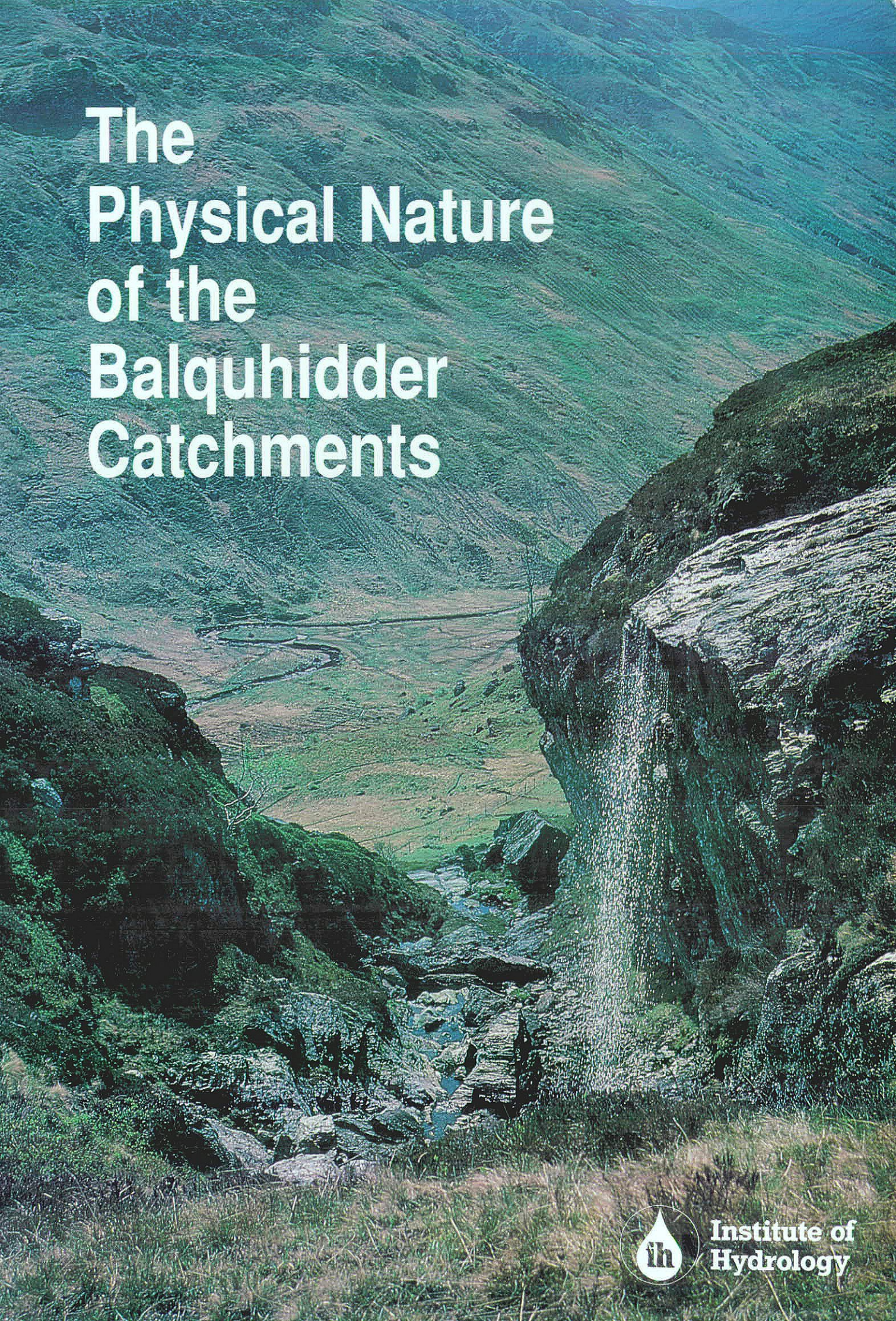
The Physical Nature of the Balquhidder Catchments



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The Physical Nature of the Balquhidder Catchments

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ABSTRACT

The Balquhidder experimental catchments, Kirkton and Monachyle, are in the Highlands of Scotland 60 km north of Glasgow. Research has been carried out there by the Institute of Hydrology since 1981, investigating the effects of forestry on water quantity and quality. In this report the geology, soils, vegetation cover and land uses in both catchments are described. The physical dimensions of the catchment are tabulated including orientation, shape, area, altitude, slope and aspect. Drainage patterns have been mapped and also the widths, depths and angles of the drainage lines. Land uses changed in both catchments during 1986, and details of the clear felling in the Kirkton and land cultivation and drainage in the Monachyle are given.

1 INTRODUCTION

The Balquhidder catchment experiment was established in 1981 to study the effects of forestry practices on water resources in two 'typical' Scottish Highland glens. The two catchments were required to be physically similar, close together and to be at different stages in the forest cycle. They also had to be suitable for installing hydrometric instrument networks and there should be co-operation with the landowners for access. Initially the experiment was designed for water quantity studies but later water quality studies became equally important (Blackie, 1987; Johnson, 1991).

Scotland has become the main area of expansion in the UK forestry industry in the last decade. The plantation forestry, established some 50 years ago, has now reached maturity and clear felling is becoming widespread throughout Scotland. New areas are still being identified for afforestation as land owners change from the traditional sheep farming to the potentially more profitable forestry. The forestry industry is very much aware of the potential environmental problems associated with forestry practices and research has been encouraged which increases the understanding of forestry effects.

This report is intended to be a reference booklet giving details of the basic catchment characteristics. Map details have been obtained from the Ordnance Survey 1:10,000 maps NN 52 SW (for Kirkton) and NN 42 SE, NN 42 NE (Monachyle).

2 LOCATION OF THE BALQUHIDDER CATCHMENTS

The Balquhidder catchments, Kirkton and Monachyle, are located 60 km north of Glasgow, in the Grampian Mountain range also referred to as the Southern Highlands, Figure 1. The two catchments are on the north side of the main Balquhidder Glen (OS Grid Reference NN 5020) (Figure 2), a deeply glaciated valley which contains the two lochs, Voil and Doine. A small catchment, Glen Crotha, separates the Kirkton and Monachyle catchments by 2 km. A sub-catchment, the Upper Monachyle, forms a northern lobe of the Monachyle catchment.

The main topographic features in the surrounding area are Ben More, 3 km to the west of the Monachyle catchment, Loch Lomond, 20 km to the south west, the Southern Highland fault line, 15 km to the south and Ben Vorlich, 10 km to the east of the Kirkton catchment.

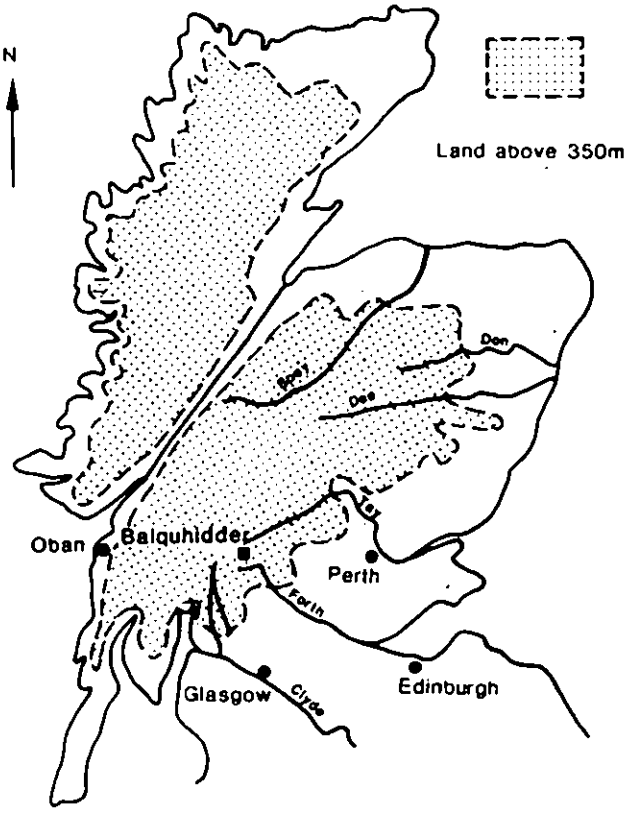


Figure 1 Location of Balquhidder in Scotland

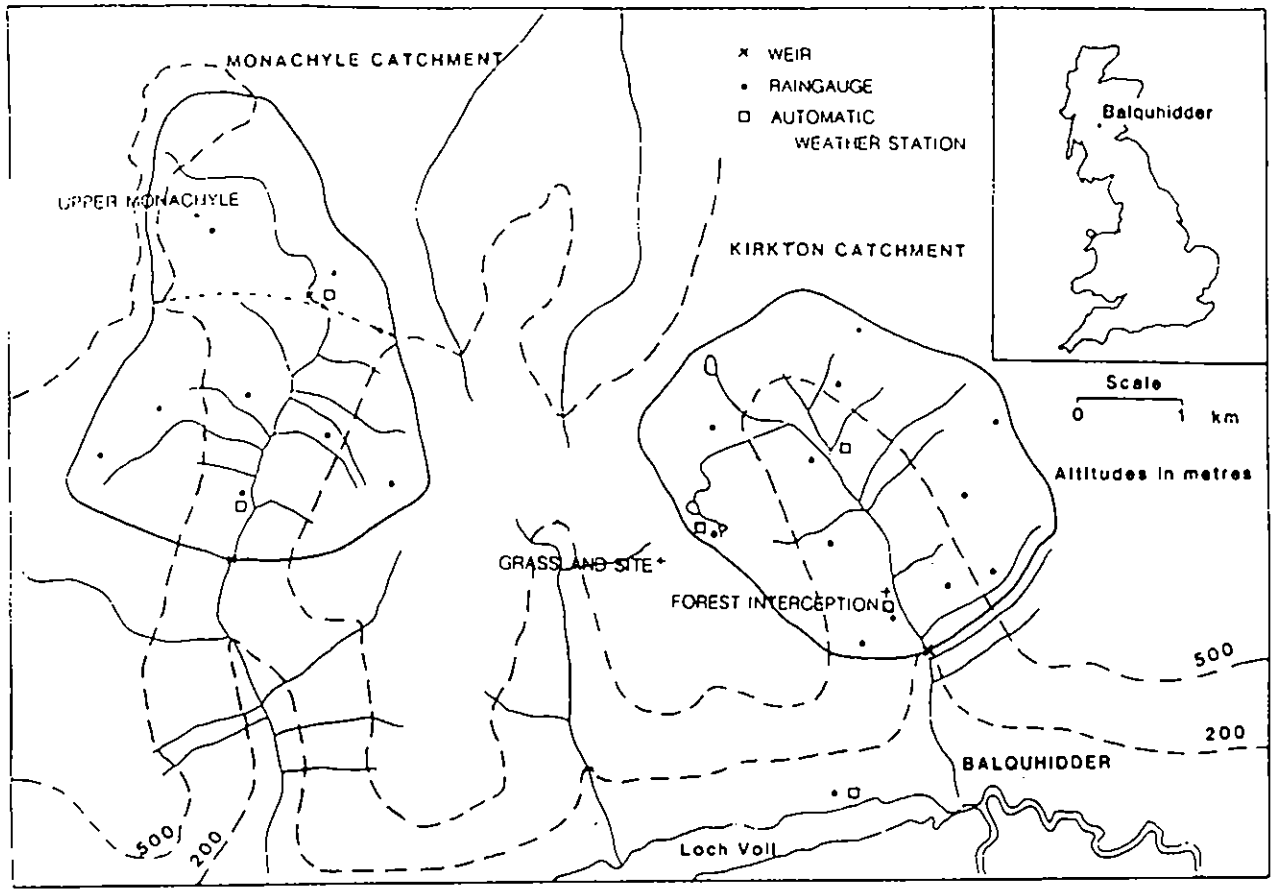


Figure 2 The Monachyle and Kirkton catchments with their main instrument networks

3 GEOLOGY, SOILS AND VEGETATION

3.1 Geology

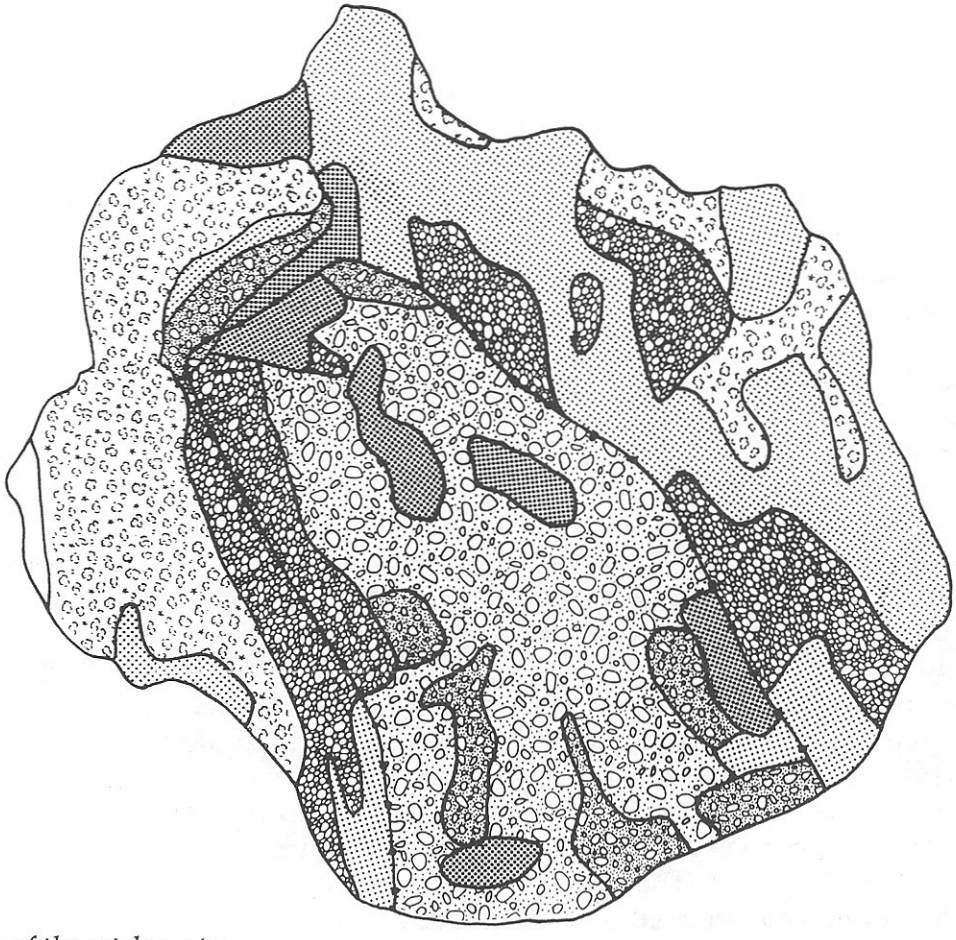
The rock of the area belongs to the Ben Lui Schists, Loch Tay Limestones and Southern Highland Groups of the Dalradian Supergroup (Robins & Mendum, 1987). The metasediments were deposited at around 550-560 Ma and originally consisted of greywackes overlain by limestones and then further greywackes with tuffaceous horizons. The sequence was strongly deformed, folded and metamorphosed in the Grampian Orogeny (540-440 Ma). The rocks now form part of the inverted limb of a large regional recumbent anticline termed the Tay Nappe.

The Loch Tay limestone only outcrops on the east side of the Kirkton Glen. It consists of several grey banded, recrystallised, limestone units with semi-pelitic schists and quartzose greywacke interbeds. Several post-orogenic sills and dykes cross the area in both catchments.

The Southern Highlands have been subjected to several past glaciations leaving good examples of erosional and depositional features. Valleys are straight and U shaped and often contain large lochs formed behind moranic deposits. Many side valleys are hanging, including the Kirkton. Glacial till deposits are deep and irregular, extending up valley sides to an altitude of some 450m. The Upper Monachyle sub-catchment appears to have once been the headwaters of a northward facing glen but was blocked and diverted into the Monachyle by glacial till deposits.

3.2 Soils

The soils in the catchments are of the Strichen association derived from the

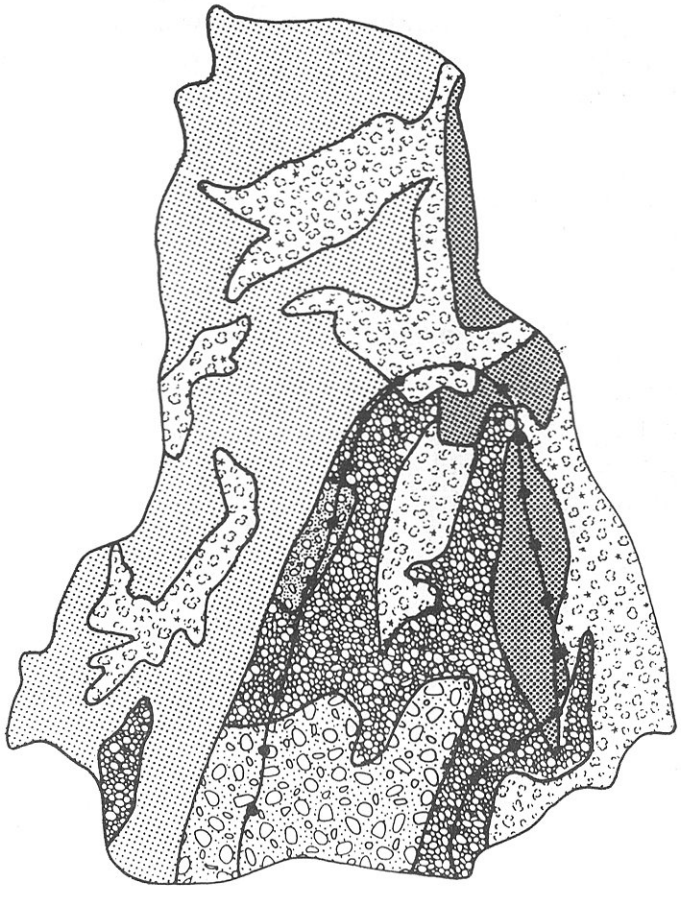


Figures 3 & 4 Soil maps of the catchments:
Figure 3 (above) Kirkton
Figure 4 (below) Monachyle

KEY:

- Ranker
- Peat
- Peaty Gley
- Surface Water Gley
- Humus Iron Podzols
- Brown Forest Soils

Forest Fence



drift deposits and underlying schist bedrock. Soil texture is generally stony, sandy loam or loamy sand. Soil types range from blanket peat on the flatter ground to rankers on the steeper slopes and higher ground. Other soil types are surface water gleys, peaty gleys, peaty podsols, humus iron and brown forest soils.

Soil details have been derived from the 1:250,000 soil survey map of the area: Eastern Scotland (Macaulay Institute, 1982) and from the 1:10,000 survey maps produced by the Forestry Commission, Kirkton 1985/6 and Monachyle 1982/3. Simplified versions of the Forestry Commission maps are given in Figures 3 and 4. Soil depths have been measured at 298 random points in the catchments. Details of the percentage cover of the soil types with their mean depths are given in Table 1. Soil depths are very variable with little obvious correlation between depth and altitude. There are variations which can be associated with small scale topographic features, i.e. the shallow soils are generally on top of hummocks. Figure 5 shows this variability in the histograms of the soil depth measurements made in each soil type.

Table 1 Percentage cover of the soil types in the Balquhidder catchments with mean soil depths

	Percentage cover	*Mean soil depth (cm)*	
		Kirkton	*Monachyle*
Ranker	25	35	26
Peat	12	26	30
Peaty Gley	20	15	29
Surface Water Gley	28		38
Humus Iron/ Peaty Podsol	10	12	34
Brown Forest Soil	5	5	26

The ranker soils are shallow layers of weathered material: they dominate the steeper slopes and altitudes above 450 m. Within this group are ranker and rock complexes, gley ranker, peaty ranker and rock and scree outcrops. Peats are generally found at low altitudes on gentle slopes but can also occur at high altitudes above 600 m.

Peaty gleys dominate the valley sides of the Monachyle catchment but in the Kirkton are only extensively found outside of the forested area. The surface water gleys generally develop in valley bottoms where drainage can be poor. They dominate the Kirkton catchment within the forested area and are less common in the Monachyle.

Humus iron podsols and peaty podsols are found in both catchments on moderate slopes. In some areas iron-pan development is sufficient to impede the downward movement of water. The brown forest soils are located in isolated patches on the better drained slopes.

3.3 Vegetation

Catchment vegetation maps were prepared by a combination of remote sensing and ground surveys (Roberts *et al.*, in press). The remotely sensed images available were:

1: A three band (red, green, infrared) image, ground resolution 20m, taken by the Systeme Probatoire d'Observation de la Terre (SPOT) satellite on the 17th April 1987;

2: Colour/infrared stereo aerial photographs taken from the NERC aircraft on the 14th/15th September 1988.

These images were classified into vegetation types using ground surveys carried out on a 250x250m grid system. Areas of relatively homogeneous vegetation were identified and used to classify the remainder of the catchments.

A reasonable agreement was achieved

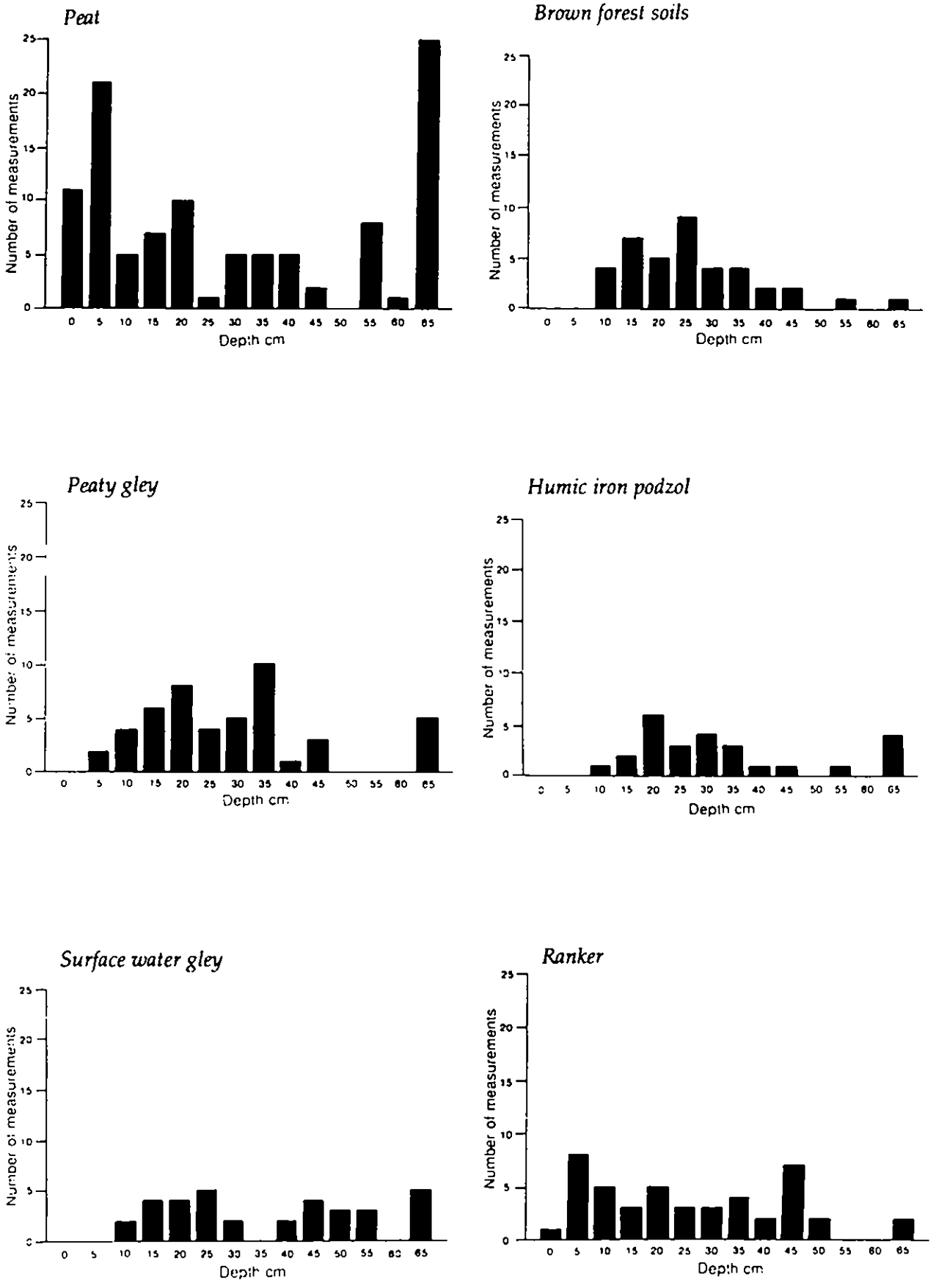


Figure 5 Variability in measured soil depths for each soil type

between the areal covers of vegetation types by the remote sensing and the ground truth method. Discrepancies had been expected because of the heterogeneous nature of the ground cover. Vegetation was classified into forest, hill grass, bilberry, heather moss, bracken and forest roads. The percentage cover for each vegetation type is shown in Table 2 and the percentage cover in 100 m altitude ranges shown in Table 3.

Table 2 *Percentages of the main vegetation types in the Balquhidder catchments*

Kirkton:		***Monachyle:***	
Heather	*5*	*Heather*	*36*
Bilberry	*10*	*Bilberry*	*14*
Moss	*14*	*Moss*	*13*
Grass	*30*	*Grass*	*36*
Bracken	*0*	*Bracken*	*1*
Trees	*36*	*Trees*	*0*
Roads	*5*	*Roads*	*0*

Table 3 *Percentages of the main vegetation types in the Balquhidder catchments in given altitude ranges (same order as in Table 2)*

	H	*Bil*	*Moss*	*G*	*Br*	*Trees*
Kirkton:						
< 400 m	*0*	*0*	*0*	*0*	*0*	*100*
400-500 m	*0*	*0*	*0*	*0*	*0*	*100*
500-600 m	*1*	*18*	*19*	*45*	*0*	*17*
600-700 m	*11*	*14*	*23*	*52*	*0*	*0*
700+ m	*12*	*17*	*27*	*44*	*0*	*0*
Monachyle:						
<400 m	*20*	*12*	*10*	*53*	*5*	*0*
400-500 m	*40*	*10*	*16*	*32*	*2*	*0*
500-600 m	*45*	*16*	*9*	*30*	*0*	*0*
600-700 m	*32*	*17*	*11*	*40*	*0*	*0*
700+ m	*19*	*28*	*21*	*32*	*0*	*0*

4 CATCHMENT DIMENSIONS

4.1 Shape

The total lengths of the catchments from the catchment outfall to the catchment boundary furthest away are:

Kirkton	*3.32 km*
Monachyle	*3.71 km*

Maximum widths perpendicular to the main stream:

Kirkton	*2.72 km*
Monachyle	*2.82 km*

Ratios of length to width:

Kirkton	*1.22*
Monachyle	*1.32*

Ratios of length to area (Section 4.3):

Kirkton	*0.48*
Monachyle	*0.48*

4.2 Orientation

The orientations of the lines joining the catchment outfalls to the most distant boundary points are:

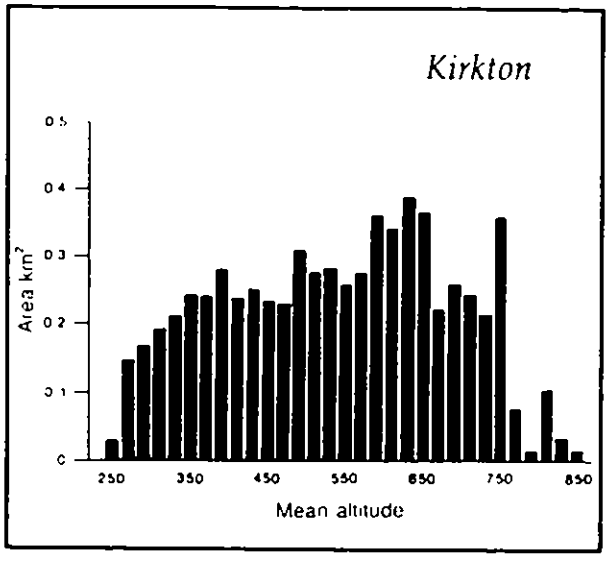
Kirkton	*343 degrees*
Monachyle	*006 degrees*

4.3 Area

Catchment areas measured by planimeter from the 1:10,000 maps of the catchments are:

Kirkton	*6.850 km²*
Monachyle	*7.700 km²*
Upper Monachyle	*2.237 km²*

Distributions of catchment areas within 20 m altitude ranges are shown in Figures 6 (Kirkton), 7 (Lower Monachyle) and 8 (Upper Monachyle) and summarised in Table 4.



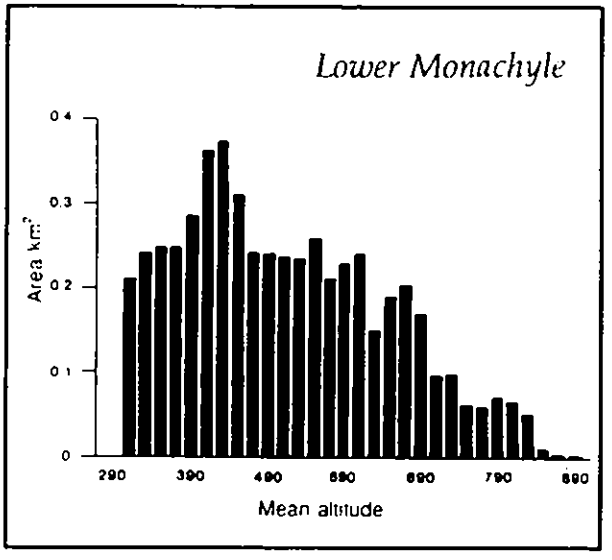


Table 4 Catchment areas within altitude ranges

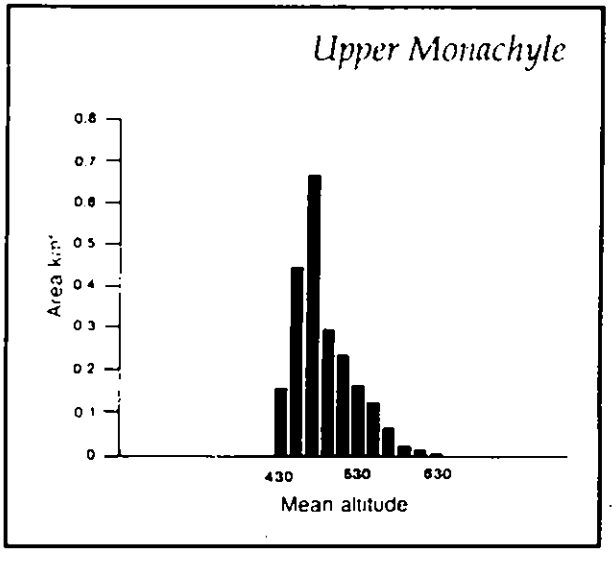
Range m	Kirkton Area ha	Kirkton %age of total	Monachyle Area ha	Monachyle %age of total
200-300	34	5	2	0
300-400	117	17	122	15
400-500	126	18	309	40
500-600	142	21	182	24
600-700	156	23	102	14
700-800	102	15	38	5
800-900	8	1	15	2

The surface area in each 250x250 metres grid area was calculated using the mean slope angle within each block. The total surface areas of the catchments are:

Kirkton	*west*	*2.64 km²*
	east	*4.72 km²*
Lower Monachyle	*west*	*2.92 km²*
	east	*2.31 km²*
Upper Monachyle	*west*	*1.15 km²*
	east	*0.95 km²*

4.4 Altitude

Catchment altitude details are given in Table 5. Although the altitude ranges are similar the highest points are on opposite sides of the catchments, east Kirkton and west Monachyle. The median catchment altitude was derived by measuring mapped areas between 20 metre contour lines (Figures 6 to 8).



Figures 6 to 8 Area of catchments in altitude ranges

Table 5 Catchment altitude (metres)

	Min.	Max.	Range	Median
Kirkton	*242*	*852*	*610*	*540*
east	*242*	*852*	*610*	*580*
west	*242*	*675*	*433*	*490*
Monachyle	*292*	*906*	*614*	*470*
east	*292*	*753*	*461*	*470*
west	*292*	*906*	*614*	*480*
Upper Monachyle	*434*	*630*	*196*	*470*
east	*434*	*560*	*126*	*470*
west	*434*	*630*	*196*	*470*

4.5 Slope

The mean slope angle for each 250x250 metre block has been derived from the 1:10,000 maps. Figure 9 shows the distributions of slope angles and Table 6 gives the catchment details. The Kirkton is therefore the steeper catchment although the Monachyle figures are greatly influenced by the relatively flat Upper Monachyle sub-catchment.

Table 6 Catchment slope (degrees)

	Mean	*Maximum*	*Minimum*
Kirkton	*19.9*	*39.3*	*8.1*
east	*21.1*	*39.3*	*8.1*
west	*18.0*	*36.9*	*8.1*
Monachyle	*15.8*	*34.8*	*3.1*
east	*15.2*	*28.3*	*3.1*
west	*16.3*	*34.8*	*3.4*
Upper Monachyle	*10.1*	*20.6*	*3.1*
east	*9.4*	*16.7*	*3.1*
west	*10.6*	*20.6*	*3.4*

4.6 Aspect

Figure 10 and Table 7 show the distribution of slope aspects derived from the mean slope in each 250x250 metre square. The Kirkton easterly aspects include the south facing slopes on the east side of the main Kirkton burn. Figure 10 shows the Monachyle to be more open to the north and so these southern facing slopes are not so frequent in this catchment. Again it is the Upper Monachyle sub-catchment which influences the Monachyle median value.

Table 7 Median catchment aspect (degrees)

Kirkton east	*220*
Kirkton west	*070*
Monachyle east	*300*
Monachyle west	*090*
Upper Monachyle east	*180*
Upper Monachyle west	*070*

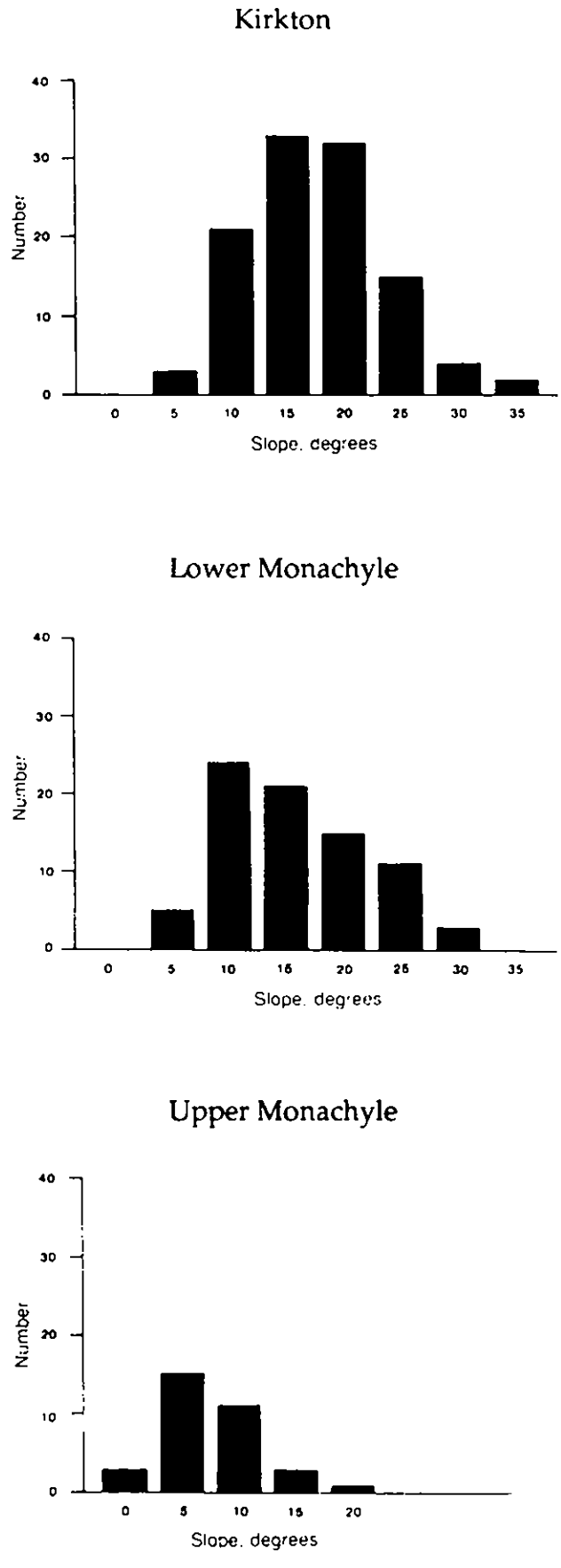
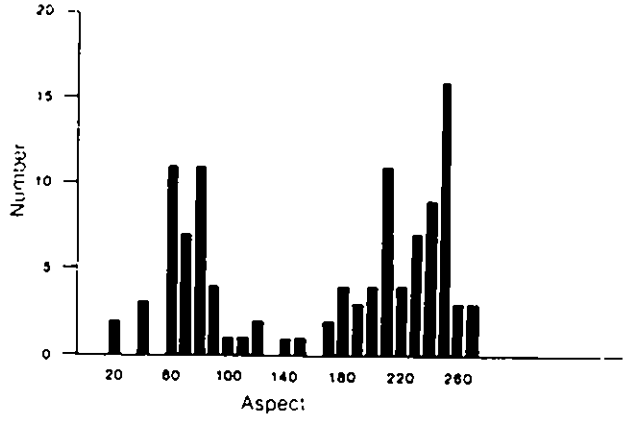
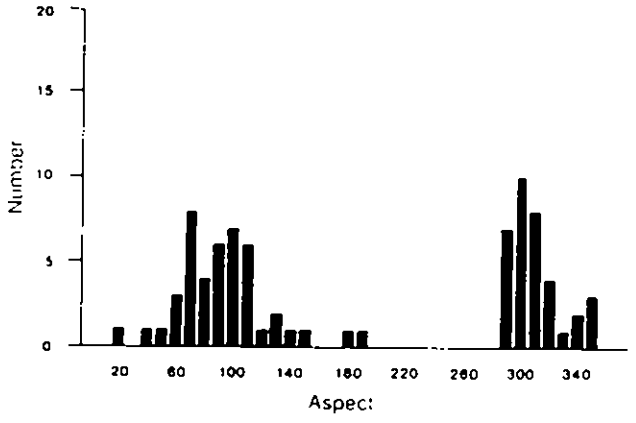


Figure 9 Distribution of slopes in the Balquhidder catchments

Kirkton



Lower Monachyle



Upper Monachyle

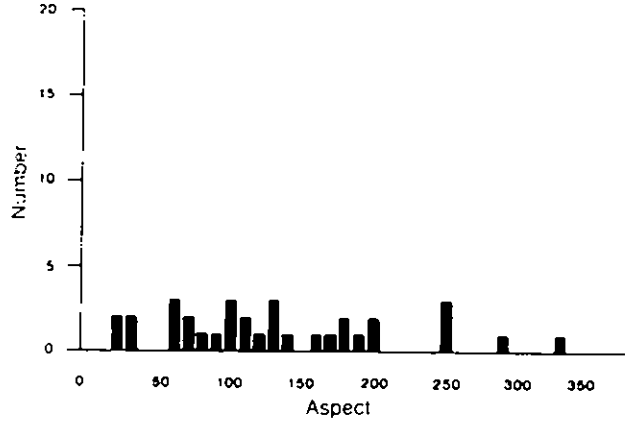


Figure 10 *Distribution of slope aspects in the Balquhidder catchments*

5 CATCHMENT DRAINAGE

All burns which were flowing throughout the 1988 and 1989 summers have been mapped (Figures 11 and 12), numbering 31 in the Kirkton and 22 in the Monachyle. This has showed up an inadequacy of the 1:10,000 maps, from which several burns and considerable detail in the source areas are missing. The Upper Monachyle sub-catchment has previously been shown to be a large, flat peat covered area and consequently drainage patterns were found to be too complex to map. Therefore, most of the following details of the Monachyle only refer to the lower Monachyle.

The drainage patterns in both catchments are good examples of lateral drainage, comprising both first and second order streams. Details of the drainage, given in Table 8, show significant differences between the catchments, especially in the mean angle of the main burns, the widths of the tributaries and the drainage densities. The angle of the main burns can be compared in Figure 13, the profiles of both stream-lines. It is interesting that the angle of the steeper headwater sections are similar but below this the Kirkton is much steeper than the Monachyle. This is probably due to a ridge spur from the east Monachyle Glen which partially blocks the Glen and the Kirkton being a glacial hanging valley.

Table 8 Catchment drainage details (excluding Upper Monachyle)

	Kirkton	*Monachyle*
Main streams		
Source altitude (m)	*588*	*434*
Length (m)	*3180*	*2655*
Mean angle (degrees)	*6.2*	*3.1*
Tributaries		
Mean width (m)	*0.92*	*0.59*
Mean depth (m)	*0.25*	*0.22*
Mean length (m)	*1004.*	*834.*
Mean angle (degrees)	*15.7*	*14.4*
Drainage density (km/km²)	*5.1*	*3.8*

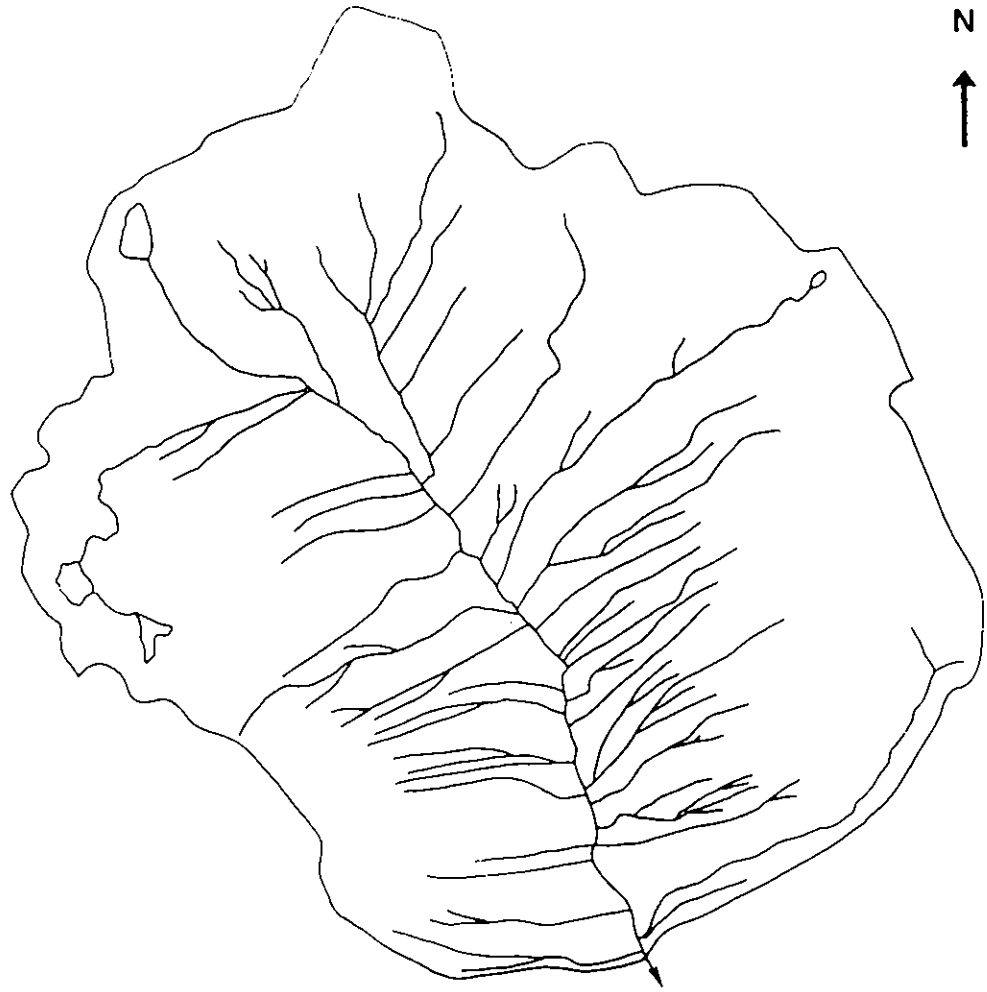


Figure 11 Drainage map of the Kirkton catchment

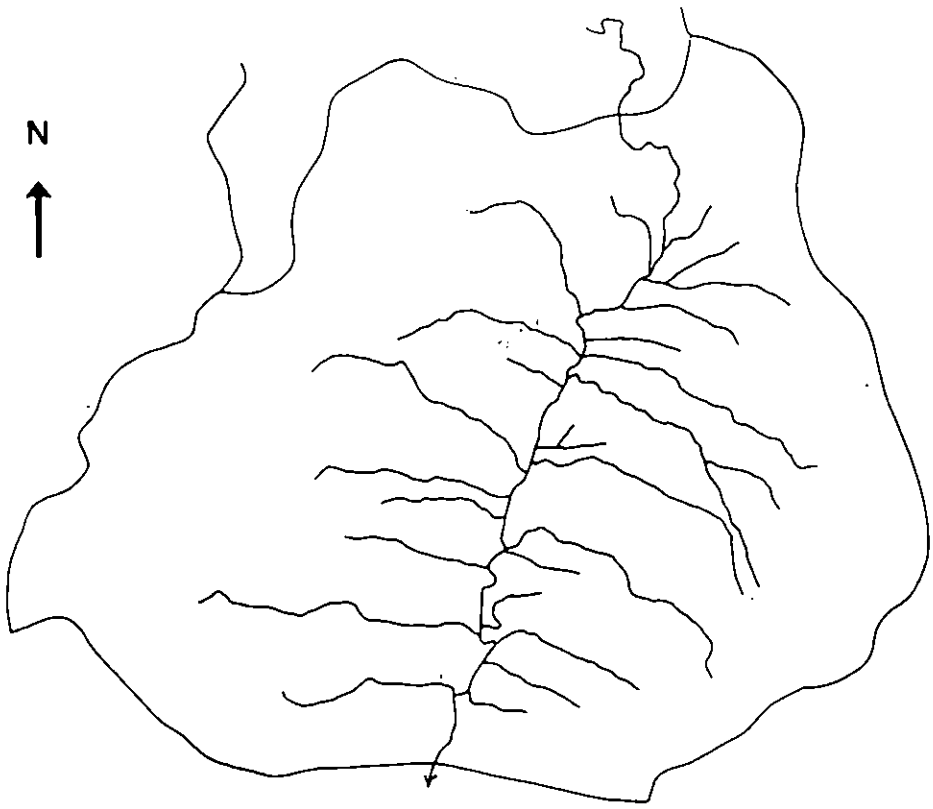


Figure 12 Drainage map of the Monachyle catchment

6 LAND USE

6.1 Forestry

When the experiment began in 1981 the Kirkton catchment had a 41 per cent cover of forest (Table 9); the Monachyle catchment had no forestry although the Forestry Commission deer fence had just been erected. The Kirkton forest was planted between 1932 and 1944 with a mixture of species, mainly sitka spruce and Norway spruce. Some improvements were made to the drainage in the lower parts of the catchment but these ditches had mostly become overgrown and inactive by the start of the study. A dense network of roads had been constructed, 10 km total length within the experimental part of the forest.

In late 1985 road upgrading started in preparation for the clear felling which started in April 1986. Felling has been mainly on the west side of the catchment up to 1990, generally proceeding from the south to the north. Table 9 shows areas felled in each year. Timber extraction to the forestry roads has mostly been by cable crane with some forwarder extraction on gentler slopes. The construction of new stacking areas and turning areas has been necessary for the articulated logging lorries which remove the timber from the forest.

Table 9 Details of the Kirkton forest areal cover (km²)

Area within upper edge of plantation:		*2.787*
Areas of windthrow clearing before felling started:		*0.122*
Area of road surface:		*0.306*
Area of standing trees before felling		*2.359*
Areas of forest felled each year:	*1986*	*0.409*
	1987	*0.544*
	1988	*0.228*
	1989	*0.069*

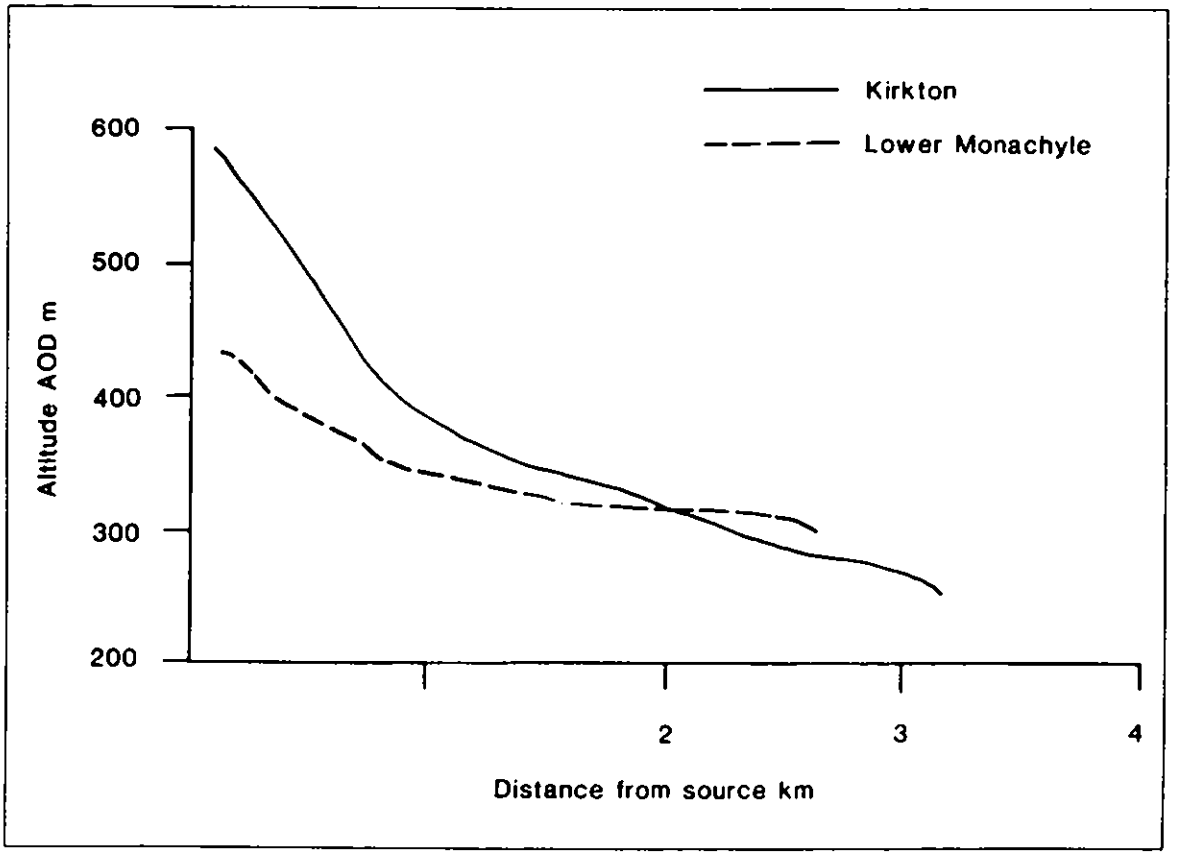


Figure 13 Long profiles of the Kirkton and Monachyle main streams

In the Monachyle catchment ground preparation was carried out in April to June 1986, with planting starting that summer. The total area of ploughing was 45 ha, i.e. 6 per cent of the total catchment area. Plough lines 20-30 cm deep were perpendicular to the contours with cut-off drains, 60 cm deep, dug where necessary and 15-20 metres wide buffer zones left on either side of the main burn. By 1990 the average depths of the plough lines had increased to 35 cm and the cut-off drains to 80 cm. The plough lines had also become revegetated but the cut-off drains were still exposed soils and tills.

Figure 14 shows the areas drained both mechanically and manually and the positions of the cut-off drains. The total length of plough lines is 170 km and the length of cut-off drains is 5 km, increasing the Monachyle drainage density from 3.8 to 36.1 km/km^2. The total area planted is only 111 ha of the total 205 ha. owned by the Forestry Commission, i.e. 14 per cent of the total catchment area.

6.2 Farming

The areas above the Forestry Commission ground are privately owned and used for the traditional sheep farming, grouse shooting and deer stalking. The numbers of animals is small and variable because of the relatively poor vegetation, especially in the winter. Sheep populations are generally around 200 per hill, i.e. some 100/km^2.

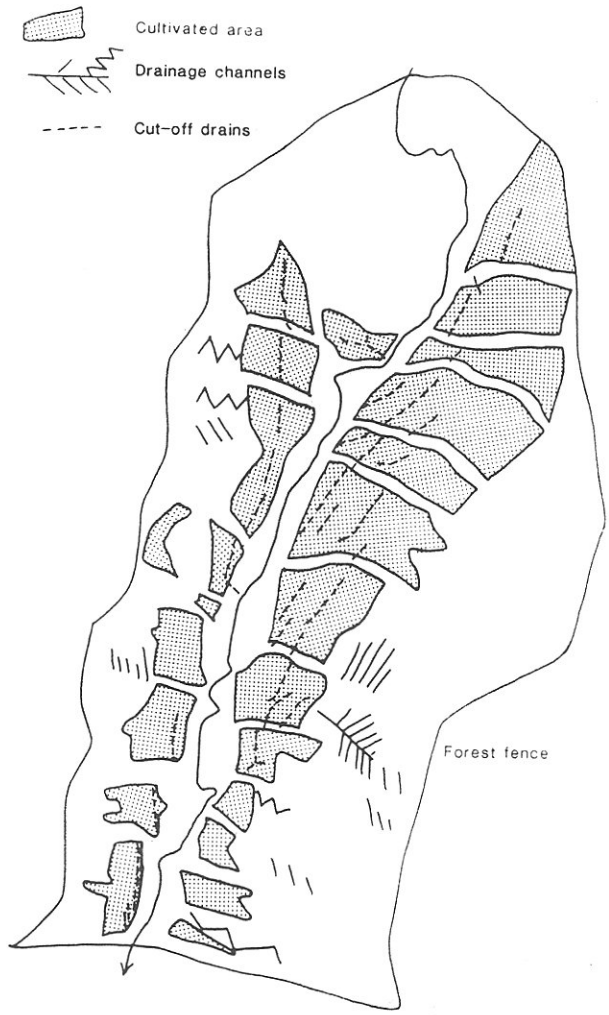


Figure 14 Areas of cultivation and drainage in the Monachyle catchment

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