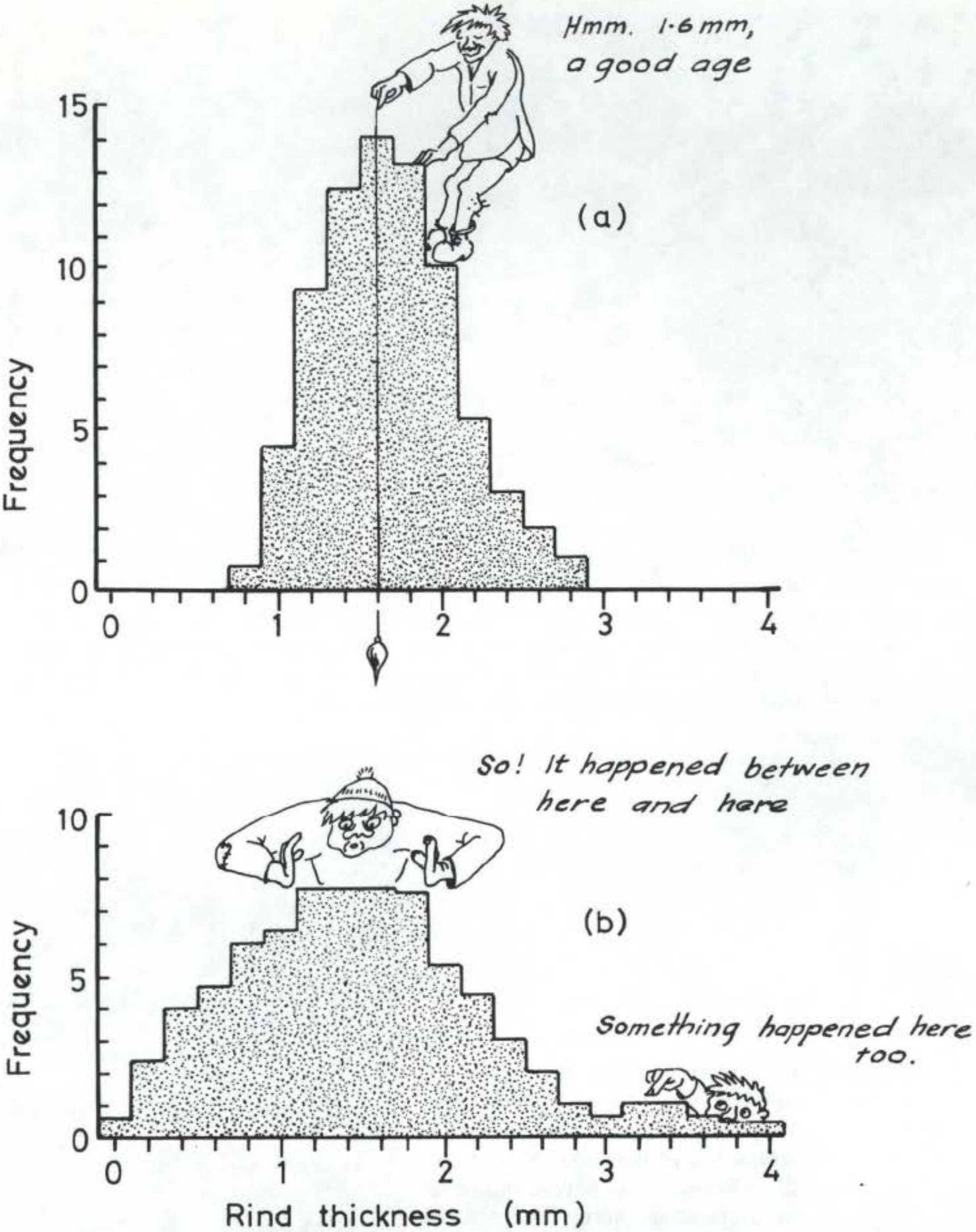

Figure 5. Rind thickness histograms:
(a) Bloody Point Landslide, Godley Valley (Grid Ref S80 119571,)
(b) Scree, Ryton Valley (Grid Ref S66 085043).

Figure 6. Screes off Laings Hill and Trigg EE (Red Hill behind), south-western end of Craigieburn Range, Canterbury. Base of screes are red coloured, grading through pink to grey up the scree. Weathering rind thickness from screes on the left of the photograph indicate that this scree surface is at least 500 years old.

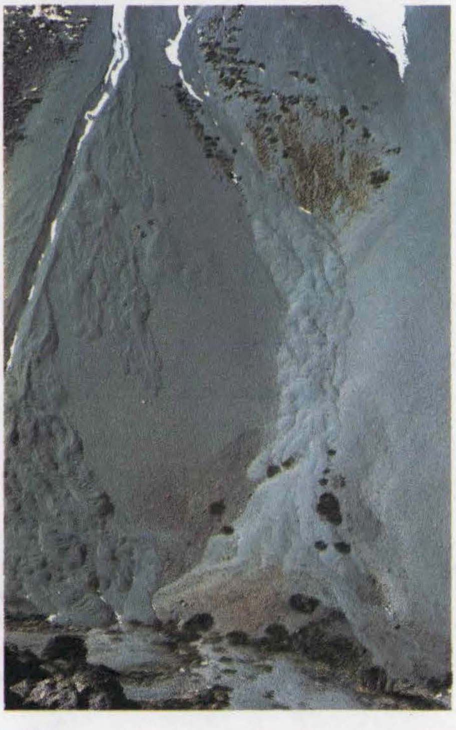

Figure 7. Base of scree in the Ryton Valley, western side of Craigieburn Range. Very recent debris flows can be seen on the left of the scree. With time, these become subdued, as shown on the right of the scree. These flows cover older scree surfaces, which themselves may be subdued debris flow deposits. Weathering rind measurements on the red coloured surface on the bottom right of the scree indicate that this part of the surface is at least 500 years old.

at the base of the scree, between two scree cones, or on a portion of a scree surface protected from vigorous scree processes by a rock-outcrop or vegetation above. Normally, the colour grades up from a red to a pink base, through a brown-coloured zone, to grey unweathered boulders at the head of the screes as shown in Figure 6.

The transition in colour down the screes of Figure 6 indicates that, while material is constantly being added to the screes from above, the scree surface itself is a permanent feature, with components at least five hundred years old. The presence of grey and brown boulders scattered over predominantly red and pink coloured older surfaces indicates that rare rockfalls and movements of rock by snow avalanching are the processes that have very slowly built this scree by adding rock material intermittently. This quite common pattern of surface age is one of several lines of evidence that refute the commonly accepted scree creep model for this and other screes.

In a few instances, screes may be covered by rocks with rinds thicker than 0.4–0.6 mm. Such ancient screes are often found on slopes above the old meltwater channels of the past Ice-Age glaciers. They vary widely in age, from mature screes 2200 years old, like that shown in Figure 5 (b), to very old screes like one sampled in Paddle Creek (S81 636528), near the South Ashburton River. This scree is much older than the maximum age datable by greywacke weathering rinds. The surface boulders are so deeply weathered that they disintegrate when attacked with the sledgehammer. The inner weathering rind boundary is often vague and diffuse and the weathering rind appears to comprise the whole rock in many samples. An age of at least 20,000 years seems likely for this scree, as it lies on a slope behind a moraine of about that age, yet it has large areas as yet unvegetated.

Another interesting group of screes are the brownish to pinkish screes cut from top to bottom by thin steel grey ribbons that may expand into a complex of lobes at the base (Figure 7). Our observations to date suggest that these are stable screes that grow intermittently by torrential mudflows during rare violent storms, occurring every 25 years or so. Following the deposition of these lobes, processes like snow creep, loess deposition or winnowing of fines, smooth the lobes and may eventually obliterate any sign of them.

Progressive removal of the soil mantle also may develop screes. If this occurs on flat or moderately sloping terrain, the stones exposed will form a lag deposit. Surface colour and rinds measured on these stones will indicate when they were exposed by surface degradation. Care must be taken in interpreting rinds from these deposits as exhumed rinds may be included. These rinds from rocks which were once weathering above the surface but were then buried by soil, and are now re-exposed as the soil is lost. Soil cover preserves rinds developed during the first period of atmospheric weathering, although when re-exposed, these rinds often have a very distinctive surgary texture and the rocks are initially light brown in colour.

We have not bothered to mention all of the problems to be encountered, but it may be of interest to note that the wide difference in climate throughout the Alps is *not* one of them. The major problem which remains outstanding is that we have not been able to determine whether the presence of a plant cover makes a difference to the rate of weathering.

We recommend this technique for anybody (whether a runholder, soil conservator, academic or naturalist) who is interested in finding how old or how young surfaces composed of greywacke boulders are. To ensure the best possible results, eyesight should be checked on a colour test chart and safety glasses worn. Readers might be surprised to find that many screes have been around for a long time and have an interesting story of their own to tell, as do those whose rinds are illustrated in Figure 8. Perhaps, in time, screescapes will come to be regarded as one of the beauties of nature, and not as an evil eyesore.

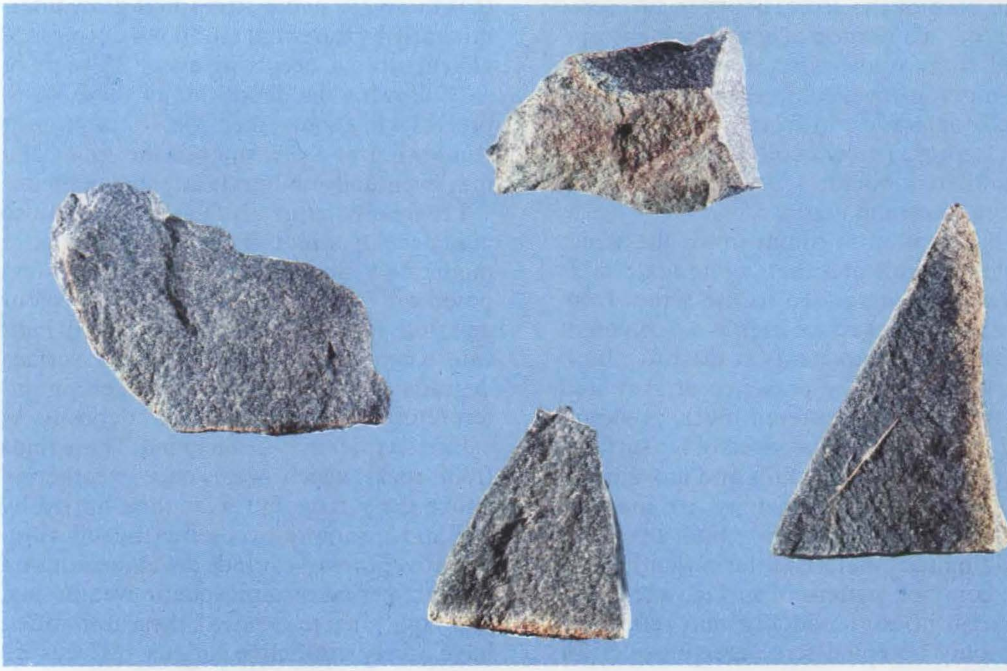

Figure 8. A selection of rocks from different age surfaces showing variations in rind thickness.

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Bullock Creek

A sobering story

M. Paul Mosley

Introduction

Success in soil conservation is not always assured even though tried and tested techniques are used, and it is important that the results of soil conservation programmes be regularly evaluated and modified. We may learn as much, if not more, from our failures as from our spectacular successes.

A dramatic example of an unsuccessful soil conservation programme is provided by the Bullock Creek catchment, Mount Thomas State Forest (Figure 1). The southeast flank of Mount Thomas, an upfaulted greywacke block overlooking Rangiora and the Canterbury Plains, is cut by a series of gullies and ravines. It has been regularly burned and grazed since the first pastoral lease was issued in 1851.

Concern about the on-site and downstream effects of erosion on Mount Thomas prompted its purchase in 1969 by the NZ Forest Service; cessation of burning and grazing and a vigorous programme of exotic tree planting has brought about a substantial improvement in vegetation cover.

However, the most serious erosion features on Mount Thomas, the Bullock Creek ravines and fan, have continued to deteriorate, and prospects for successful management are bleak. During a series of storms in April 1978, (in which a total of 325 mm of rain fell), about 170 000 m^3 of mud, gravel, and boulders were deposited by fast-moving debris-flows on the fan, over an area of 12.5 ha (Figure 2). Each successive storm has resulted in additional deposition and the toe of the fan is slowly extending down towards the State Forest boundary. Below the boundary are two sheep farms which operate under the terms of North Canterbury Catchment Board Farm Plans.

Bullock Creek catchment – its physical background

Bullock Creek has a particularly unfavourable combination of the factors which control the type and severity of erosion (lithology and tectonic setting, topography, vegetation, climate, and past management practices), making it one of the most intractable soil conservation problems in Canterbury.

Lithology and tectonic setting

The bedrock exposed in the ravines consists of alternating beds of sandstone and argillite which have been intensely deformed and faulted, and the ravines follow faults and associated crush zones. The crushed and shattered sandstone and argillite is consequently highly erodible, and steeply-dipping beds provide failure planes along which mass movements may occur.

The 1948 Cheviot earthquake was responsible for an extensive concentric system of tension cracks that bound some 20 hectares around the southern and middle ravines (Figure 3). These tension cracks indicate that vertical movement along deep-seated failure planes occurred, and it is probable that such movement will continue.

Topography

The forested face of Mount Thomas is very steep, and the ravines have probably existed

Figure 1. The Bullock Creek headwater ravines and fan, looking northwest.

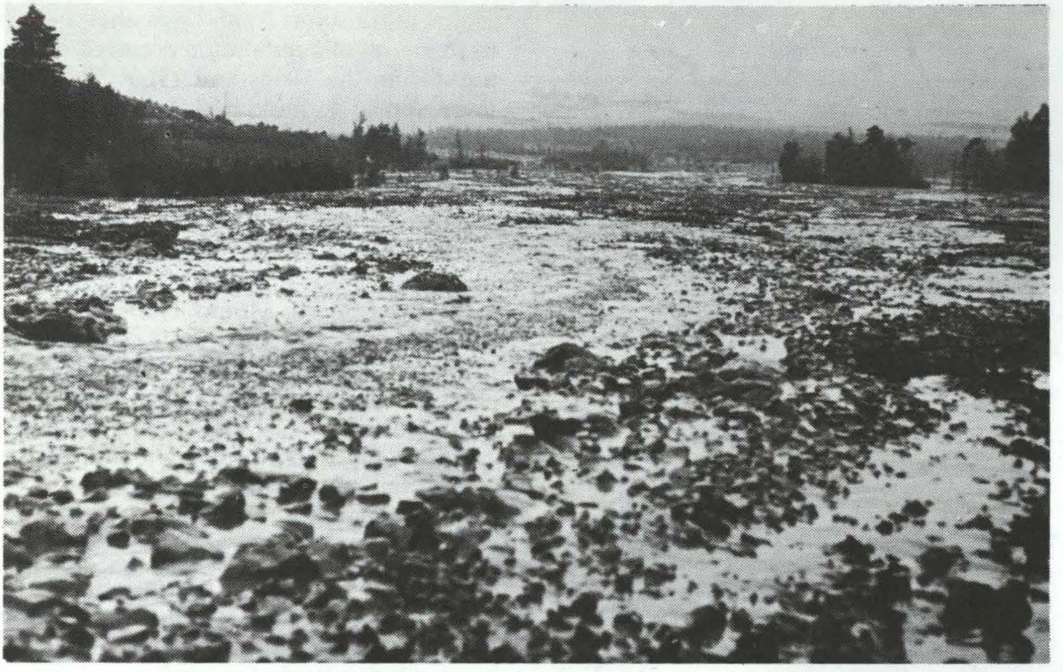

Figure 2. The Bullock Creek fan during the April 1978 storm.

for many thousands of years. Traces of earlier alluvial fans at the foot of the Bullock Creek ravines attest to past activity (Figure 3). The old fan, below the presently active one, covers an area of 140 hectares and extends nearly two kilometres past the present fan. The lobate form of its downstream edge indicates that debris-flows, similar to those presently occurring, played a role in its formation.

Vegetation and management

The composition of the original vegetation on the flank of Mount Thomas is unknown, but it is certain that the area was grazed and repeatedly burned for over a century with predictable effects upon the composition and quality of the vegetation. The northern Bullock Creek ravine still has a beech cover, and a photograph taken in 1923 indicates that the middle ravine was also forested at that time. Evidence suggests that the southern ravine was the source of gravel moving from the headwaters at that time, and therefore was probably denuded of vegetation.

Trenching at the head of the present fan, at Lundy Road, has revealed a mature forest soil, 1.7 metres deep, buried beneath freshly deposited gravels (Figure 4) and overlying debris-flow material which probably dates back to the late glacial period. Stumps of mountain beech rooted in the buried soil have fine rootlets preserved which suggests that the trees were buried no more than fifty years ago. Apparently, then, the Bullock Creek ravines were quiescent for about 12 000 years – from the end of the rigorous climatic conditions of the last glacial period until the last few decades. It is therefore reasonable to conclude that a period of renewed erosion in Bullock Creek has been associated with land use practices since European settlement.

Climate

Although the North Canterbury climate is not severe, periodic intense or prolonged rainstorms which are largely responsible for

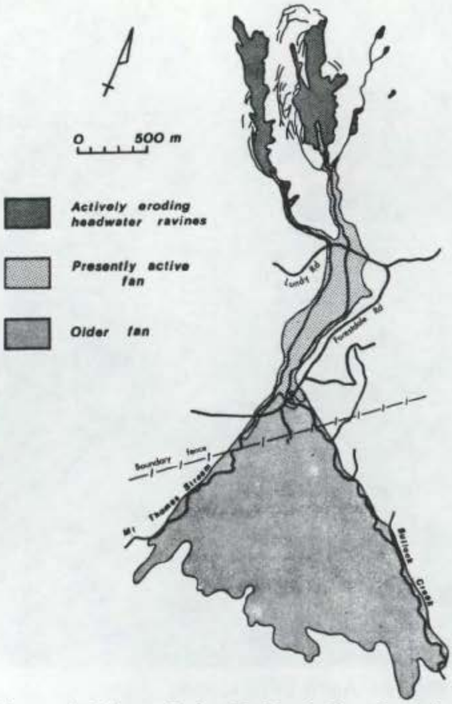

Figure 3. Map of the Bullock Creek ravine-fan system.

erosion in Bullock Creek can occur. One local resident considered that major erosion occurred every ten years on average, but observations in recent years suggest that the tempo of change may be accelerating.

History of Bullock Creek

Bullock Creek was troublesome in the 1920s when gravel buried floodgates across the creek. The middle ravine became active some time in the 1920s or 1930s, when the beech trees at the head of the active fan were first buried, and a major deterioration occurred in the 1940s – possibly as a result of a storm in 1941.

The Cheviot earthquake in 1948 caused major, deep-seated mass movements around the head of the southern and middle ravines, setting the stage for a dramatic increase in erosion. A severe storm in 1951 caused major sediment transport from the ravines and up to 15 metres of aggradation occurred on the fan during the 1950s and 1960s, although there appear to have been long periods of inactivity. However, it was during this period that concern for the effects of erosion in Bullock Creek upon farmland downstream reached a climax. After studies by the New Zealand Forest Service, New Zealand Geological Survey, and the North Canterbury Catchment Board, Mount Thomas was incorporated into Mount Thomas State Forest in 1969.

Since then the New Zealand Forest Service, with assistance and advice from the North Canterbury Catchment Board, has carried out an intensive programme of soil conservation.

Upper slopes

Pinus nigra and *P. radiata* have been planted on 87 hectares of the upper catchment of Bullock Creek, with minor plantings of other species. The objectives were to reduce soil moisture levels and thus the chance of mass earth movement, to reduce runoff during storms, and to provide mechanical stability by root systems.

Ravines

No efforts to manage the ravines, using either vegetation or structural techniques, have been made. Revegetation trials on similar sites on Mount Thomas have been generally unsuccessful.

Fan

The fan was completely planted in 1972 with *P. radiata* and six on-the-contour bands of poplars and willows, together with additional willow plantings along Forestdale Road. However, storms in 1974, 1978 and 1980 destroyed a large part of the plantings; with the destruction of additional plantings in 1975 and 1979 the direct loss amounted to almost $10,000, excluding costs of bulldozer time for road clearance, loss of fencing, and other incidentals.

Figure 4. The trench incised across Lundy Road during the April 1978 storm. Note the re-excavated beech stumps in growing position on a mature forest soil profile.

Management problems

Apart from concern over the continuing loss of soil from burning and grazing, the original reason for a programme of soil conservation was to prevent sedimentation and flooding on Bullock Creek and Bullock Hill farms downstream. During the 1950s and 1960s, the main problem for the landowners was that periodic movement of the stream channels on the fan diverted flow, first through one farm and then through the other, via Mount Thomas Stream (Bullock Hill farm) or Bullock Creek (Bullock Creek farm). As a result, one farm or the other received firstly an excess of water which caused flooding, disrupted farm access, and deposited sediment and flotsam on paddocks, and secondly a deficiency which caused problems with the water supply for stock.

As the frequency and severity of erosion in Bullock Creek have increased, concern has tended to focus on the possibility that, as the locus of deposition is moving down fan, the fan may extend below the State Forest boundary and so bury productive farmland. In the 1978 and 1980 storms a large stand of mature beech on the lower fan and much of Forestdale Road were buried to an extent not hitherto seen (Figure 5), and it is certain that high suspended sediment loads will affect water quality and cause siltation and reduction of stream channel capacity.

Although Mount Thomas State Forest has a significant protection role, it is managed as a productive forest and the Bullock Creek ravine-fan has important implications for on-site management. Both Lundy Road and Forestdale Road have been cut several times for periods ranging from hours to months. During 1978, Lundy Road was cut by a 15 metre deep trench (Figure 4) and Forestdale Road has been buried several times by 2–3 m of debris. Such loss of access has a serious effect on routine forest management – pruning, planting, and so on – and perhaps even more importantly, on fire control.

In addition, deposition on the fan has destroyed almost $10,000 of plantings (although these were always recognised as being at high risk) while the tension cracks marking slump blocks around the ravines bound a further 20 hectares of plantings which are also at risk.

Management options

Despite substantial expenditure, there is little doubt that erosion and sedimentation in the Bullock Creek catchment has been unaffected by the recent soil conservation programme. It is necessary to carefully evaluate the various management options available so that a future strategy may be planned.

The source of the problem is the southern and middle ravines, where stream action has removed support from the side slopes. The tension cracks that first appeared in 1948, bounding a volume of rock of the order of 10 million cubic metres, will ensure a sediment supply for many years. The cracks were nearly vertical at the surface and even tree root systems are largely incapable of reducing movement along them. On the other hand, the weight of a tree crop on the edge of the ravine together with wind shear in the canopy may decrease stability, although this will not be a significant consideration for some years.

Much of the sediment deposited on the fan during 1978 came from the slumping of relatively small masses of loose rubble from the unvegetated ravine sides. Trials have already shown that revegetation techniques are unsuccessful in this environment, and engineering stabilisation techniques such as grouting and rockbolting cannot be considered on financial grounds.

Sediment was also produced by stream channel degradation in the ravine and by trenching of the unconsolidated deposits at the head of the fan. Both locations are extremely high energy environments; surging debris-flows with a velocity of up to 5 m/sec and carrying boulders 1 metre in diameter are probably beyond practical structural control because the structures would be undercut, buried, outflanked, or simply flattened.

On the middle and lower fan, as gradients decline, debris-flows did not incise into the earlier deposits but spread out into thin sheets and eventually stopped. Only in one or two places has the depth of deposition been influenced by the presence of vegetation (young pines, gorse, or mature beech). Generally the moving debris flowed around obstructions, and the location of deposition appeared to be primarily controlled by slope angle (Figure 5). Thus, it appears unlikely that tree planting on most of the fan can increase rates of deposition over what occurs naturally, especially bearing in mind the limited chances of survival for such vegetation.

Towards the toe of the fan, however, the environment is one of low energy, where debris-flows are slow moving because of the reduced slope angle of the fan surface. Here, a dense belt of vegetation may be able to slow the recent downslope extension of the fan towards the developed farmland. Fortunately, a good vegetation cover has already been established between the toe of the present active fan and the State Forest boundary, although an unplanted access route leads directly to the apex of the older inactive fan, providing a corridor at a critical point in the whole fan system.

The major problem in the past, concentration of flow into either Mount Thomas Stream or Bullock Creek, has been caused by periodic diversion of the streams flowing from the three ravines. A stopbank to prevent such diversion has been proposed in the past but never constructed, and in view of the depth of deposition recently observed, such a stopbank is unlikely to be of assistance. Diversion of channels back to their

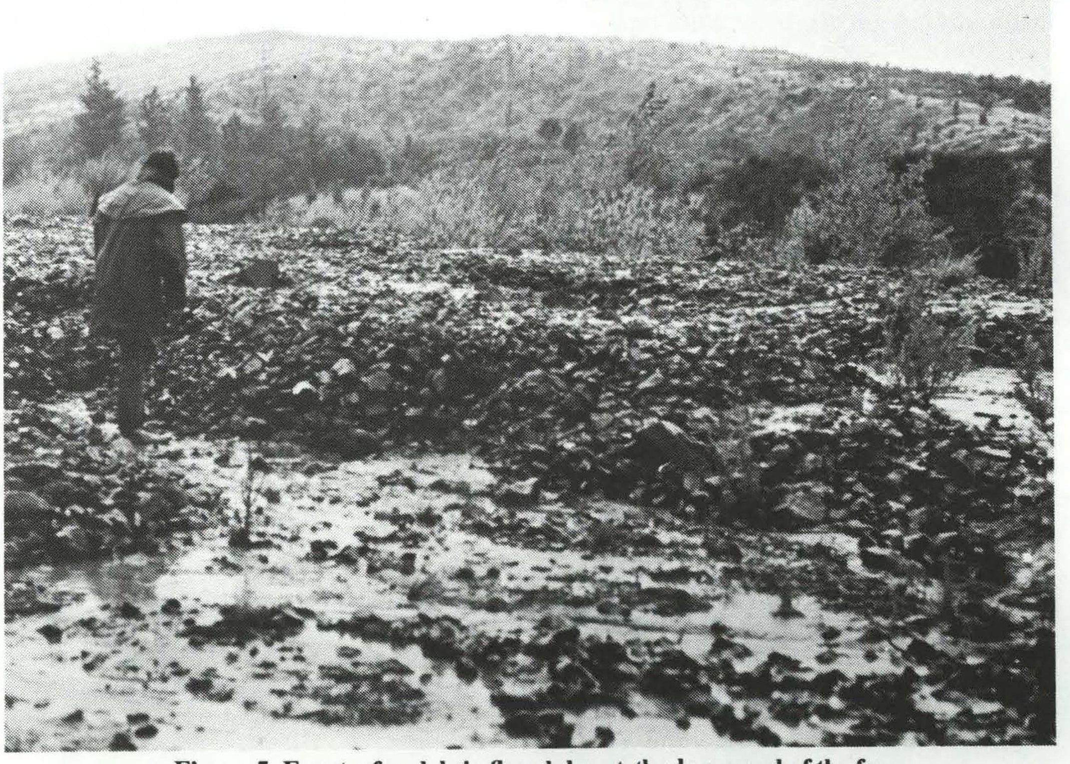

Figure 5. Front of a debris-flow lobe at the lower end of the fan.

original courses after each storm appears to be the only practicable solution. However, periodic diversion of streams flowing across an active fan is only to be expected and it may be unrealistic to attempt to maintain an equal flow in the two streams draining from the toe of the fan.

Similarly, there seems to be no permanent solution to the problem of access road maintenance across the Bullock Creek fan. The Lundy Road crossing at the head of the fan is a high-energy environment where rapid channel degradation and lateral migration in unconsolidated materials have been observed. The only plausible option appears to be the periodic re-formation of the road crossing with a bulldozer, as storm damage dictates. Again, in the case of Forestdale Road, the only option is to re-form the road after storms. Realignment to the State Forest boundary would be a more permanent solution, but would rely on the downslope advance of the toe of the fan being halted, either naturally or by vegetative control measures.

Discussion

The Bullock Creek catchment is a clear example of a natural system adversely affected by the activity associated with European settlement. It seems unlikely that the present problems on the fan would have existed had the upper slopes of Mount Thomas not been exploited for pastoral production.

Once the stability of the catchment was destroyed, the lithologic and topographic factors responsible for high rates of geomorphic change became paramount and the possibility of effective control was lost. A geomorphic "law" has been proposed; that a natural system, responding to a change in its environment (the removal of vegetation cover, for example), will adjust at a rate that is initially very rapid but that progressively declines. The southern ravine in the Bullock Creek catchment, active for some decades, appears now to have become relatively quiescent, but the middle ravine is in the early stages of adjustment, and rates of change there will remain dramatically high until a new state of stability is attained. This fact demonstrates the importance of preventing a new cycle of erosion in the northern ravine or reactivation of the cycle in the southern ravine, both of which could be caused by stream bed degradation moving back from the present fan-head trench.

The recent history of the Bullock Creek catchment should demonstrate the importance of identifying the underlying problems and the factors involved, and predicting the likely future course of events so that an efficient strategy may be planned. In hindsight, it is clear that the tree planting programme around the head of the ravines and on the upper and middle fan was never likely to be of much benefit, in the face of the natural forces in these areas.

However, an understanding of the situation may show the conservator where he could intervene with some effect. Because deposition occurs naturally in the low energy environment at the toe of the fan, this point in the system is most amenable to management, and a significant impact may be obtained at a fraction of the cost of a "blanket" approach in which management of the entire system is attempted. The conservator should attempt to work with nature, and to encourage favourable trends. Furthermore, recognition that the toe of the fan, the corridor between the active fan and the farmland on the older fan below, is the critical link in the whole system concentrates our attention, and ideally our effort, at this point.

Nevertheless, in some situations – and Bullock Creek is one of them – a permanent solution may be an impossibility. It may be possible to limit the encroachment of the active fan onto productive farmland, but the maintenance of road access within the State Forest and of the course of the streams from the toe of the fan will rely on a continual effort dictated by the occurrence of storms. It may even be necessary to accept that the quantities of sediment coming from the upper catchment are too great to regulate, and that land use changes are unavoidable.

Growing trees in the high country

N. J. Ledgard and J. T. Miller

A series of articles on the growing of trees in the high country will be published in the next few issues of "Review". This first article deals with the selection of species. Other aspects such as the raising of stock to good plantable size, site preparation, planting procedure, fertilising, and animal control, will be covered later. Most of the details given here are presented in more condensed form in the Revegetation section's Field Manual (1977) which is obtainable from the Protection Forestry Division on request.

Information has been derived mostly from work conducted in the Craigieburn Range, North Canterbury. As such, the details may not always relate accurately to the rest of New Zealand, especially in regard to altitudinal limits.

For over 20 years growing plants in the high country has been the major preoccupation of the Revegetation section of the Protection Forestry Divison of the Forest Research Institute (PFD/FRI). A team of six scientists accompanied by technicians and other staff has tested hundreds of species and provenances of both herbaceous and woody plants on sites ranging from intact grasslands to steep eroding slopes at altitudes between 900 and 1500m. Problems and early progress in this field of research have been described by the Division's late Director, Jack Holloway, in *Review* 18, 1970. As mentioned in Holloway's article, grasses and legumes play an important role in erosion control programmes but trees are normally required to fill the more permanent positions.

I. Selecting suitable trees

Seed sources –

Selection of the right variety of tree within a species can be as important as the selection of the right species itself. Seed should therefore come from proven parent trees before the stock is either grown or purchased. Recommendations as to the better seed origins are given below.

Shelter –

Little experience is needed of high country conditions to realise that the most important factor affecting plant growth is shelter – primarily from drying and physically damaging winds. Without shelter the list of the species which will grow in the high country is not long. In this article we have assumed that trees are to be grown on a bare landscape with minimal protection from wind, sun and snow.

Spread of trees –

Much has been said in recent years about the potential spread of certain exotic tree species particularly lodgepole pine *(Pinus contorta)* on to undeveloped land. Any tree, once mature, will produce seed which could lead to undesired spread of that species. Within the high country today natural spread of most of the species discussed below can be found in areas that are lightly grazed. On the other hand a number of areas exist where correct land management around existing seed-producing trees has allowed no natural spread – witness the hundreds of miles of mature pines growing amongst developed pasture on the Canterbury plains, with little evident natural regeneration.

Protection from animals –

For successful establishment trees must be protected from grazing and browsing animals. In the case of sheep, cattle, deer and other ungulates, this should not be hard to achieve, but protection against opossums, rabbits and hares is much more difficult and some damage to seedlings from these animals may have to be endured. Protection from animals will be discussed more fully in a later article.

The following is a list of species which, from our experience to date, could be considered useful in undeveloped high country conditions. Appendix I lists all the woody species evaluated by the Protection Forestry Division since 1954.

Native species

Generally, native species have proved unsatisfactory in unsheltered conditions. *Hebe* and *Cassinia* species and occasionally mountain beech (*Nothofagus solandri* var. *cliffortioides*) have survived and grown even on bare sites particularly with the aid of fertilisers. However, if these species or other natives are desired it is recommended that they are planted at a later date in the shelter of more vigorous and hardy exotic species.

Conifers

1. Douglas fir (*Pseudotsuga menziesii*)

This species is successful to 1000m on stable topsoil and subsoil sites and shows potential as a production forestry species up to 900m. Good general purpose seed is produced from seed stands developed within high quality plantations, officially approved e.g., seed stand B22, Compartment 12, Ashley Forest.

2. Larch (*Larix* spp.)

Larix decidua (European larch) has the greatest potential of this group. It can be grown on most sites to 1100m and has production forestry potential to 900m. Good larch sites are usually identified as sheltered slopes with free draining, loamy soils but well watered after the spring flush. Larch is intolerant of strong winds and can be susceptible to summer frosts and to oppossum damage. As an amenity species it forms an attractive contrast to pines. The recommended seed sources are the approved seed stands developed by the Forest Service in Hanmer and Omihi Forests.

Larix leptolepis (Japanese larch) is not recommended for use at any altitude over 600m.

Larix eurolepis (Hybrid larch) will normally outgrow its two parents but details of its altitudinal limits are not yet clear. Young trees at 850m have grown well without damage to date. The species is certain to be of interest in the future but so far there are no New Zealand seed sources.

3. Pines (*Pinus* spp.)

Pinus contorta (lodgepole pine) is successful on most sites to 1400m. It has potential as a production species to 1100m but spreads

Figure 1. Lodgepole pine (*P. contorta*) at 950m in Craigieburn Forest Park. These trees are in their fourth growing season after planting as part of a trial to test seedlings grown in various types of container. No fertilisers have been used.

vigorously from natural seeding, especially in the absence of grazing. Some provenances with slower growth rates may prove to have better form and durability. The recommended seed sources are from stands developed in Mt Thomas, Eyrewell and Kaingaroa Forests.

Pinus mugo (mountain pine) is successful on all sites to 1600m. It is resistant to wind and snowpack damage and grows well on dry slopes. It forms a low spreading canopy ideally suited to erosion control. The recommended seed sources are FRI stands in the Craigieburn Range.

Pinus uncinata is closely related and in appearance is similar to *P. mugo* but with a single-leader growth habit. Site tolerance and seed sources are as for *P. mugo*.

Pinus nigra (Corsican pine) is a single leader tree species with potential up to 1100m on many sites. There are good quality seed stands at Balmoral and Rankleburn Forests.

Pinus ponderosa is successful on all sites to 1150m and has production forestry potential to 1000m. It is not readily damaged by snow and wind, maintaining good form when open grown. A young Forest Service seed stand producing small quantities of seed exists at Tara Hills. Seed supplies are thus limited but a number of good private stands exist in the high country.

Pinus radiata is not recommended as a high country revegetation species but will grow on selected stable sites to 1000m. On exposed sites this species becomes severely stunted, being prone to climate damage above 1000m. Difficulties could be experienced in establishment above 800m.

Pinus sylvestris (Scots pine) is successful on many sites with the exception of scree to 1250m. It has potential as a production species to 1100m but aphid attack can cause severe defoliation and it is susceptible to snow and wind damage above 900m. Suitable seed sources are at Glyn Wye (Waiau), and from the Forest Service ("Boxholm" origin) at Golden Downs and Berwick Forest.

A number of other pine species (e.g. *P. jeffreyi*, *P. muricata*, *P. resinosa* and the five-

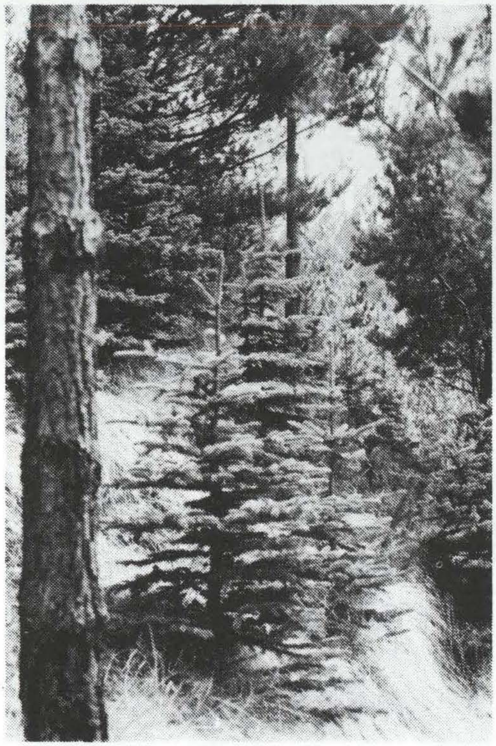

Figure 2. Engleman's spruce (*Picea engelmannii*) growing among Scot's pine and snow gums (*Euc. pauciflora*) at 900m in Craigieburn Forest Park. These fifteen-year-old trees are currently growing over 20cm annually after a characteristically slow start for the first four to five years.

needle pines) have shown good growth at altitudes to 1000m but as yet they cannot safely be recommended for general high country use.

4. Firs (*Abies* spp.)

Although a number of species have been established for many years in parks, gardens and private properties the potential of this genus in the high country has yet to be fully explored. Species showing initial promise at 600m are *Abies grandis*, *A. concolor*, and *A. procera*. *Abies pinsapo* has shown ability to survive on drier sites. In general, *Abies* species do not make good pioneers, preferring the role of interplants or underplants in forest soils where their nutrient requirements can be met. They are intolerant of grass competition.

5. Spruce (*Picea* spp.)
These are not suited to eroding sites, but *Picea abies, P. glauca* and *P. engelmannii* have shown promise on moist slopes with intact soils. Growth is usually very slow for 4–5 years after planting.

6. *Sequoiadendron giganteum*
Lone trees have grown to impressive dimensions in a number of intact sites up to 800m. This altitude could no doubt be increased. The species is very resistant to snow and wind damage.

7. Other genera
Experience with other conifers such as *Cedrus deodara, Cuppressus arizonica, Cupressocyparis leylandii, Libocedrus decurrens* and *Thuja plicata* is limited, although with shelter most should grow on intact soils up to 900m.

Broadleaves

1. Alders (*Alnus* spp.)
Alnus viridis (European green alder) has been successful on actively eroding sites to 1600m. It prefers moist scree and is resistant to snow, wind, and avalanche damage. Root nodules fix atmospheric nitrogen. Green alder forms a dense (deciduous) canopy and develops a strong extensive root system, ideally suited for scree stabilisation. Seed stands in the Craigieburn Forest Park are the recommended source.

2. Birches (*Betula* spp.)
Betula verrucosa (silver birch) has been successful to 1300m but is very susceptible to damage by snow and opossums. It has potential as an amenity species. Local inland origins are the recommended seed source.

3. Gums (*Eucalyptus* spp.)
E. pauciflora (snow gum) has grown successfully to 1100m. Further species are under

Figure 3. Beech, pines, tussock and bare ground at 900m in Craigieburn Forest Park.

trial. They are susceptible to opossum browse especially when young.

Other gum species under trial are *E. coccifera, E. cypellocarpa, E. dalrympleana, E. delegatensis, E. glaucescens, E. gunnii, E. johnstonii, E. nitens, E. parvifolia, E. perrineana, E. rubida, E. stellulata* and *E. viminalis*.

4. Poplars and Aspens (*Populus* spp.)

A number of species will grow on free draining sites such as river terraces, and outwash fans. Catchment Board and limited F.R.I. trials have shown *P. yunnanensis, P. rumford* and *P. strathglass* to be fast growing at altitudes of up to at least 1000m. The latter two are not rust resistant and in rust areas could be replaced by the variety 'Flevo'.

5. Willows (*Salix* spp.)

Pole, wand and rooted stock plantings can be made to 1100m for gully stabilisation. Willows dislike pine subsoil sites. A number of species are suitable, but if opossums are present, the 'bitter' willows such as *Salix glaucophylloides* (formerly *S. piperi*), *S. purpurea* and varieties should be used. Tree willows such as the *S. matsudana* × *alba* hybrid have recently been released and could well have a role as a shelter tree in parts of the high country.

6. Other genera

Some further genera that may be considered for special purposes (e.g. amenity plantings) in sheltered sites up to 900m, are maples (*Acer* spp.), oaks (*Quercus* spp.), beeches (*Fagus* spp.), limes (*Tilia* spp.), elms (*Ulnus* spp.), *Robinea pseudoacacia* and *Sorbus* spp.

No doubt readers of *Review* will know of high country trees which have not been mentioned. Among Forest Service plantations there are also individuals or small groups of the less common trees not mentioned here which are growing successfully. Invariably such trees are sited in the more sheltered choice positions where conditions are much more favourable than on the exposed tussock/grassland swards which dominate most of the high country. However, they should not be ignored as knowledge of tree growth can accumulate only slowly, and if these trees are to play a role in the future, facts recorded today will save costly mistakes tomorrow. All high country landowners, while recognising the basic limitations imposed by exposure, frost and fertility, should regard themselves as pioneer tree planters. For the sake of diversifying and improving the environment in which they live, they should try to increase the range of trees and shrubs available for high country use.

Appendix 1

PFD/FRI Species List

This list records (alphabetically by genera) the woody species which have passed through PFD/FRI hands since 1954. Provenances, varieties, hybrids, etc., are not included except under *Salix* and *Populus*. Further details of species performance can be given on request.

N.B. (M) – signifies species tested only at Makahu Saddle Station, Kaweka Range, Hawkes Bay.

Native species

Cassinia vauvilliersii
Coriaria arborea
Dracophyllum recurvum
Dracophyllum uniflorum
Hebe odora
Hebe pinguifolia
Hebe venustula (M)
Nothofagus cliffortioides
Nothofagus fusca (M)
Nothofagus menziesii
Podocarpus hallii (M)
Podocarpus nivalis

Introduced Coniferous species

Abies amabilis
Abies cephalonica
Abies concolor
Abies firma
Abies grandis
Abies lasiocarpa
Abies magnifica
Abies nobilis
Abies nordmanniana
Abies numidica
Abies pinsapo
Abies procera
Abies religiosa (M)
Cedrus atlantica
Cedrus deodara
Cedrus libani
Chamaecyparis lawsoniana
Chamaecyparis nootkatensis
Cupressus arizonica
Cupressus lusitanica
Cupressus torulosa
Juniperus scopulorum
Juniperus osteosperma
Juniperus wallichiana
Larix decidua
Larix eurolepis
Larix leptolepis
Larix lyallii
Larix occidentalis
Larix sibirica
Libocedrus chilensis
Libocedrus decurrens
Picea abies
Picea breweriana
Picea engelmannii
Picea excelsa
Picea glauca
Picea jezoensis
Picea mariana
Picea omorika
Picea pungens
Picea rubens
Picea schrenkiana
Picea sitchensis
Picea smithiana
Pinus albicaulis
Pinus aristata
Pinus attenuata
Pinus ayacahuite
Pinus balfouriana
Pinus banksiana
Pinus cembra
Picea cembroides
Pinus contorta
Pinus coulteri
Pinus densiflora
Pinus durangensis (M)
Pinus edulis
Pinus flexilis
Pinus halepensis
Pinus hartwegii
Pinus heldreichii
Pinus jeffreyi
Pinus koraiensis
Pinus lambertiana
Pinus monticola
Pinus mugo
Pinus nigra
Pinus parviflora
Pinus peuce
Pinus pinaster
Pinus ponderosa
Pinus radiata
Pinus resinosa
Pinus rigida
Pinus sabiniana
Pinus strobus (M)
Pinus sylvestris
Pinus tabulaeformis
Pinus uncinata
Pinus virginiana
Pinus washoensis
Pseudotsuga glauca
Pseudotsuga menziesii
Sequoia gigantea
Thuja plicata
Tsuga canadensis
Tsuga heterophylla
Tsuga mertensiana

Introduced Broadleaf species

Acacia melanoxylon
Acer glabrum
Acer negundo
Acer platanoides
Acer pseudoplatanus
Ailanthus altissima (M)
Alnus crispa

Alnus glutinosa
Alnus hirsuta
Alnus incana
Alnus inokumae
Alnus japonica
Alnus jorullensis
Alnus nepalensis
Alnus matsumurai
Alnus rhombifolia
Alnus rubra
Alnus sinuata
Alnus tenuifolia
Alnus viridis
Amelanchier alnifolia
Araucaria araucana
Arctostaphylos uva-ursi
Artemisia tridentata
Betula alba
Betula ermannii
Betula glandulosa
Betula maximowicziana
Betula papyrifera
Betula platyphylla
Betula populifolia
Betula pubescens
Betula utilis
Betula verrucosa
Caragana arborescens
Casuarina nana
Ceanothus cordulatus
Ceanothus integerrimus
Ceanothus prostratus
Ceanothus sanguineus
Ceanothus velutinus
Cercocarpus ledifolius
Cercocarpus montanus
Chrysothamnus viscidiflorus
Chrysothamnus nauseosus
Cistus albidus
Cistus ladaniferus
Cistus monospeliensis
Cistus purpureus
Cistus villosus
Cornus nuttallii
Cotoneaster microphylla
Cowania stansburiana
Dasyphyllum diacanthoides
Discaria serratifolia
Drimys winteri
Embothrium coccineum
Empetrum nigrum
Eucalyptus coccifera
Eucalyptus delegatensis
Eucalyptus gigantea
Eucalyptus gunnii
Eucalyptus johnstonii
Eucalyptus niphophila
Eucalyptus parvifolia
Eucalyptus pauciflora
Eucalyptus perriniana
Eucalyptus stellulata
Eucalyptus subcrenulata
Eucalyptus urnigera
Eucryphia glutinosa
Euonymus bungeanus (M)
Fagus sylvatica
Gaultheria shallon
Laburnum alpinum
Laburnum anagyroides
Lonicera nitida (M)
Lonicera tartarica
Mahonia aquifolium
Nothofagus alpina
Nothofagus antarctica
Nothofagus dombeyi
Nothofagus nervosa
Nothofagus obliqua
Nothofagus pumilio
Podocarpus andina
Populus balsamifera
Populus berolinensis
Populus deltoides
Populus eugenei
Populus flevo
Populus frye
Populus generosa
Populus I 30
Populus marilandica
Populus nigra
Populus O.P. 63
Populus robusta
Populus rochester
Populus roxbury
Populus rumford
Populus serotina
Populus strathglass
Populus tremula
Populus trichocarpa
Populus yunnanensis
Purshia tridentata

Purshia glandulosa
Quillaja saponaria
Rhus trilobata
Robinia pseudoacacia
Salix argyracea
Salix cinerea
Salix daphnoides
Salix discolor
Salix gilliotii
Salix glaucophylloides
Salix gracilistyla
Salix herbacea
Salix hippophaefolia
Salix incana
Salix laurina
Salix medemii
Salix mooreana
Salix nigricans
Salix pentandra
Salix pontederana
Salix pseudolapponum
Salix purpurea
Salix retusa
Salix rubra
Salix sachalinensis
Salix viminalis
Salix vitellina
Salix waldesteiniana
Sambucus callicarpa
Sambucus coerulea
Schinus patagonicus
Sedum sempervirens
Shepherdia canadensis
Sorbaria tomentosa
Sorbus aucuparia
Symphoricarpus occidentalis
Symphoricarpus orbiculatis (M)
Viburnum alnifolium
Weinmannia trichosperma

Preparation for land management in the 1980s

W. T. Devine

This article looks at the relevance today of the 1970 Physical Environment Conference recommendations on Land Resources and Land Use and provides a commentary on the extent to which these recommendations have been implemented. The author who is executive officer (Land Management) in the Wellington District Office of the Department of Lands and Survey, stresses that the views he expresses here are his own and not necessarily those of the Department.

Rational land use

The nineteen seventies in New Zealand began with a growing social movement in response to "... the increasing urgency of environmental problems in this country and throughout the world, created by technological change, by industrialisation, urbanisation and population growth"[1], reflecting public concern over the use of land resources. The Physical Environment Conference 1970 was concerned with how "we are to continue to develop and improve our standard of material comfort whilst at the same time sensibly preserve the limited resources of nature"[2]. The Working Party on Land Resources and Land Use pointed out that the land and its resources are our basic assets, providing most of our wealth and remaining our greatest source of trade today[3]. Owing to the potential for conflict between the interests of different land uses, the task of the Working Party was to investigate ways in which a more rational use of our land resources could be attained.

Collecting information

The Working Party dealt initially with Land Use Determination and Land Management Requirements, stressing the importance of information about land resources and of giving a high national priority to the land inventory series, perhaps the most comprehensive survey as yet under way. Also noted was the urgent need for an objective assessment of the nature and degree of coordination of existing land resource surveys. This was to involve an investigation by the State Services Commission into the structure of the Government agencies concerned with land use and land management. The Commission decided, after careful consideration, that a specific inquiry was not necessary at the time, due to, among other things, the continuing routine review procedures included under Section 12 State Services Act 1962 (H. R. Hughes pers. comm.)

The inquiry recommended was to be coupled with an appraisal of the adequacy and availability of basic information on the country's land resources, requiring only an absolute minimum of data to be included in a computer-based system[4]. By 1978, the aims of this project were refined to identify the likely major users of such an information system, to draft specifications for a demonstration computer system, and to prepare a detailed estimation of resource requirements[5].

Developing land use criteria

The Working Party reported on the need for a "land use advisory commission" to develop cohesive land use criteria[3]. The Land Use

Advisory Council was thus established by 1972. Its terms of reference required it to have regard to physical, ecological, economic, social, environmental and other relevant factors, and to determine means by which these factors may be more precisely defined[6]. The Council was comprised of interests representing a variety of perspectives, and although its decisions were primarily intended to guide the use of Crown lands, it was expected that they would find a wider application.

Administered by the Department of Lands and Survey, the Council proposed that its task should be to develop a New Zealand land use policy, based on clear statements of national objectives on a number of land use issues, in order to resolve "... what are tending in many cases to become emotive issues of environmental conflict"[7]. The Department's 1975 annual report mentions " ... the need for early action on measures to ensure that the fast growing forestry industry obtains the land it requires in locations suited to this type of development and where there will be little or no conflict with agriculture, recreation, or other land uses contributing to overall community needs." This theme was not developed in later reports, but was taken up by the Director-General of Forests, who asserted that fears about the threat to farming activity are "... exaggerated and need to be dispelled." He believed that: "Whenever and wherever competition between alternative land uses becomes a problem, consideration will need to be given to whether it is best worked out in the market-place or by more sophisticated land-use planning than any previously attempted"[8].

In 1976, the Council assumed responsibility for the formulation of " ... more specific guidelines which will help day to day ... at the field level, where a series of minor decisions can over a period of time create an established pattern of land use over large areas"[4]. By 1977, the Council had formed regional links, and by 1978, had put out its first publication, the Land Information Handbook.

In May 1978, the Council invited public submissions on two papers; a review of progress and a statement of intention on the New Zealand Land Information system mentioned earlier, and a discussion paper on the development of a New Zealand Land Use Policy, leading to a major national land use conference planned for late 1979.

Alternative land uses

In looking at the competing demands brought to bear on rural lands, the Working Party isolated the localised urbanisation of high producing farm land and the impact of mineral extraction, and concluded that the recommendations of the National Development Conference relating to the protection of public reserves should be embodied in mining legislation. (The Mining Bill had been introduced in 1969.) The argument that " ... the exploitation of our mineral resources is of growing importance in the diversification and development of our national economy" was, however, considered to justify the deleterious effect on the physical environment[3].

In contrast, the National Parks Authority saw mining in national parks and reserves as incompatible with the international concept of fully protected natural areas, believing that, if prospecting was allowed (not in itself, necessarily, a damaging process), then mining could follow as of right. The inevitable adverse effects would result, not only from mineral extraction, but through construction of access, accommodation and other buildings, subsidiary plant and machinery, and with the pollution resulting from the disposal of overburden and wastes[6]. The Department of Lands and Survey, by 1977, was able to report that: "The mining industry now appears to recognise that the automatic mining right has worked to its detriment and may be ready to accept an amendment (to Section 57 Mining Act 1971) in so far as it applies to national parks." Such a change was effected in 1978.

Conservation and the protection of natural beauty

Bearing in mind the threat to large areas of natural scenery in the West Coast beech forests, the West Taupo forests and the Kaimai Range, the Working Party was in conflict with the conservation movement when it asserted, in 1970, that the man-made landscape based on agriculture or forestry need be no less interesting or satisfying than the natural landscape[3], particularly since it did openly acknowledge the current emphasis on preservation. Indeed, "The instinct of the caged animal to return to the wild seems to persist in that most domesticated of all animals, man . . ."[9], and it can be said that "Biologically and aesthetically the best human environment is the most varied one and has a predominantly indigenous flavour"[10].

The Working Pary reported that the central problem was to combine the most effective and most socially desirable use of New Zealand's unique soil, water and plant resources with the maintenance of scientific and scenic values[3]. Because of the complexity of social values, as exemplified by the continuing furore about the logging of native forests, universal approval for any development project in our natural areas is unlikely. However, the Government has, in accordance with a Working Party recommendation, given greater recognition to the fundamental importance of conservation.

In addition to the Nature Conservation Council, the Environmental Council and the Commission for the Environment, set up as a result of the Physical Environment Conference, have played a significant role in this change in emphasis.

Research and education

The study commissioned in mid-1970 by the Department and the National Parks Authority, and undertaken by Ray Chapman-Taylor[11], was an important contribution to the advancement of environmental education. The Working Party had recommended that the environmental education programmes already established in national parks in 1970 should be extended, although the Chapman-Taylor report demonstrated that the present and future demand for the educational use of natural areas could be met in a variety of venues, not only to ensure the protection of the parks from over-use, but also for the convenience of schools and to encourage appreciation of the wider natural resources of New Zealand. The general policy of the National Parks Authority is to place the responsibility for nature education at the broader level upon the schools, seeing the role of education in the parks as complementary to the study of other sites.

One of the topics explored at the Outdoor Planning Symposium 1977, jointly sponsored by the Department of Lands and Survey and the New Zealand Council for Recreation and Sport, was the need for more information about the social uses of scenic and recreational areas. At this symposium, the Department's Marlborough Pilot Study for Outdoor Recreation Planning was presented, comprising a strategy for the provision of recreational opportunities through an application of contemporary planning processes.[12] The Working Party also recommended that a greater number of comprehensive handbooks giving information about public reserves should be published and made available through the Department of Lands and Survey. The Department's July 1977 Publications List shows 58 leaflets or booklets of this type to be available throughout the country. Although incomplete, the most comprehensive series comprises the Scenic Reserve booklets for each Land District, published by the Government Printer.

The rural scene

The Working Party's recommendations concerning roading, beautification, and the protection and enhancement of scenic, natural and recreational values focussed on the New Zealand habit of compartmentalising the differing requirements of beautification and engineering, rather than attempting some form of reconciliation and thus ensuring the enrichment of development and construction[3]. This habit is still deeply entrenched in rural attitudes to public works, to the detriment of our back-country roads. Careless scars are evident throughout many scenic and allied reserves, as testament to the overriding importance of financial considerations. As a result, the Department of Lands and Survey quickly learnt the value of utilising the skills of landscape experts[13].

An important project, demonstrating full utilisation of landscape expertise in roading planning, was the reconstruction of SH 6 through the Punakaiki Scenic Reserve and adjacent lands. Emphasis was placed not only on restoration and management after roadworks, but also on reduction in the scale of impact through modifications to the engineering design[14]. Agreement has now been reached between other interested parties and the National Roads Board over guidelines for roading in National Parks and allied Reserves to reconcile such conflicts.

Planning for recreational areas

The Working Party made various recommendations about the role to be played by regional bodies in the development of areas of recreational and scenic value. However, these goals are far from fruition, the Auckland Regional Authority standing alone as an effective example of local body involvement, with the Wellington Regional Planning Authority and the Hamilton City Council, through a voluntary association of local bodies for reserve purchase, displaying involvement to a somewhat more limited degree.

The Working Party also recommended that criteria be established to determine the significance of existing or potential public reserve areas and to regulate the provision and allocation of money for the development and/or acquisition of these areas[3], drawing special attention to the need for closer integration of local and Central Government planning processes. Town and Country Planning legislation and procedures would function as the most suitable vehicle for this purpose, although progress is somewhat hampered by the paucity of any other studies as comprehensive as the outdoor recreation plan for Marlborough already mentioned. In the Foreword to this study report, the Director-General of Lands, Mr N. S. Coad, indicated that the aim of the study was to develop a method with the potential for application by any local or regional authority.

There is a need for local government to commit greater resources to this aspect of land use planning, to ensure that outdoor recreation (and allied aspects of conservation) will receive adequate consideration in the allocation of New Zealand's land[12]. The pilot study warns of the dangers of limiting the range of options for the future and thus pre-empting suitable land resources from future recreation use. Because of the difficulties in making sufficient provision for all significant requirements, the need for flexibility to cope with changing circumstances and the limited resource base of many local authorities, the Team pointed to the need for overall co-ordination and integration of major outdoor recreational functions and the concomitant preservation plans.

"Careless scars are evident throughout many scenic and allied reserves, as testament to the overriding importance of financial considerations. As a result, the Department of Lands and Survey quickly learnt the value of utilising the skills of landscape experts."

The achievement of this aim is questionable, since there are many agencies involved even at a national level (see Table I of the pilot study report). Conservation groups have suggested an amalgamation of some central government agencies into a Ministry of Natural Resources, despite the fact that large government departments formed in this manner still tend to be subject to internal rivalry, to suffer from diversity of function and to maintain unequal concentrations of influence. As an alternative, therefore, to the status quo, the outdoor recreation plans proposed by the Working Party must be given effect through regional and district schemes.

The Working Party noted that the Department of Lands and Survey was classifying areas covered by its coastal reserves survey in accordance with their national, regional and local significance. The Department, in conjunction with the New Zealand Historic Places Trust, has also developed guidelines for identifying historic sites of national significance[15], although these have yet to be applied as part of an acquisition programme.

In July 1979 a Government Caucus Committee also dealt with defining the significance of reserves when reviewing their administrative structure. It considered national reserves should include those classified for historic, scenic, nature and scientific purposes. In the area of reserves finance, the ultimate determinant of policies and priorities, the Working Party referred to the report of an interdepartmental committee investigation, the results of which have never been made public.

The Working Party concluded this section of its report with a recommendation that the acquisition and development of recreational and conservational areas should be given high priority by both central and local government in the allocation of funds, and referred to such areas as "... both social and financial investments for the future ..."[3].

Planning and management of national reserves

There is an obvious need to co-ordinate regional and national land management practices and policies for reserves and other public lands, to maximise the utilisation of these areas as a recreational resource. This co-ordination can best be achieved through national input to the regional outdoor recreation plans previously mentioned. Only the employment of comprehensive user and demand surveys, such as those conducted in the Marlborough pilot study, can remedy the current state of haphazard and ineffectual activity, and there is an ever present danger that recommendations may become an ideal rather than a goal.

The Reserves Act 1977 provides a more realistic basis for the co-ordination of national and local policies than did its predecessor of 1953. Section 13 of the Act provides for the special identification of some reserves which are to be administered "... to provide for the application of management policies to protect the values of national or international significance and for the co-ordination of management with other national reserves." The extent to which this section of the Act will be applied has yet to be developed.

"There is an obvious need to co-ordinate regional and national land management practices and polices for reserves and other public lands, to maximise the utilisation of these areas as a recreational resource. This co-ordination can best be achieved through national input to the regional outdoor recreation plans previously mentioned. Only the employment of comprehensive user and demand surveys, such as those conducted in the Marlborough pilot study, can remedy the current state of haphazard and ineffectual activity, and there is an ever present danger that recommendations may become an ideal rather than a goal."

The Physical Environment Conference amended the Working Party's recommendations to the effect that State Forest working plans should be made available for public inspection. The Forest Service has risen to this challenge, in response to "growing public interest"[16], by way of the Forests Amendment Act 1976, and public involvement is, under the Reserves Act, mandatory for reserve management plans. Opportunities for prior submissions and for comment on a draft plan are available.

To a degree, the New Zealand Forest Service has been more successful in reconciling public use with silviculture than has the Department of Lands and Survey in doing so with farming, although there remains a cautious optimism about the future[17]. The Department has shown a greater awareness, in the past decade, of conservational considerations in land development and has prepared environmental impact reports on its proposals for the Moutoa and Waipori Farm Settlements. The Commissioner for the Environment, in his audit of the Waipori report in 1978, observed that "... the social benefits to the region and nation of increased rural settlement opportunities are clear ..." but added "... the present means of determining land use options for the Crown appear to be unduly restrictive and conducive to single use approaches." The Commissioner accepted, however, that the Waipori proposal was a "... commendable effort to incorporate multiple-use concepts into a Land Settlement Board Scheme ..." as it sought to "... retain and enhance existing scientific, recreational, historical and water management values." Nonetheless, he recommended a review of the present methods used to determine land development. The Land Use Advisory Council has taken up this challenge.

During 1978, the Land Settlement Board adopted guidelines for the incorporation of farm settlements into regional parks, and considered the concept of public demonstration farms.

Protection of coastline, lakeshores and riverbanks

In the Reserves Act 1977, particular emphasis was given to the preservation of the natural character of the coastal environment and the margins of lakes and rivers for public use. The Working Party report contained a wide range of recommendations, but it is intended here to look only at the proposal that "Coastal... surveys being undertaken by the Department of Lands and Survey should be completed as soon as possible and the necessary resources should be provided to enable this to be done"[3]. This study was initiated in 1966, developing an increasingly sophisticated methodology during the following decade, with a greater emphasis on public release of reports. High priority was given to the surveys in the Northland, Bay of Plenty and Coromandel coasts, identified as key areas by the Working Party. The survey was forecast for completion in 1980[18] but the necessary resources were not available. A total of 34 out of 85 schemed reports have been finalised but one third of the New Zealand coastline had been covered by 1972[19].

Access

Under this heading, the Land Resources and Land Use Working Party reviewed legislation providing for the retention of public land on the margins of water bodies, noting the problem of damage to property through the negligence and ignorance of sportsmen and trampers. This has led to a "noticeable but natural tightening up by property owners (including the Crown) who are understandably loathe to suffer preventable losses by inconsiderate users of accessways through their properties"[3]. The Working Party made several recommendations, but did not foresee those subsequent developments which culminated in the New Zealand Walkways Act 1975.

These developments included the concept of a national walkway network from "North Cape to Bluff", which eventually became a proposal for providing tracks for walks of two to three hours in duration near urban areas, as well as longer tracks forming part of a national network. This project was furthered in 1973 by the establishment of district committees, serviced by the Department of Lands and Survey and responsible to the Central Working Party. On the passing of the Act, the Central Working Party was replaced by the New Zealand Walkway Commission and the district committees continued to function, although on a more formal basis. To deal with the problems identified by the Land Resources and Land Use Working Party in 1970, the manner in which walkways may be used has been prescribed and there is provision for compensation for damage to private property.

Preservation of Wetlands

The Land Resources and Land Use Working Party highlighted one of New Zealand's most neglected conservation issues, in pointing out that "... The conversion of wetland areas into agriculturally productive land use has now gone so far ... that only remnants of natural wetlands are left ..." The Working Party asserted that "... wetlands are rich as resources for recreation, scientific research, and a healthy balance of water level and their conservation is a moral, aesthetic, scientific and economic necessity"[3]. Despite these imperatives, an area of 10,700 hectares at Kopuatai in the Thames Valley, the largest remaining peat dome in New Zealand, has been proposed for preservation since 1966, yet no commitment to its preservation has been made[20]. In contrast with native forests, wetlands excite surprisingly little public enthusiasm, apart from some interest in waterfowl management for recreational hunting.

The Wildlife Service, the government agency responsible for wildlife protection and management, has no easy task in attempting to prevent development of the remaining wetlands, despite support from acclimatisation societies, since agricultural exports remain the key to New Zealand's ultimate economic recovery. The Department of Lands and Survey has the mandate on wetlands protection under the Reserves Act, but must balance this with its other responsibilities under the Land Act.

In the Report of the Commission of Inquiry into the Organisation of Wildlife Management and Research in New Zealand, two years before the Physical Environment Conference, two pertinent questions were posed:

(a) In deference to the unity of nature through the interaction of wildlife species and their environment, should both animals and habitat be controlled by a common agency?

(b) Is this proposition of practical value, considering the delegation of jurisdiction over different habitat types?

The Commission considered that, as an agency for wildlife control, the Department of Lands and Survey suffered from two major disabilities: conflict of interest (through land development activities) and a traditional reliance on other agencies for scientific research. Nevertheless, it was the final recommendation of the Inquiry "That the National Wildlife Service be a separate division of the Department of Lands and Survey supported by all the Department's resources"[21]. This recommendation has not been adopted, although the Department has now employed its own scientific advisory officers and is recognised as a science budget department.

"The Wildlife Service, the government agency responsible for wildlife protection and management, has no easy task in attempting to prevent development of the remaining wetlands, despite support from acclimatisation societies, since agricultural exports remain the key to New Zealand's ultimate economic recovery. The Department of Lands and Survey has the mandate on wetlands protection under the Reserves Act, but must balance this with its other responsibilities under the Land Act."

In a nation where areas such as the Kopuatai peat bog form a unique, untapped, recreational resource and a threatened scientific and biological asset, one question remains: Who will speak unequivocally for the disappearing wetlands of New Zealand? Although, in 1975, the New Zealand Government ratified the Convention on Wetlands of International Importance and appointed the Department of Lands and Survey as the body responsible for nominating areas for designation, only two coastal areas have been pledged so far[4]. The establishment of a representative sample of all wetland types in New Zealand is hampered by the loss of wetlands and the continuing competition for their drainage or pollution to facilitate economic development. The prospect of this country making a major international contribution seems slight.

Scientific areas

In contrast to the situation for individual species of fauna, the Working Party commented that "... there does not seem to be any comparable or adequate machinery for protecting individual plant species or, more importantly, non-forest plant associations."

By 1972 it had become evident to the DSIR that a documentation scheme would be necessary for the conservation of rare or endangered plants, and as a consequence, a "Threatened Plants of New Zealand" register was established in 1976, although there has been no further legislative action. Preservation of complete ecosystems, special geological features and of each of the major soil types was also considered to require attention[3].

The Working Party recommended that the appropriate divisions of the DSIR, in collaboration with the Royal Society, should review the adequacy of existing scientific reserves, and, where necessary, instigate the establishment of others. This has been done to some extent in association with forestry development. Where DSIR officers have identified areas that should be given protected status, a high degree of co-operation has been achieved between the Department of Lands and Survey, the New Zealand Forest Service and the Ministry of Energy (P. A. Atkinson pers. comm).

Historic and archaeological sites

The Working Party, in drawing a comparison between the preservation of New Zealand's historic and archaeological sites and the conservation of its natural heritage, identified the most urgent needs. The New Zealand Historic Places Trust has been working under its own Act, and in conjunction with the Department of Lands and Survey, in such assessments, and a joint review of historic reserves, already under way at the time of the Physical Environment Conference, is now nearing completion.

The Department of Lands and Survey intends to prepare a long-range plan to ensure representativeness of historic reserves and an appropriate balance, both geographically and in the subjects to be covered[15].

Coastal waters and the sea bed

The Working Party extended the boundaries of its concern in order to draw attention to the need for conservation of marine resources through the application of the principles outlined for land use[3]. This need has been recognised by the provision for Maritime Planning in Part V, Town and Country Planning Act 1977.

The Marine Reserves Act, in force since 1971 and administered by the Ministry of Agriculture and Fisheries, is analogous in aim and function to the Reserves Act 1977, for the management of terrestrial scientific reserves. The authority of this Act for the establishment of marine reserves has been exercised in only one instance. Public demand has failed to motivate administrators and politicians, since those conservation groups interested in the marine environment have been more concerned about activities such as international whaling and the slaughter of fur seals in the Northern Hemisphere. However, there is a definite need for an effective system of marine parks and reserves to complement that existing on the land.

Conclusions

In his closing address to the Physical Environment Conference, the Hon P. B. Allen expressed the hope that the Conference would be seen as a milestone in the field of land resource management during the following decade, and that the accumulation of small but significant changes would be more effective than large scale reorganisation. Despite problems inherent in the policy-making process, he felt that the Conference had given much-needed impetus to many areas of environmental protection and enhancement.

With respect to the coming decade, it is obvious that financial priorities set in 1970 must be reappraised, since they will no longer be recognised by the Government as valid under such drastically changed circumstances as the five-fold increase in oil prices between 1973–78, as well as the rising costs of imports generally. If, in the public mind, those priorities remain the same, they must be re-stated with equal conviction, perhaps through a "Physical Environment Conference 1980". There is much to be learnt from overseas experience; for example, at the 1977 Congress of the National Recreation and Parks Association of the USA, the following policies were adopted:

(a) To emphasize human development, human dignity, social action and community cohesion in recreation and park management.
(b) To promote social planning which will encourage identification of needs, coordination and mobilisation of public and private resources, integration of services, and meaningful citizen participation.
(c) To give increased priority to social planning in the selection of services and resources.
(d) To promote environmental beautification, preservation, open-space planning, and concern for all aspects of a community's living environment.
(e) To reassess the energy and environmental costs of established park and recreation areas.
(f) To encourage all public land-managing agencies to review their land-use policies relative to energy-consuming and/or environmentally detrimental forms of recreational use.
(g) To encourage the use of public transport to and within national parks, recreation and wildlife areas.
(h) To lessen the possibility of further deterioration in the position of disadvantaged members of society, should future energy cost increases affect recreation availability[22].

One further principle of concern remains as valid as when it was stated in these terms by the Working Party on Land Resources and Land use in concluding its report: "The integrity and usefulness of our national parks and reserves of all kinds will depend on the quality of the environment which surrounds them. It is patently absurd to have islands of nature ringed by a visually polluted landscape. Nor can these areas retain their natural worth and significance if air and water are polluted."

Although there has been much to learn from the Physical Environment Conference 1970, the 1980s will present a new set of circumstances accompanied by a different level of problems. To deal with these, it will be vital for the community opinion to find full expression.

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The Laughing Owl
(Sceloglaux albifacies)

M. H. Douglas

"If its cry resembles laughter at all, it is the uncontrollable outburst, the convulsive shout of insanity; we have never been able to trace the faintest approach to mirthful sound in the unearthly yells of this once mysterious night bird – mysterious, because for years unsuccessful attempts had been made to secure a specimen of this dismal visitor, whose fitful presence at eventide was scarcely observed before its form was lost to view in the deepening gloom of approaching night." (Potts 1870).

Thus did Potts (1870) describe the call of the laughing owl, (Sceloglaux albifacies). Found only in New Zealand, it has not been positively identified alive since 1916.

Because there is a slim chance that the species still survives, Mr Douglas, in this review, seeks to spur an interest among those who frequent remote areas of New Zealand where, perhaps, any surviving owls may be located. Although laughing owls have been recorded in the North Island, most of the information in this paper pertains only to the South Island.

Introduction

The laughing owl, laughing jackass, ground or rock owl as it was known by the early European settlers – the whekau, ruruwhekau, hakoke or kakaha to the Maoris – was endemic to New Zealand's 'open' country, while the more common morepork or ruru (*Ninox novaeseelandiae*) inhabited the forests. The laughing owl was never common. In 1892, Buller wrote "this fine owl is now on the verge of extinction" (Buller 1892). Many birds became extinct as European civilisations developed new countries. One commentator referred specifically to a laughing owl which met its end in a more direct way. "We saw a fine bird which had been caught on the preceding night by a bushman on the Upper Rangitata flat; the intelligent captor signalized his good fortune by chopping off the head of this victim with the ever-ready axe. The look of satisfied triumph as the bird was pointed at we never saw equalled, except perhaps on one occasion, when a friend, fresh from town, entered the house with the mangled remains of a tame kaka, which he had blown almost to pieces in a kowhai tree, from whence poor Bess had unfortunately studied the stranger's face too closely." (Potts 1870).

Description

The laughing owl, about 38cm (15″) in length, is considerably larger than the morepork, which measures about 29cm (11½″) (Falla *et al* 1979). The size difference is illustrated in Figure 1.

The plumage of the laughing owl is a yellowish brown, striped with brown and, in many instances, the facial disc is white; the wings and tail are brown with brownish white bars. Although the plumage is yellower and more clearly streaked and mottled on the back than that of the morepork (Figure 2), and the laughing owl is much larger, the two species can be confused. The underparts and head of the laughing owl are less streaked and mottled, and its tail is noticeably shorter in proportion to its overall length (Williams and Harrison 1972). The iris of the laughing owl is a dark reddish brown while that of the morepork is a golden yellow (Falla *et al* 1979).

Habitat

Smith (1884), who studied these birds in the limestone cliffs at Albury, South Canterbury, wrote "the species lives in the fissures of high rocks, where perhaps field naturalists would not risk life or limb in securing specimens. Be this as it may, the fissures of high rocks form the stronghold of the *Sceloglaux* where it lives during the day, and where in the months of October and November it rears its young." Williams and Harrison noted that the species was generally found in and around rocky areas, either in open country or at the margins of scrub or forest. Although it apparently hunted for its food over open ground, perhaps spending an appreciable amount of time on the ground itself, it roosted and nested in rock fissures. Haast's dog captured one amongst the rocky precipices in a creek near the Lindis Pass (Potts 1870). In North Canterbury, Hope (1927) considered their favourite resorts to be high limestone ridges in the open country, where crevices and caves in the limestone rock afforded shelter.

Elsdon Best recorded that, according to the Maori, the birds lived in holes in cliffs of the higher ranges. He noted that in the 1890s some of the older members of the Tuhoe tribe could point out certain 'pari hakoke' (laughing owl cliffs) formerly frequented by these rock owls. Best had also heard precipitous places described as being 'Me te pari hakoke' – like a laughing owl cliff (Best 1942). Thomson (1927) noted their occurrence in the rocky bush-covered ground on the harbourside of Signal Hill, Dunedin.

Population Incidence

Williams and Harrison noted that, for the 40 dated laughing owl records, 40 percent refer to the period 1843–75, 25 percent to the period 1876–1900, 22 percent to 1901–1925, and 13 percent to 1925–1960. In the South Island, reports of laughing owls diminished in number after 1880 and the rapid decline of the species seems to have generally occurred during the last quarter of the nineteenth century. Significantly, this period also saw the rapid population decline of many other endemic bird species on the mainland such as the Saddleback (*Philesturnus curunculatus*), New Zealand Thrush (*Turnagra capensis*), Huia (*Heteralocha acutirostris*) or Kakapo (*Strigops habroptilus*) (Myers 1923; Williams 1973).

Bone remains, found in caves, in Maori cooking middens, or on former Maori camp sites, are evidence of the owls' presence on the eastern seaboard of the South Island and on Stewart Island. The midden remains suggest the capture by Maoris for food. Beattie further supported this contention by relating a story about a Maori friend who went to the upper Clutha River gold diggings in 1862. His friend commented "When in the Moonlight Gully my dog caught some big moreporks in the rocks there, and we called the place 'Kohaka-ruru' (nest of moreporks). These birds were not the small bush owls known as ruru but the bigger open country ones known as ruru-whenua. They were big and fat, and when cooked the whole party ate them, and they tasted so good that even the white men smacked their lips over them". Beattie indicated that, before this report, he had never heard of Maoris eating owls. It was generally believed that they regarded owls with a good deal of awe (Beattie 1920).

The South Island distribution, obtained from data presented by Williams and Harrison, Beattie (1920), Buller (1873) and Thomson (1927), and detailed in Figure 3, shows the location of birds captured or killed, collected eggs or eggshells, and sight and call records. These recorded locations, are only approximate. As stated, the roosting and nesting sites were among rocks or in cliff crevices, and in any locality, these would be sites favoured by the owls.

Laughing owls appear to have been fairly common in some areas. Once Smith had perfected a technique, he captured five owls in the Albury area. There are a number of reports from the Dunedin-Waitati-Waikouaiti area, and Thomson reported that the last of the species he had heard or seen was a pair

Figure 1. A front view of the laughing owl (right) and morepork, showing the more pronounced mottling on the morepork and the facial disc of the laughing owl. (Photo: I. E. Whitehouse.)

Figure 2. Differences in size and plumage between the laughing owl (left) and morepork are well illustrated in the photograph. (Photo: I. E. Whitehouse.)

in his Dunedin garden in 1903. Further details and source references about laughing owl distribution are available in the review paper by Williams and Harrison.

Loss to collections

It is difficult to ascertain the number of laughing owls, dead or alive, which were sent to world collectors and the areas from which these specimens were collected. The New Zealand examples are noted in the distribution list in the review by Williams and Harrison. Buller (1898), for instance, comments on New Zealand bird skins at the Liverpool museum which had been collected by a Captain Stanley about 1845, and included some half dozen *Sceloglaux albifacies* skins. Buller also saw a live specimen at Norfolk, and, according to Williams and Harrison, at least five birds survived the journey to Europe last century.

Breeding and nesting behaviour

In their general survey of the species, Williams and Harrison comment that nests were made under boulders or in fissures among rocks, and consisted of dry grass on bare ground. In the Mackenzie Country, Enys found a nest under the shelter of a boulder (Buller 1875). Breeding began in September-October, with the average clutch consisting of two eggs and the young were reared in October–November. It is of conservational interest that Smith was able to breed birds in captivity (Buller 1883).

Food

Owls regurgitate pellets of undigested food, and thus, some information about the diet of laughing owls is known. When examining a "conglomerate of exuviae", Smith found the older owl casts to be composed entirely of light brown hair, from, he suggests, the Polynesian rat (*Rattus exulans*), as well as small bones. The more recent casts were composed mainly of beetle parts. Although laughing owls were known to subsist on rats, mice and lizards, Smith concluded that, by

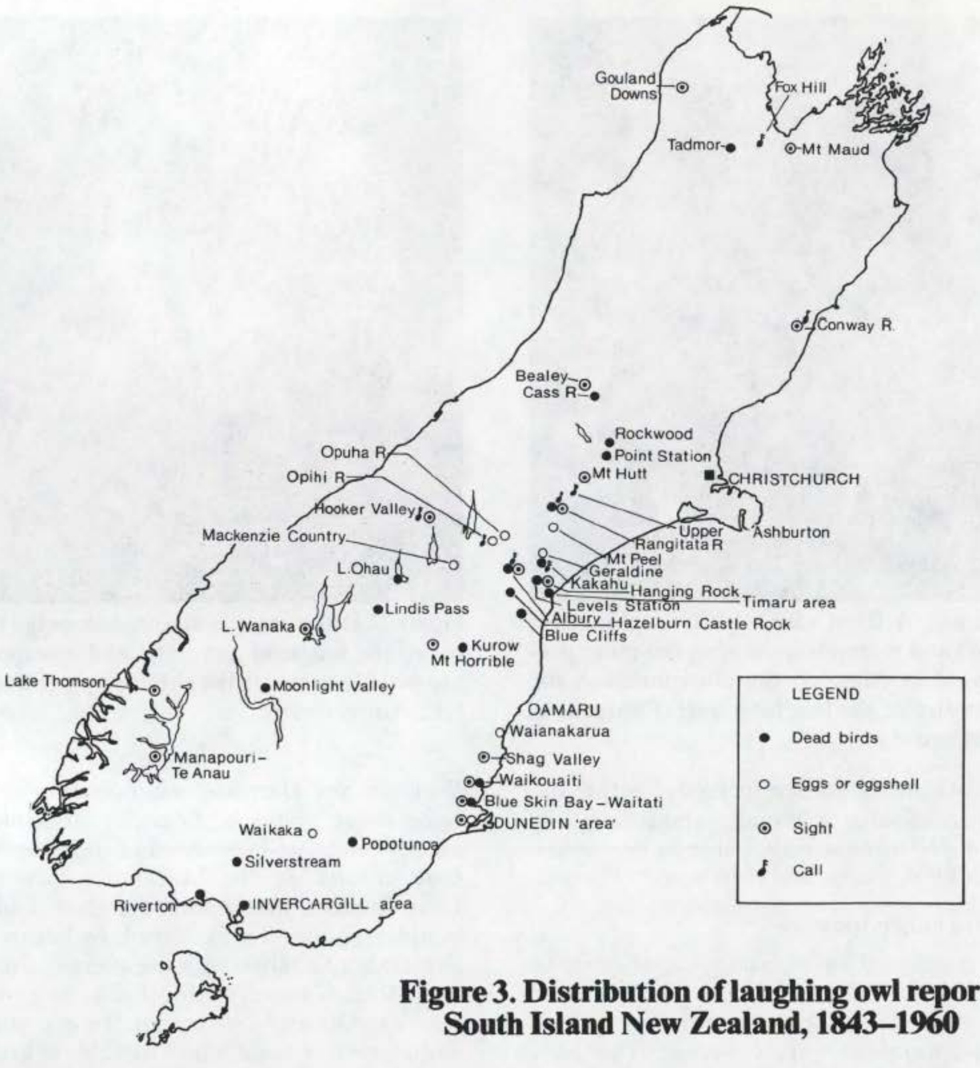
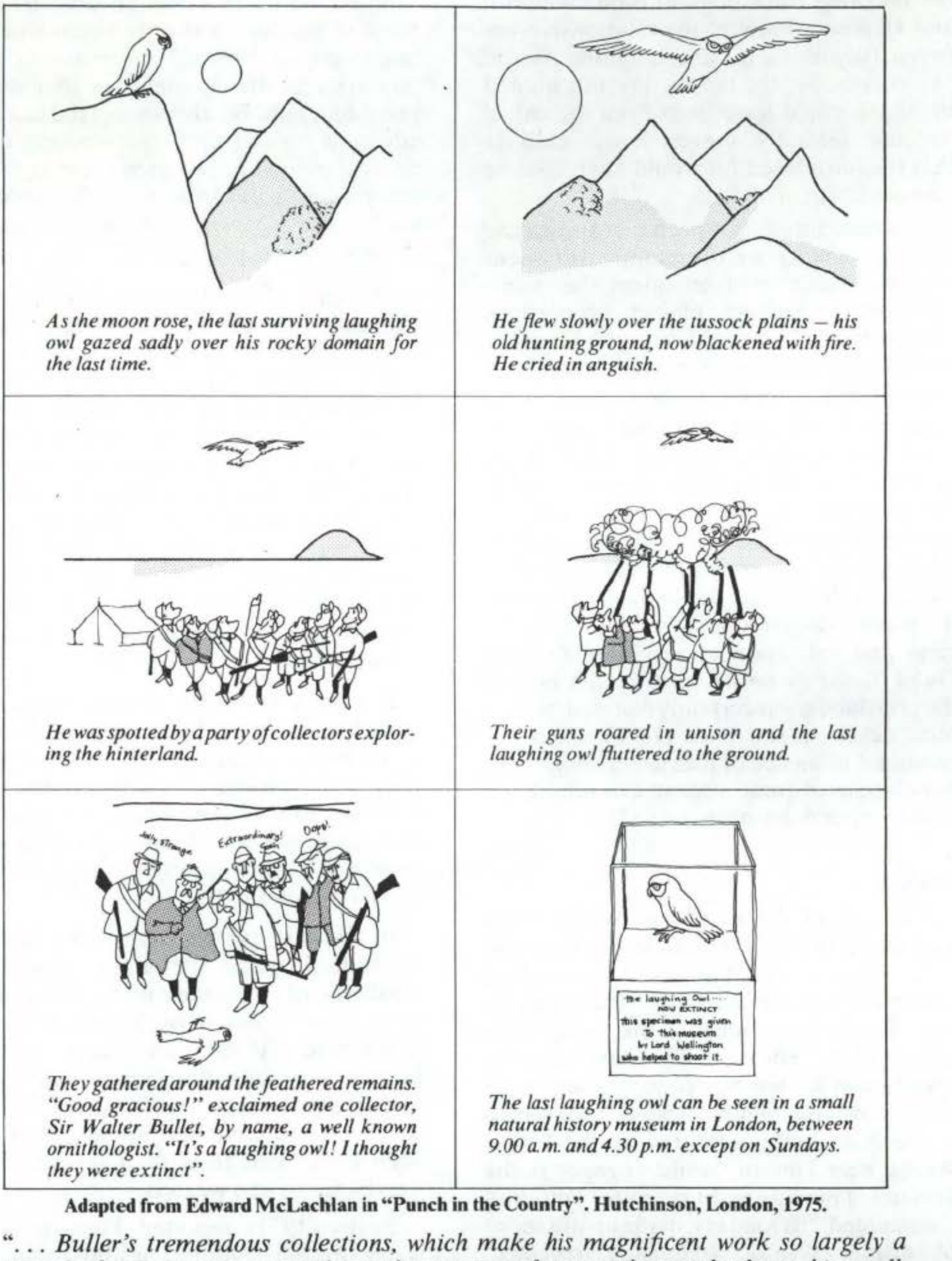


Figure 3. Distribution of laughing owl reports South Island New Zealand, 1843–1960

the 1880s, their principal food was beetles. Having found the remains of 'nearly a dozen' birds which had died in the rocks, Smith hypothesised that, as a result of changed environmental conditions, a food supply of beetles was inadequate to support this large bird, and commented that 'we need no longer wonder at the rapid decline of this splendid owl' (Smith 1884).

It was also Buller's opinion that the disappearance of the owl was related to that of the Polynesian rat, which had given way before the other two introduced species *R. rattus* and *R. norvegicus*. Hutton took Buller to task on this relationship, and pointed out there was no evidence to suggest that an indigenous rat ever existed in New Zealand, or that laughing owls were formerly more plentiful (Buller 1873). Buller replied that the Maori evidence considered that laughing owls had formerly been more abundant.

Today, it is accepted that the Polynesian rat was a recent introduction to New Zealand, and was certainly only present since Maori occupation (Gibb and Flux 1973). As Myers relates, this rat could not have been



Adapted from Edward McLachlan in "Punch in the Country". Hutchinson, London, 1975.

"*. . . Buller's tremendous collections, which make his magnificent work so largely a record of massacre, were made, in the opinion of one, at least, who knew him well, under the firm conviction that the birds of New Zealand were already doomed, and that it therefore behoved every ornithologist to obtain for posterity as complete a collection as possible while there was yet time.*" (Myers; J. G., 1922. Our Native Birds. *The Forest Magazine – New Zealand Out-of-doors 1:* 116).

the laughing owl's original food. Williams and Harrison discount the relationship between Polynesian rat and laughing owl on two counts. Firstly, the dietary fur, quoted by Smith, could have been from the native bat and, secondly, suggest it was unlikely that the introduced rat would have become an essential item of diet.

The introduced European rats and mouse (*Mus musculus*) were certainly prevalent from the beginning of settlement, their numbers often reaching plague proportions (Wodzicki 1950). It could be argued that the rodent portion of laughing owl diet had been improved by European settlement.

As Williams and Harrison suggest, if *Sceloglaux* was primarily a ground feeder in open country, the consequences of burning and grazing would have been a serious threat to the feeding range. Undoubtedly, pastoral development using fire and creating habitat alteration decimated the endemic fauna of the grasslands and scrublands. The rapid decline and extinction of the New Zealand Quail (*Coturnix novae zelandiae*), a bird of the grasslands, was certainly fostered by pastoral development. Potts (1870) noted the profound influence of fire, when comparing populations of quail, after an extensive burn in the Upper Ashburton in 1857.

Calls

The call of the laughing owl has been noted frequently by numerous observers. In 1861, Haast was kept awake when camping under Mt Potts on the Upper Rangitata by the 'shrieking clamour' of the flying birds (Potts 1870). Potts (1882) noted that the species was known by upcountry settlers as the big owl or laughing jackass, and records a specimen being procured at the Levels station near Timaru "whilst engaged in the very act of making night hideous." Potts also commented, "its loud cry, made up of a series of dismal shrieks, frequently repeated, waking the tired sleeper with almost a shudder, at once distinguishes the 'Laughing Jackass' as one of the peculiarities of the mountain districts" (Potts 1870).

Smith noted that the uncontrolled outburst of laughter was only heard when the birds were on the wing and generally either on dark and drizzly nights or immediately preceding rain. He also wrote "the call of the adults in waking up in the evening is precisely the same as two men cooeing to each other from a distance, with the male it is louder and hoarser, with the female it is shriller and less prolonged."

The call of the laughing owl has been likened to the call of a number of petrels. Potts considered the call of Cooks petrel (*Pterodroma cooki*) to be a mild version of that of the laughing owl, and was wanting in "the intensity of the dreadful doleful shrieks to which the owl gives utterance" (Potts 1870). Black, who knew the bird well in South Canterbury, stated that the cry was a prolonged cack-cack-cack, which could be heard incessantly on rainy nights, and was similar to but slower and more gutteral than the call of the mottled petrel (*P. inexpectata*) (Williams and Harrison 1972).

In 1899, Charles Douglas recorded that a 'weird skirrling cry" can often be heard at night in the mountains of Otago, Canterbury, and Westland. The diggers used to call it the laughing jackass, from its mocking cry, and many pounds of shot were fired to the skies in the vain hope of bringing something down (Pascoe 1957).

In the past, petrels were also a common 'night bird', when after a day at sea, they would fly inland to their nests. These migrations were reported by Stead (1927) and Studholme (1940). The calls certainly impressed young Studholme, who wrote "those shrieks gave me the creeps". Both writers considered that these petrels had been eliminated from their inland nesting sites by stoats and weasels.

Evans (1973) reported Huttons Shearwater (*Puffinus huttoni*) nesting in the tussock grasslands of the seaward Kaikoura ranges, and thus supported the contention that unusual bird calls in the mountains could still be nesting sea birds.

Figure 5. Cliff faces near the upper Sterndale Valley road, near Albury, South Canterbury, would be typical of laughing owl habitat.

Apart from the problems of misidentification, Williams and Harrison currently believe that petrel-like calls heard after dark in areas of suitable habitat are the best indication of the possible presence of laughing owls.

Discussion

Is the laughing owl extinct?

Myers, writing in 1923, said "there seems no valid reason why the laughing owl should not exist and continue to maintain itself in spite of Buller's opinion (1905) that it was on the verge of extinction." Myers also considered that the rugged haunts and nocturnal habits of the laughing owl would help it to escape observation. However, his comments should, perhaps, be modified by considering the disappearance of the laughing owl from the Urewera country in the North Island, since its 'fairly plentiful' occurrence in 1855, and its extinction prior to the introduction of weasels (Myers 1923). In his discussion of New Zealand bird populations, Williams observed that many species were declining in numbers prior to mustelid introduction.

It is worth noting that other New Zealand raptors, the harrier hawk (*Circus approximans*), the falcon (*Falco novae seelandiae*) and the morepork have all survived the changed environmental conditions resulting from European settlement. There is some concern about the stability of falcon populations, but this is probably a matter of educating target shooters rather than a question of habitat alteration.

Williams and Harrison, in their survey of a near extinct species, considered the most likely site for a surviving population to be Stewart Island, 'as that island's avifauna has suffered proportionately less change than the North or South Islands.' The recent 'rediscovery' of Kakapo (*Strigops habroptilus*) on Stewart Island is significant because it indicates that much of New Zealand is unexplored because of its inaccessibility. Similarly, the rediscovery of the Chatham

"This bird, on being taken from its cage to be photographed by Mr Henry Wright, manifested so persistent a desire to get away from the light, and to hide itself in the shade of the ferns among which I had placed it, that it was very difficult to obtain a momentary shot in focus, although in the end the result was a highly satisfactory one. During the day it had a listless, dazed look, and generally kept its eyes partly closed. The only occasion on which I saw it awake from this lethargy was when I brought a live Hawk (Circus gouldi) near to the wire-netting of its enclosure. It did not then manifest any excitement or alarm, but slowly raised itself up to its full height two or three times in succession, with the feathers of the head puffed out and the eyes open to their full extent, as if in silent wonderment at so strange an apparition." (Buller; W. L., 1905. The Birds of New Zealand. 2: 63.)

The bird referred to above is thought to be the same as in this photograph from the Wright Collection, Alexander Turnbull Library, Wellington.

Island Taiko (*Pterodroma magentae*) reveals the difficulty of finding a bird whose activities are nocturnal and surreptitious.

An observer was adamant that he had seen and heard laughing owls during the 1950s and early 1960s at Waianakarua. Egg fragments found there, which were identified by Kikkawa (in Williams and Harrison 1972), certainly lent further support to this possibility. Other observers considered the calls to have been those of petrels. In the 1960s, a school boy claimed to have seen a laughing owl in broad daylight on Banks Peninsula, and strange bird calls were heard in the same vicinity at night (Scarlett pers. comm.). Occasionally, an Australian barn owl arrives in New Zealand, and, because of its size and scarcity in this country, could, at least by the inexperienced ornithologist, be easily mistaken for a laughing owl (Tunnicliffe pers. comm.).

A hunting friend of the author's photographed Kakapo on Stewart Island in the early 1960s, yet he did not realise that he had done so until this species was rediscovered recently. Are there similar incidents which relate to laughing owls? Not all birds have the easily identifiable 'white face' and a laughing owl could be mistaken for a morepork if no comparison of size can be made.

If you have heard unusual bird cries, particularly inland, or have seen a large owl, the author would be interested to hear from you. A further plea must be made on behalf of museum staff – egg shells and feathers are a ready aid to positive bird identification. There is hope, albeit remote, that the laughing owl can be relocated, and perhaps maintained to continue the Sceloglaux lineage, the only member of that genus in the world.

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Sheep farming in early New Zealand

Late in 1855, J. B. A. Acland and C. G. T. Tripp journeyed up the Rangitata Valley and were the first white men to set foot on the Mount Peel country. In May 1856 they started their own station at Mount Peel and during the next three or four years increased their holding to about 250,000 acres, including Mount Peel, Mount Somers, Mount Possession and Orari Gorge.

According to an article in "The Press", Christchurch July 5 1930, they were "the first people in Canterbury who conceived the idea that the hill country overlooking the plains could be successfully stocked with sheep".

The article acclaims Acland and Tripp as "two of the best employers Canterbury ever knew. Coming from traditional land-owning families in the West of England, they understood the duty and the policy of encouraging their employees to settle down and bring up their families on the property. They therefore showed them every consideration, building comfortable cottages for the men and encouraging them to deal in stock on their own account and to become land owners . . . In 1862 Acland and Tripp dissolved their partnership, Acland taking the Mount Peel property of 100,000 acres."

In 1858 J. B. A. Acland wrote an account of high country farming, part of which is reprinted here by courtesy of his grandson, Sir John Acland. The full account was published in the Bath and West of England Agricultural Journal, volume VI, 1858.

Missionaries went to New Zealand in 1814, but no systematic colonizing commenced till 1839. Meantime the Australian settlers had discovered that sheepfarming was a profitable speculation, and within the last thirty years the amount of wool sent from the Australasian colonies has increased to an enormous extent. In 1828 the total weight of wool imported into England was 30,235,915 lbs, of which about 22,000,000 lbs came from Germany, and from Australia and Van Diemen's Land only 1,574,186 lbs. In 1856, the total import of wool was 116,211,392 lbs., of which 52,052,139 came from the Australasian colonies, and in 1857 the quantity imported was 127,390,885 lbs. At the same time the import of German wool has decreased to about 10,000,000 lbs.

The population of Australia is now about one million. The systematic colonization of New Zealand commenced in 1839 – less than twenty years ago. The settlers for the first ten years had very great difficulties to contend with; but the Anglo-Saxon race is not easily discouraged, and the difficulties have been in a great measure overcome. Many settlers, attracted by what they heard of the capabilities of the country, went over from Australia, many belonging to the upper classes went out from England, and the white population now numbers about fifty thousand souls. There is a great difference in the character of the two principal islands included in the colony of New Zealand. Taken together, they are rather larger than Great Britain and Ireland, containing nearly eighty millions of acres, and extending over fourteen degrees of latitude – viz., from 34° to 48° south.

These two islands are termed the Northern Island and the Middle Island – there being a smaller island to the south. The Northern Island, with the exception of part of the province of Wellington, is not adapted for sheep-farming. There are about seventy thousand of the Maoris, or aboriginal natives, dispersed over it, and large tracts of country are so entirely covered with dense forest as to preclude the possiblity of any sort of agriculture until the ground has been cleared, which is to be done only at a great expense. The Middle Island is very different; the entire number of natives is under two thousand. The forests are nowhere so extensive as to interfere with sheep-farming. In some parts timber is so scarce that the settlers have to go a distance of ten, or even twenty, miles to fetch their firewood, wood being the universal fuel of the country. Coal is found in many places, but of an inferior description.

Canterbury

There is probably no one part of New Zealand – or, perhaps, of Australia – so admirably adapted, in its wild and uncultivated state, for pastoral purposes as the eastern part of the province of Canterbury, which province occupies the middle portion of the Middle Island. The great extent of well-watered plains; the low hills between the plains and the snowy mountains; the stony ground preventing footrot; the absence of forest; the freedom from the dingo, or indigenous wild dog of Australia – all mark this province out as pre-eminently a pastoral district, until the time shall come when the settled and cultivated districts have so far expanded that agriculture will take the place of sheepfarming.

With the exception of Banks Peninsula – a mass of hills, of volcanic origin, and varying from one thousand to three thousand feet in height – the entire line of coast bounding the plains is one uninterrupted, low, sandy, or shingle beach. The plains appear, at first sight, perfectly flat; but there is in fact a gradual rise of about twelve feet in a mile from the sea towards the mountains. These mountains rise to a height of from five thousand to eight thousand feet, and their summits are covered the greater part of the year with snow. Between the plains and mountains are a considerable number of comparatively low hills, rising from five hundred to fifteen hundred feet above the plains. These low hills, as well as the greater part of the plains, are well adapted for feeding sheep, while the parts of the plains near the sea are swampy, and at present only fit for cattle; but being easily drained, and consisting of a fine alluvial soil, will utimately prove to be the best agricultural land. The plains are divided, as it were, into sections by rivers, of which there are three large, six smaller, and many others, comparatively insignificant. The three largest – named the Waimakariri Rakaia, and Rangitata – take their rise a long way back in the snowy mountains (indeed, the source is not known of any one of them), flow through narrow valleys and precipitous gorges, and cut right through the ranges nearest the plains. They are sometimes impassable for weeks together: this occurs in the early part of summer, when the snow is melted, either by thunderstorms in the hills, or by a hot wind, termed by the settlers a nor'wester. The six smaller rivers are seldom affected by snow, but rise rapidly with rain and are sometimes impassable for a day, but seldom more. The writer has seen a horse swimming in one of them after eighteen hours rain, whereas, the day before, the water would probably have been but little above his knees. These rivers are a great drawback to the country, being far too rapid to admit of navigation, too broad to admit of bridges being thrown over them, except at an enormous expense, one having a shingle bed a mile wide, which in a high flood is entirely covered, and from the shifting nature of the shingle it is difficult to establish a permanent ford or ferry.

Climate

Still, the rivers have their advantages. New Zealand is always a well-watered country, instead of being subject, like Australia, to be parched up with drought; and for the sheep-farmer they form admirable boundaries. The climate (I speak of Canterbury in particular) is splendid, and generally suited to the constitution of Englishmen. There are, perhaps, within certain limits, greater more sudden changes of temperature than in England; but on the whole, it is far more temperate, seldom oppressively hot in summer, while in winter, except on the hills, frost and snow are almost unknown. There is less rain than in England, the average number of wet days in the year having been estimated by some persons as low as a hundred, by others as high as a hundred and thirty. In London the number is about a hundred and sixty.

The above remark on the general aspect of the country will show that it is well suited for sheep; and the breed which is found to answer by far the best, combining in the most advantageous proportions, weight of carcase, weight of fleece, and value of wool per pound, is the German or Spanish merino. It has been said by F. A. Weld, Esq., an eminent New Zealand sheep-farmer, that "as a general rule the heavier breeds of sheep formed for a life of luxury and ease, are as much out of their element on our New Zealand uplands as an alderman of London would be had he daily, gun in hand, to seek his sustenance in our tangled forests." I do not know about the sheep, but I think that the health of the alderman might possibly be improved by the process.

Merinos

The merinos were taken out, in the first place, from Spain and Germany, to Australia and Van Diemen's Land, whence they have been introduced into New Zealand, and some gentlemen have gone to great expense in procuring pure merino rams from Germany, for the sake of improving their flocks by introducing fresh blood. The merino in New Zealand attains an average weight of from fourteen to sixteen pounds per quarter; but generally the weight of the carcase is a secondary consideration with the sheep-farmer, except in so far as a small animal cannot carry a large fleece, for the chief profit lies in the wool. In New South Wales the wool is of a somewhat finer quality than in New Zealand, but the fleece seldom weighs more than from two pounds and a quarter to two pounds and a half, while in New Zealand a good flock should always average from three pounds and a half to four pounds, and often more. One gentlemen, with a flock of nearly five thousand sheep, told me, in 1856, that his preceding clip had averaged four pounds and a quarter all round, though many lambs had been shorn.

I cannot, by taking the average of past years, give a fair estimate of the value of New Zealand wool, because, for reasons to be presently stated, it is steadily rising in price: still the price may be said generally to be from 1s 6d to 2s. per pound in England. Last August some scoured New Zealand wool was sold at the high price of 2s. 9d. and some wool (clean but not scoured) belonging to the writer realized 2s. 0½d. Wool was then unusually high; it has now fallen; but the price current for March, 1858, quotes 'New Zealand scoured.' 1s. 11d. to 2s. 9d., and 'average to good,' 1s. 6 to 2s.0½d. The highest price quoted for Australian scoured is 2s 11½d.; a slight calculation will show that the increase of weight in the New Zealand fleece more than compensates for the greater value per pound of the Australian. For some time the New Zealand wool was sent to this country very badly got up, partly from carelessness, partly from the inexperience of the sheep-farmers, who were, in fact, only learning their business, and partly from want of labour.

Many of the sheep-farmers knew little about sheep; and cared less, and thought that, so long as the animal had four legs and carried a certain amount of wool on his back, all was right. The consequence, of course, was, that many had inferior and mixed flocks: now, however, they are becoming more experienced, and pay more attention both to the quality of their sheep and the getting up of the wool, which is also becoming more known in the London market, and valued as a fine combing-wool.

Acquiring a run

Before speaking of the general management of sheep, it will be as well to mention the way in which a sheep-farmer settles himself on his sheep-walk, or 'run' as it is called, and also to state the terms on which he holds it. A man with good practical and sound common sense, who makes it a rule to profit by every mistake – i.e. never to do the like again – may do very well without having had any previous agricultural knowledge. Amongst our Canterbury sheep-farmers I can reckon clergymen, barristers, doctors, officers of the Austrian as well as the English army, sailors, both royal navy and merchant service, besides farmers by education and country gentlemen. The best course for a man to adopt who intends sheep-farming is to reside six or twelve months at a sheep-station, where he will learn his business, and probably gain some experience without paying too dearly for it. He must then explore unknown or unoccupied country, until he finds a tract suitable for his purpose. He then goes to the land-office of the province, describes the natural boundaries, the estimated extent of country, and the number of sheep he intends to place on it.

The extent of run granted is regulated by the number of sheep. Sir G. Grey, when Governor of New Zealand, adopted a sort of sliding-scale, taking into consideration the quality of the pasture. If a man started with five hundred sheep, he was allowed pasturage sufficient for five thousand; if he had one thousand, pasturage was given him for seven thousand five hundred; if he had two thousand, he was allowed pasturage for eleven thousand five hundred, and so on, the addition decreasing, to prevent monopoly, but at the same time allowing a reasonable increase for the sheep-farmer's flocks, as the number he starts with – say a thousand breeding ewes – will not pay expenses till the end of his third year, when his flock should consist of three thousand to four thousand sheep and lambs.

In the Canterbury province the system is altered; the sheep-farmer is allowed twenty acres for every sheep, whatever number he begins with; this allows for a fivefold or sevenfold increase, according to the quality of the pasture. The sheep-farmer receives a licence to occupy for fourteen years; this licence he forfeits if he does not stock his run within twelve months; he also has to vacate if the fee simple of the land is bought by a land-purchaser, although he is allowed a certain pre-emptive right over parts of his run; the rent however is almost nominal – one farthing per acre per annum for the first two years, one halfpenny per acre per annum for the next two and three farthings per acre per annum for the remainder of the fourteen years. Sir G. Grey's regulations as to rent were different – rather lower. First, £1 per annum for each thousand sheep that the run was considered capable of carrying, and one penny per annum for every sheep actually on the run. For all purposes of estimating stock, each head of horses or horned cattle is considered equal to six sheep.

Settlement

When the sheep-farmer goes to occupy his run, he must take at least two or three men with him to saw and split timber, put up his house, stock-yard, sheepyard, and woolshed. If he takes his sheep with him, he will want a shepherd as well; the best way is not to take the sheep until the house and sheep-yards are up, which may be done in two months. If shearing-time is coming on, he must also make a place to wash his sheep; he will also wish to enclose a spot of ground for a garden – a few potatoes, at least, are invaluable. If he can also enclose fifty acres as a paddock for his horses he will find it most useful.

As to capital he ought to have not much less than £2000 in order to begin in the most advantageous manner; he will be probably able to buy a thousand ewes with £1000. His dray, team of eight bullocks, tools, household utensils, the first year's stores, and the expense of putting up house, etc will cost over £500; and he ought to have nearly £500 in reserve, to meet wages at the end of the year, and any casual expenses, as the first year's wool will certainly not cover the annual expenses and it is doubtful whether the second year will, but the third year ought to pay well.

Management

The general management of a flock of sheep in New Zealand differs widely from the English system. In the first place, two thousand is considered a fair number for a flock; quite enough, but by no means excessive. The sheep are left as much to themselves as possible, the main business of the shepherd being to keep the flock on their proper feeding ground: he ought to visit the flock every day to see that none are missing, and even with a flock of the size mentioned, he ought to perceive whether this is the case at a glance. The process of counting would be difficult, if not impossible on open ground, unless the shepherd had two or three perfect sheep-dogs – a class of sheepdog not often met with in New Zealand, though sometimes found in the Highlands of Scotland.

The extent of country required by a flock of this size is very considerable. It is generally considered, by those who have had the most experience in the matter, that, on the average, three acres of land in the wild and uncultivated state are required to support one sheep. Now, I do not mean to say that three acres of wild land are always required to keep one sheep throughout the year; I think that often a sheep would do well on far less, and in other cases would starve in the midst of plenty on six acres.

Burning

The case is this: the only way in which a sheep-walk, or 'run' is cultivated, and the pasturage improved, is by putting a lucifer-match under a tuft of grass and setting the whole country in a blaze. About three weeks after this, the grass comes up young and tender, and the sheep delight to feed on it; but after some months it becomes rank, and the sheep will almost starve rather than feed on it. The second year the tufts of grass are full of yellow seed-stems and withered bents, though there are some young and tender grasses and plants growing between, and the third year the grass will burn again. From this it will be evident that though the sheep may require his three acres, he probably will not feed over more than one half in any year, and it is my own belief, that as the runs become fully stocked and more regularly fed over, the land will support a greater number of sheep (perhaps one sheep on two acres), while the grass will seldom, if ever, require burning; at present it is absolutely essential, as, in the first place, the rough grass and some small prickly shrubs can be cleared off and kept down in no other way that will pay for the labour; and second, the character of the grass is wonderfully improved after one or two burnings.

Lambing

The lambing season is of course a most important and anxious time for the sheep-farmer, and, singular as it may appear, the sheep-farmers have not yet been able to decide which is the best season for lambing, and both the spring lambing and autumn lambing have their most strenuous advocates. Some sheep farmers, when commencing with a small flock, which they are anxious to increase as rapidly as possible, turn the rams into the flock, and leave them there, and, in fact, lamb all the year round. No one defends this system, but some have adopted it for the first two years, and obtained a very large increase. Others have, with the same object of rapid increase, put the rams into the flock twice in the year, generally in March and September; this will probably succeed the first year, and a large increase be obtained; but from my own observation I think it likely that after the first or second year only about half the flock would take the ram at each season, and therefore no advantage be gained. Others, with better success, will have three lambings in two years; the first probably in February, the second in October, and the third in June. The last-mentioned month, June, is a bad one, being midwinter, and there is a great danger of bad weather, in which case, as no shelter can be afforded to the flocks, numbers of lambs would die. All these several plans, however, would certainly be given up as soon as the run became fully stocked, as one lambing would be found amply sufficient to maintain the flock in the best condition, and the sheep-farmer has then to choose between autumn and spring. My own opinion is that autumn is the best, for this reason: that although the vegetation is not entirely checked either by heat in summer or cold in winter, yet a very hot summer might make grass very scarce.

In autumn, after the summer heat is passed, there will be plenty of food to enable the ewe to keep up her condition certainly through the greater part of winter. The lamb will be weaned on the fine young spring grass, and will, at shearing time, have a good nine-month's fleece on him. But now I must be careful, for I have heard that one of the great offences of which the New Zealand sheep-farmers are guilty is that of "actually sending home wool shorn from sheep nine months old as 'lambs'." In my ignorance, I supposed all sheep under a twelve month old to be lambs, and should consequently have supposed wool shorn from a sheep nine months old to be lamb's wool. I never had any to send of that description, but if I had, I should have called it lamb's wool.

If the sheep-farmer prefers autumn lambing, he should commence at the beginning of March, and finish before the end of April, "our autumn;" or if he chooses the spring, it should be September and October. The choice of the lambing time may very much depend on the shearing. If the sheep-farmer intends to shear as early as possible – that is, in October or November – there can be no question that autumn is the best time for lambing. If, however, late shearing – January or February – is intended, the lambing then would be better in September, as the lambs by January would be fit to wean; and it is needless to say that young lambs about with the flock in shearing time are a great nuisance.

About a fortnight after the lambing is over the operation of "cutting and tailing" is performed, and then the sheep-farmer takes stock of his lambs.

The merinos are not a rapidly increasing breed of sheep; they seldom have doublets like the Leicesters, and 80 per cent of lambs is considered a very good return; it is in fact, a high average; few would grumble at 70.

Shearing

Next to lambing, shearing is the most important season; it is, in fact, the sheep-farmer's harvest. The number of shearers being limited, the shearing usually goes on from October to March; I should consider the end of November about the best time.

Too little attention is often given to the washing, yet on this the getting up of wool depends. Some persons will content themselves with swimming the sheep through a pool or branch of a river once or twice; others, after throwing the sheep into a pool, and letting them swim for about five minutes, pass them separately before a man who stands in a tub fixed at one end of the pool, examines each sheep separately as it passes, and sees that it is thoroughly clean. A third method is what is termed spout-washing; each sheep, after swimming about, and soaking for five minutes, is brought under a shoot of water falling from a height of about two feet; the sheep is held under this for about half a minute and turned over so as to bring, as nearly as may be, all parts of the fleece under the spout. This method effectually cleans the fleece, but is said by some persons to knock it about too much. By this last method, three men could wash about six hundred sheep in the day; by the second, I know, speaking from experience, that two men and a boy can wash twelve hundred, and look after a flock at the same time. The shearing generally begins about three days after the washing. The shearers get through their work with a rapidity unknown in England. A man would be thought a poor shearer if he could not shear sixty sheep in a day; the usual number would be seventy or eighty, and some men will shear a hundred. The shearers are paid £1 to £1.5s. per hundred, are fed, and generally have an allowance of spirits besides. The fleeces are folded up, not tied, and packed in bales, which weigh from 300 to 380lbs., according to the way in which they are packed.

Scab

There is one other less pleasant operation which sometimes takes place at a sheep-station, which the sheep-farmer would gladly never see or hear of, unless obliged;

I mean dipping for scab. The sheep are singularly free from most of the diseases which affect them both in England and in Australia; catarrh and foot-rot are unknown. The fly never touches the live sheep; and yet the country swarms with blowflies. Scab, however, is very prevalent in some parts of the colony. The provincial council (i.e. the parliament) of the province of Canterbury have passed some very stringent laws on the subject, * not only fining a man for importing or driving scabby sheep, but making the mere possession penal; the owner is allowed six months from the time of the disease breaking out to clean his flock, and at the end of that time, unless the sheep are clean, he is fined 1s. or 5s per head and if one scabby sheep is found, the whole flock are, by law, scabby also.

The consequence of these laws is, that there are not above four or five scabby flocks in the province, and the owners are doing their best to clean them. The apparatus used for dressing is not one of those pretty little machines we see in the show-yard of the Royal Agricultural Society, but a good strong, serviceable trough, about twenty feet long, five feet wide at the top and four and a half deep. Into this the sheep are thrown bodily, allowed to swim about for two or three minutes, and then walk up an inclined plane on to a stage large enough to hold one hundred and fifty sheep, where they stand to let the stuff drain off from them. With a trough like this, and a couple of boilers holding one hundred or two hundred gallons each, going all day, five men would dip three thousand sheep.

Every man who knows anything about sheep has, of course, an infallible recipe for curing scabs; and there are at least a dozen different ones in New Zealand and none of them successful. The usual dipping mixture is compounded of arsenic soda, corrosive sublimate, sulphur, tobacco, spirits of tar, and sulphuric acid. One or more of these drugs, mixed in special proportions, according to the particular infallibility which is to be tried.

The great difficulty of cleaning the sheep consists, I believe, in getting a clean muster; for if one is left behind, the whole flock may be reinfected. The sheep are generally dipped three times at intervals of ten days, and they ought to be put on fresh ground after each dipping.

Sheep are occasionally dipped in tobacco after shearing, to kill the ticks; the tobacco is also said to improve the growth of the wool, acting as a sort of Rowland's Macassar. The tobacco may be grown at the station, it will grow well in most parts of New Zealand, but it is a very exhausting crop, and an old sheep-yard is considered the best place to grow it.

I stated above that the Dingo or indigenous wild dog of Australia is unknown in New Zealand; this is true, but there are a certain number of wild dogs of a mongrel breed, runaways from the native pahs or villages, and sometimes crossed by dogs belonging to the settlers. These dogs occasionally come and do serious damage among the flocks; then, of course, the settler must be on the look-out, watch the flock by night, gun in hand, or else set baits poisoned with strychnia. This latter plan is inconvenient, because you cannot use your own sheep-dogs on the poisoned country. These dogs are very seldom met with, and soon destroyed by the settlers.

Statistics

I will now mention some statistics connected with the Canterbury province, first requesting my readers to remember that the settlement was founded in the year 1850, and that the first body of colonists landed in December of that year.

In March 1857 – or only six years and three months after they landed – the population amounted to 6,230. In January, 1856, it was 5,347. The amount of land fenced in, in March 1857; was 24,357 acres, of which 4,027 were in wheat, 360 barley, and 918 oats.

The amount of stock in the province, both in January, 1856, and March, 1857, is shown by the following table:

* One gentlemen standing for a seat in the Council said, in addressing his constituents, that he "came forward actuated solely by scab."

	January, 1856	March, 1857
Horses	1,189	1,307
Mules	13	20
Horned cattle	12,424	15,355
Sheep	220,788	276,089
Goats	401	336
Pigs	4,996	5,817

The wool exported from Canterbury in 1856 amounted to 791,621 lbs.

The entire value of the exports in that year was estimated at £60,386, and of the imports at £88,0121. The exports, however, were undervalued, for the wool alone would amount to more than the sum named. Parts of the Canterbury province are still so little known that it is difficult to estimate the pastoral capabilities of the province, but I think it is no exaggeration to say that the province will support two millions of sheep, and that (counting each head of cattle as six sheep) within ten years there probably will be that number.

Ideal colonists

I may perhaps be excused for concluding this paper by saying a few words to a class of persons who would do well if they packed up their boxes, and started, by the next ship, for New Zealand; I mean small farmers, industrious, hard-working men, but possessed of too small a capital to hold their own against the competition of the present day, who find themselves, slowly but steadily, going back in the world, step by step, in spite of all their endeavours, until they see clearly that they or their children will end by being mere labourers. Now, the industrious man of this class had better save what he still has left, and emigrate. The idle ones may as well stop at home; we do not want them. The hard workers are just, of all others, the men fitted for colonists.

Men go out to the colonies for various reasons:

First. A man may go out merely officially, holding some military or other Government appointment.

Secondly. He may be travelling in search of health, or pleasure, or for scientific purposes.

Thirdly. He may go out intending to make as much money as he can in a few years, and return to England.

Fourthly. He may be wishing to improve his condition by finding and making for himself a new home in a new land, and, as a true colonist, be prepared to cast his lot in with the fortunes of his new country, be they what they may.

It is to those who have this last object in view that New Zealand offers special advantages, and it is with this object that the class of persons to whom I have alluded should go out. Let them not form visionary ideas of making fortunes; they will not do that, but they may, one and all, make a solid improvement in their condition, acquire a moderate competence, and leave their children settled on their own freehold land, in a fair way of doing well. I have stated above that a man possessed of £2,000 may engage in sheep-farming; but a man who lands in the colony with a tenth part of that sum * in his pocket may buy twenty to forty acres of land at £2 per acre, and engage in agriculture; but even if he has been a farmer in England, he will do well to lay aside his pride, and go and work as a labourer for five or six months, until he is able to form his own judgement as to what will be the wisest course for him to pursue in his individual case. He need not be ashamed of working thus; better men have done it before, and probably will do so again.

* The expense of a passage to New Zealand is – first cabin, £40 to £60 per head: intermediate, £25 to £30; and steerage, £18 to £22. Besides this, the outfit of clothes and bedding will cost about £5. Strong clothes, fit for a working-man should be taken; enough to last a year, but no more. And I cannot caution persons too strongly on this point, the less taken the better, you are not hampered with useless things when you land. And, above all, take nothing for sale, it involves certain delay in getting your money, and almost certain loss. Take your money in cash, or, rather, send it out through the 'Union Bank of Australia.

Killerton, March, 1858.

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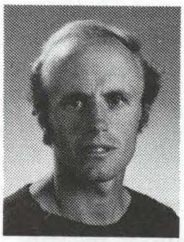
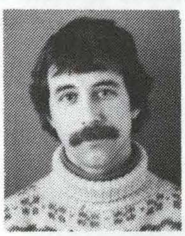
M. H. DOUGLAS, recently appointed as Officer in Charge of the Tara Hills High Country Research Station, is a pasture agronomist. His previous appointments have been as biologist with the N.Z. Forest Service (1964–66) when he worked on thar control, as an agrostologist with the Department of Agriculture, Victoria (1966–1974) and on his return to New Zealand, he was project leader for the Mountain Catchments Committee (1975–78) a policy sub committee of the Soil Conservation and Rivers Control Council. More recently (1978–1980) Mr Douglas was Senior Soil Conservator, for the Canterbury region, with the Water and Soil Division of the Ministry of Works and Development.

I. E. WHITEHOUSE is a scientist with the Alpine Processes Group, Christchurch Science Centre, MWD. He graduated B.Sc (Hons) in geology from Canterbury University in 1975 and joined the Alpine Processes Group in 1977. As a sideline he edits the N.Z. Alpine Journal. M. J. McSAVENEY and T. J. CHINN are geologists with the Alpine Processes Group also. This group, though perhaps best known for its discovery of the 12–15 m annual rainfall zone on the wet West Coast, is also involved in a quantitative study of earth surface processes to assist in evaluating management options in the high country of the South Island.



N. J. LEDGARD has been employed as a forester/scientist by the N.Z. Forest Service since the late 1960's. In 1971 he joined the Revegetation Section of the Forest Research Institute, since which time he has been engaged in the selection and propagation of woody species for revegetation work in the high country. J. T. MILLER is a scientist with the Forest Research Institute nursery at Rangiora. He joined the N.Z. Forest Service in 1949 and since 1960 has been working with the Genetics and Tree Improvement Section of the Forest Research Institute. His work is concerned with the improvement of introduced forest trees in the South Island by means of species and provenance testing and the identification and establishment of good seed sources.



T. C. PIERSON is a geologist who, for the past three years, has been NRAC post-doctoral research fellow at the Forest Research Institute, Christchurch. Dr Pierson has a B.A. degree from Middleburg College (Vermont), and M.Sc and PhD. degrees from the University of Washington. He has a broad interest in the evolution of landscapes and his research work has focused on applied problems in slope stability, mass wasting, soil erosion and hillslope hydrology.

M. P. MOSLEY recently joined the Science Centre of the Water and Soil Division of M.W.D. Christchurch, as group leader and founder member of the Environmental Hydrology Group. He graduated B.A. (Geography) from Cambridge in 1970 and M.Sc. (Geology) from Colorado State in 1972, where he also completed a Ph.D. in Earth Resources. He worked for the Manawatu Catchment Board and the Forest Research Institute before taking up his present position.

ANNUAL REPORT OF THE TUSSOCK GRASSLANDS AND MOUNTAIN LANDS INSTITUTE FOR THE YEAR 1979/80

This report summarizes the activities of the Institute during the year ended 31 March 1980. These activities cover a wide range of topics relevant to the Institute's terms of reference, and require the co-operation and involvement of many staff members, temporary workers and personnel outside the Institute. Thanks and appreciation are due to all these people and to all agencies with which the Institute is associated within its work programmes.

Perhaps the most successful task of the Institute during the past year has been the attack on the publishing backlog. Now that this formidable task has all but been completed, more regular and frequent "Reviews" will be available, as will the new newsletter "Aspect". This will facilitate the Institute's function of information dissemination.

During the year the high country production survey for 1976/78 was completed and published. It is interesting to note that, although the rate of increase in stock units has slowed over the last period, the nine percent increase has been considerably in advance of the almost unchanged New Zealand total. This highlights the potential that exists in the tussock grasslands and it is essential that this rate of increase be at least maintained.

The survey showed a slowing down in the rate of increase in stock units from a 26% increase between the first group of surveys to nine percent for the last period. Cattle numbers appear to have reached a peak. Two thirds of sheep traded are now sold as fat, compared with one third in 1965/67. Average lambing performance in the same period has risen from 79 percent to 86 percent with a wide range between 60 percent and 120 percent. Wool production per head is down by 0.2 kilograms. The range of wool production is wide – from 2.5 kilograms to 5.0 kilograms per head.

Extension

The Institute's activities in the extension field have covered a wide area. Acting as a centre to facilitate the co-ordination of research, it organised a meeting of interested parties to discuss the problem of *Hieracium*. A report "*Hieracium Research*" was subsequently compiled for distribution to agencies and personnel involved.

Special interest seminars relevant to the Institute's work have been attended, and, in some cases, organised by Institute staff. Where possible, appropriate field days and conferences were attended and several talks and papers given. In co-operation with Lincoln College and the Ministry of Agriculture and Fisheries, two winter feed forums were held in early September.

A number of visits were made to farms in the course of discussions on the result of the Institute's high country production survey; others were undertaken at requests from runholders, advisors, field officers and soil conservators. Many others were made in connection with particular investigations, such as grazing management, weed control, irrigation development, over-drilling, and hill country management generally. Whenever possible, visits were made to field staff of all agencies working in the hill and high country, many in response to requests by the agencies themselves. Management officers participated in a number of discussion groups in the tussock grasslands. A major undertaking was the organization of a hill and high country seminar in July. This provided a 2½ day forum for users of tussock grasslands and mountain lands, and some 150 attended. Copies of the proceedings were sent to all who attended and are available to other interested parties on request.

Information register

Part of the Institute's information service is to provide readily available information from published and unpublished sources on past and current research in the tussock grasslands and mountain lands.

In the storage of information the Institute is making use of computer technology. A simple system is being developed for archiving basic and already computerized data from projects for easy accessibility for future researchers. The practicalities of a computer-based bibliography of literature related to all aspects of New Zealand tussock grasslands and mountain lands are being considered together with a design for such a system.

An Avalanche Bibliography and Register is to be maintained for the New Zealand Mountain Safety Council Avalanche Committee.

Publishing

Excellent progress has been made in this field during the year. In addition to the works published there are a number close to the publication stage. Work on the accumulated backlog of necessity delayed the publication of "Review" and the launching of "Aspect".

The purpose of "Aspect", the name chosen for the Institute's new newsletter, is to provide a forum for the expression of view points on hill and mountainland topics and to report on recent items of interest from Government Departments, Statutory Bodies and other sources. The first issue has been edited and is ready for publication.

Pasture utilization and production

The pastoral utilization survey, to record the distribution of stocking loads on hill and high country properties, has continued, with a further 50 properties visited and information on grazing management obtained.

Several properties using intensive rotational grazing appear to have achieved large stock increases in the last few years. Block sizes have been reduced by more intensive subdivision. The analysis of grazing management data has yet to be completed.

The grazing behaviour trial at Glenthorne, studying the effects of partial area oversowing and top-dressing, has continued. A paper on the three years of pretreatment grazing behaviour has been prepared and submitted for publication.

Results of the first summer season after oversowing and top-dressing at Glenthorne tend to show that, while sheep numbers over the whole area are similar to previous seasons, the percentage of sheep grazing the oversown areas is very much higher. Concurrent with the main trial, is a study designed to determine the mineral composition of the principal species on these summer range sites, and to relate sheep preference for site and diet selection to this.

Work is continuing to determine the diet of sheep on the M.A.F. grazing trial at Tara Hills. This trial compares three grazing systems each at three stocking rates on oversown tussock. The diet of *Metacrias* (mountain tiger moth) on this site has also been analysed.

Work on the cuticle analysis of sheep dung to determine diet is continuing on other projects at the same time as the development of guides to the identification of components of sheep diet.

Pasture improvement and maintenance.

Work has continued in subsurface introduction of grasses and legumes in cooperation with the New Zealand Agricultural Engineering Institute. The aim of this project is to increase the effectiveness of surface introductions of grasses and legumes into sward and tussock situations using a modified rotary hoe fitted with seed and fertiliser boxes. In general terms grass and lucerne establishment is much improved with the roto-drill, although clover establishment is little affected by drilling method.

The Institute has two projects looking at clover-oversown grasslands; one to monitor changes in composition of clover oversowings under different aspect, altitude and grazing regimes, which is being done on a newly oversown block, (Spring 1979) and another to record and interpret runholder experience with clover oversowings. Both these projects are in their early stages.

Management influence on tall and short tussock is under review. These studies are designed to assess the effect of burning and grazing on tall tussock and the influence of defoliation on the growth and stature of fescue and poa tussocks. The influence of weeds on pastoral values and production is another study still in the exploratory stage. The project to determine the influence of plant nutrition on the composition and digestibility of fescue tussock is being prepared for publication.

Non-pastoral revegetation

A project to assess the suitability of native woody species for riparian revegetation has been continued in field and bin studies. This project has not revealed any special aptitudes of native woody material in revegetating either exposed subsoils or gravels in riparian situations. In the one case low fertility and frost heave, in the other the added problems of desiccation and instability in

The Roto-drill undergoing assessment trials in the Mackenzie Basin.

Institute technician, Mr J. Follet tending a nursery planting of *Griselinia littoralis* to be used in riparian revegetation studies.

flooding conditions, contributed to the non-recovery of such denuded riparian sites. In view of the apparent significance of such sites to the stability of stream systems, and the potential of some of these sites for amenity planting, tree crop production and channel stabilisation, the project will be continued.

Studies to develop ways of increasing the quantity of the native vegetation on the high altitude sites of drier mountains are continuing. Plantings were done in spring 1978 and 1979, with variable results depending on altitude, aspect, and variety of plant.

The interactions of fertilisers and lime on native and exotic legumes, growing in different tussock grassland soils, are at present under study in a glasshouse pot trial.

Proposals to review the experimental and practical use of Lotus cultivars and the introduction of herbaceous and woody species for non-pastoral use are at present being considered. In addition, a review on the role of Lotus for pasture improvement in tussock grasslands and mountain lands is being considered.

Resource management planning

The Institute, in assisting other agencies, is contributing towards a draft regional water and soil management plan for the Waitaki Catchment, developing alternative strategies for pastoral production in the Waitaki basin and determining the nature and extent of public administration in the hill and mountain lands.

In the course of this latter study, it is intended to compile a register of officers engaged in such work, which would be available to all agencies to help communications and co-ordination.

The Institute has been associated with a study of the socio-economic effects of Water and Soil Conservation Run Plans in Otago and is comparing production from all properties with and without Run Plans throughout the high country. In assessing the impact of hydro-electricity developments, real or proposed on mountainland resources, a case study has been carried out in conjunction with the Joint Centre of Environmental Sciences, on the impact on pastoral runs of a prospective hydo-electric development on the Upper Hurunui river. A published report is expected later this year.

Economic aspects of resource uses

Collaborating with the Economic Service of the New Zealand Meat and Wool Boards, the Institute has analysed, in real terms, changes in gross farm expenditure, and returns on capital, equity, and profitability in relation to stock performance for hill and high country farms.

Hill and high country farmers on average have increased production at a greater rate than the reduction in real terms of income per stock unit. They have therefore been able to maintain their real farm income at the 1959 level. The high country production survey is being extended to cover groups of tussock hill country farms.

An informal group involving the Ministry of Agriculture and Fisheries, Ministry of Works and Development, Department of Lands and Survey and the Institute are looking at irrigation economics in the Upper Waitaki. Aspects being considered are: the economics of irrigation within a high country run, completion of an irrigation management model, an examination of schemes which may meet government irrigation criteria, and aspects of land tenure.

Nature conservation and recreation

In the area of nature conservation and recreation, the principal project has been a study of "Mountain Recreaction in New Zealand". This work, of some years duration, is nearly complete and will be published in three volumes:

"Mountain Land Recreationist in New Zealand" contains reviews of studies of outdoor and mountain land recreationists, and a detailed examination of eight mountain land recreation activities.

"The Public Mountain Land Resource for Recreation in New Zealand" contains the governing Acts and Policies by which the Department of Lands and Survey and the New Zealand Forest Service administer Crown Lands for recreation. Recreation areas are listed, and management practices, uses, facilities and services are described for each major area, and wherever information was available.

"The Management of New Zealand Mountain Lands for Recreation" deals with changing perspectives of management, a study of the understanding of managers of Public Mountain Lands for recreation, and the use and management of pastoral lands for recreation.

A draft report on the suitability of the Summit Ridge of Old Man Range for nature conservation has been submitted for comment to the Department of Lands and Survey. Drawings are completed for this report, which may be published following the receipt of comment.

Earth and water processes

Studies of earth and water processes are centred mainly in the Torlesse and Kowai streams. In May 1980, these projects are due for major review, which will determine their future. They have been maintained and monitored during the year. A condensed version of some of the findings from these projects is being printed. In the riverbed survey of the Kowai river, 64 cross sections from permanent bench marks have been resurveyed, and calculations giving mean bed level changes over the period 1974/75 to 1979/80 recorded.

Two papers are being prepared on the Kowai river system sediments. One gives an account of sediment size distribution downstream and the other compares sediment from one sampling site with adjacent fluvioglacial deposits.

In protecting access to the Torlesse site, some river training work has been done. Experimental methods of stream control were used and the results recorded. Existing raingauges and meteorological instruments are being monitored and maintained. The upper catchment of the Torlesse is being monitored for responses to precipitation, especially with regard to gravel accumulation. Avalanches, in particular, are being surveyed and sampled to determine debris transport rate in relation to volume of snow.

Earth and water resource evaluation

The Orari survey computerisation project for the South Canterbury Catchment Board reported on last year, is nearing completion. Work this year was limited to a continuation of computer processing support.

The interpretation of land systems in the South Island high country will use existing resource survey information plus Landsat imagery. The first phase, a land systems interpretation of the Waitaki Catchment, was commenced in January, 1980.

A survey is being conducted on the present and potential use of very small hydro-electric schemes for remote areas. This survey is done under a grant from the New Zealand Energy Research and Development Committee.

In association with the N.Z. Agricultural Engineering Institute, a project is being developed to determine the technical and economic feasibility of irrigation in association with hill and high country farming in the Hakataramea Valley.

Systems ecology and environmental monitoring

A great deal of time and effort has been expended in development of the production-consumption computer model. Progress has been slower than expected, due principally to the need for extremely careful and accurate work. The next major step is the testing of the model using Tara Hills grazing trial data. The initial programme of testing should be completed by the end of this year. Studies have continued on grasshopper population densities at Camp Stream and on *Metacrias* (mountain tiger moth) on grazing trials at Tara Hills. The second annual count and distribution mapping at Tara Hills revealed a dramatic decline in numbers from the previous year, and a possible association between *Metacrias* density and sheep stocking loads.

Reports of grasslands deterioration and apparent insect damage through the Otago Catchment Board led to investigations by the Institute, and a report to the Board.

Other areas studied include the effects of tussock on microclimate, and nitrogen transformation in tall tussock grasslands, including tall tussock nutrition. A study of climatic and aspect influences on pasture production, measured by M.A.F., has been completed as a Ph.D. study and is being prepared for publication in scientific journals.

Vegetation changes occurring in the Waitaki basin are under study, with effort being made to collect and collate the surveys that have been made by various agents.

The phenology of alpine vegetation in the Grampian mountains has been observed and recorded in conjunction with other projects in the same area. The monitoring of vegetation succession following high altitude revegetation at several sites from Marlborough to Southland was continued. The recording of trends in vegetation and land condition at Molesworth, carried out every third year, continues the work carried out by Dr Moore of DSIR since 1944. In monitoring weed instances in tussock grasslands, the Institute has been responsible for writing up the results for the meeting on *Hieracium* research.

Visiting Fellow

The Institute was host from December 1979 to March 1980 to Dr F.S. Chapin III of the Institute of Arctic Biology, University of Alaska. Dr (Terry) Chapin, as a Guggenheim Fellow, carried out field, glasshouse and growth chamber studies in the phosphorus nutrition of *Chionochloa* species, in cooperation with the Director and staff of the Institute and with F.R.I. personnel.

Staff Changes

During the year Mr J. M. Kennard, an earth scientist from Australia, was appointed to the vacancy left by Dr J.A. Hayward. A junior typist, Miss S. Offord, was appointed to assist with the work of the information section. At the end of the year, Miss Lynda Budgeon resigned from the position of Research Assistant to take up a position at Head Office of the Department of Scientific and Industrial Research.

The Institute gratefully acknowledges the assistance given by staff employed on a casual basis and under the Temporary Employment Scheme.

Overseas Visits

The Director visited Europe for a month in the northern autumn. He prepared a commentary paper on the influence of grazing for an international workshop on terrestrial nitrogen cycling processes and participated in an international MAB symposium on methods and strategies for integrated development. He also visited Soil Science and Rural Social Science Centres in the Netherlands.

Under the auspices of the FAO of the United Nations, Mr Dunbar visited Bhutan as a consultant on Alpine pastures used by sheep and yak.

Management Committee

Two new members were appointed during the year: Dr G.W. Butler, Assistant Director-General of the Department of Scientific and Industrial Research, replaced Dr E. W. Wright, and Mr D. Crerar was appointed on the recommendation of the Minister of Lands to represent recreational interests.

In February the committee meeting was held at Mavora where members and staff inspected a large tract of country which had been the subject of a systematic resource evaluation and planning study by the Institute.

J.M. Wardell
for the Committee of Management

T.G.M.L.I. Publications 1979–80

Special Publication 13, A Review of Rentals for Pastoral Leases, Kerr, I.G.C., Frizzell, R. and Ross, B. J. (1979), 65 p.

Special Publication 14, Thyme in Central Otago, Wilkinson, E.L., Dann, G.M. and Smith, G.J.S. (1979), 30 p.

Special Publication 15, High Country Production Surveys – 1965/67 – 1971/73 – 1976/78, Kerr, I.G.C., Lefever, K.R. and Costello, E.J. (1979), 63 p.

Special Publication 16, The Proceedings of the 1979 Hill and High Country Seminar, ed. by B.T. Robertson, (1979), 359 p.

Special Publication 17, Hydrology and Stream Sediment from Torlesse Stream Catchment, Hayward, J.A. (In Press).

Special Publication 18, A Key to Legumes of the sub-family Papilionaceae in New Zealand, Horn, P.E., Hill, G.D. (1980), 28 p.

Lincoln Papers in Resource Management 5, Resources of Lake Wanaka, ed. by B.T. Robertson and I.D. Blair, (In Press).

Lincoln Papers in Resource Management 6, The Mountain Land Recreationist in New Zealand, Aukerman, R., Davison, J. (In Press).

Lincoln Papers in Resource Management 7, The Public Mountain Land Resource for Recreation in New Zealand, Smith, J., Davison, J. and Geden, B. (In Press).

Tussock Grasslands and Mountain Lands Institute Nineteenth Annual Report, Mountain Revegetation – Technologies and Objectives (1979), 40 p.

Tussock Grasslands and Mountain Lands Institute "Review" 38 (In Press).

New Zealand Man and the Biosphere Report 2, Prospects for New Zealand Biosphere Reserves ed. by B.T. Robertson, K.F. O'Connor, and B.P.J. Molloy, (1979), 78 p.

New Zealand Man and the Biosphere Report 3, The Economics of Pastoral Development in the Upper Waitaki, Whitby, M.C. (1979), 220 p.

New Zealand Man and the Biosphere Report 5, Science in a Rural Community ed. by G. Cant and K.F. O'Connor, (1979), 28 p.

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DAVY, B. W., Davies, T. R. H., (1979). "Entropy concepts in fluvial geomorphology; a re-evaluation." *Water Resources Research 15* (1): 103–106.

DUNBAR, G.A., Horrell. R.F. and Costello, E.J. (1980). "Establishing grasses by surface drilling in tussock country", *Tussock Grasslands and Mountain Lands Institute "Review" 38* (In Press).

HARRIS, P.S. (1979). "Feed requirements of stock and stock carrying capacities of hypothetical runs", Appendix in *New Zealand Man and the Biosphere Report 3*, The Economics of Pastoral Development in the Upper Waitaki, Whitby, M.C. (1979), 140–158.

HAYWARD, J. A. (1979): Mountain stream sediments. Physical Hydrology – New Zealand experience. Toebes Memorial volume, edited by D. L. Murray and P. Ackroyd pp 193–212. N.Z. Hydrological Society, Wellington. 229p.

KERR, I.G.C., (1979). "Potential minor and major irrigation schemes, Upper Waitaki Catchment", Appendix in *New Zealand Man and the Biosphere Report 3*, The Economics of Pastoral Development in the Upper Waitaki, Whitby M.C. (1979) 194–209.

KERR, I. G. C., Lefever, K. R. and Costello, E. J. (1979). "Production and Performance in the High Country", in *Tussock Grasslands and Mountain Lands Institute Special Publication 16,* The Proceedings of the 1979 Hill and High Country Seminar, 310–332.

KERR, I. G. C., (1979), Rentals for Pastoral Leases, in *Tussock Grasslands and Mountain Lands Institute Special Publication 16*, The Proceedings of the 1979 Hill and High Country Seminar, 1–47.

KERR, I. G. C., Lefever, K. R. and Costello, E. J. (1980) Livestock production and performance in the South Island High Country, in *Tussock Grasslands and Mountain Lands Institute "Review" 38* (In Press).

LEFEVER, K. R., (1979). Avalanche and Snow Research Bibliography, in *Snow Avalanches – a review with special reference to New Zealand*, ed. by I. F. Owens and C. L. O'Loughlin. New Zealand Mountain Safety Council Avalanche Committee Report No. 1.

MURRAY D. L., Ackroyd P., (eds) (1979). Physical Hydrology – New Zealand experience. Toebes Memorial volume, N.Z. Hydrological Society, Wellington, 229p.

O'CONNOR, K. F. (1979). A Forward Look, in *Tussock Grasslands and Mountain Lands Institute Special Publication 16.* The Proceedings of the 1979 Hill and High Country Seminar, 354–359.

O'CONNOR K. F., (1979). The High Country and Run Country – its vegetation and environs, in *The Institute of Noxious Plants Officers 1979 Conference Proceedings*, 17–20.

O'CONNOR, K. F., (1979). Mountain Revegetation – Technologies and Objectives, in *Tussock Grasslands and Mountain Lands Institute Nineteenth Annual Report, (1979)*, 40 p.

O'CONNOR, K. F., (1980). The Use of Mountains, a Review of New Zealand Experience, in *Land Use and Conservation*, New Zealand Geographical Society, Auckland.

O'CONNOR, K. F., Molloy, B. P. J., (1979). Biosphere Reserves for New Zealand: A Prefatory Essay, in *New Zealand Man and the Biosphere Report 2.* 3–7.

Unpublished reports

GRAHAM, J.R., Robertson, B.T., (1980). "Hieracium Research", a summary of a meeting held at the Tussock Grasslands and Mountain Lands Institute on September 4 and 5, 1979. Tussock Grasslands and Mountain Lands Institute unpublished report.

LEFEVER, K. R., (1979). High Country Production Surveys 1965–1978. Data Disk Files Design Documentation. 286p., including appendices. Tussock Grasslands and Mountain Lands Institute unpublished report.

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Craspedia lanata (woolly head)

In this issue:

- Debris flows
- Dating screes
- Bullock Creek
- Growing trees
- Land management
- Laughing owls
- Sheep farming in early N.Z.
- Annual report