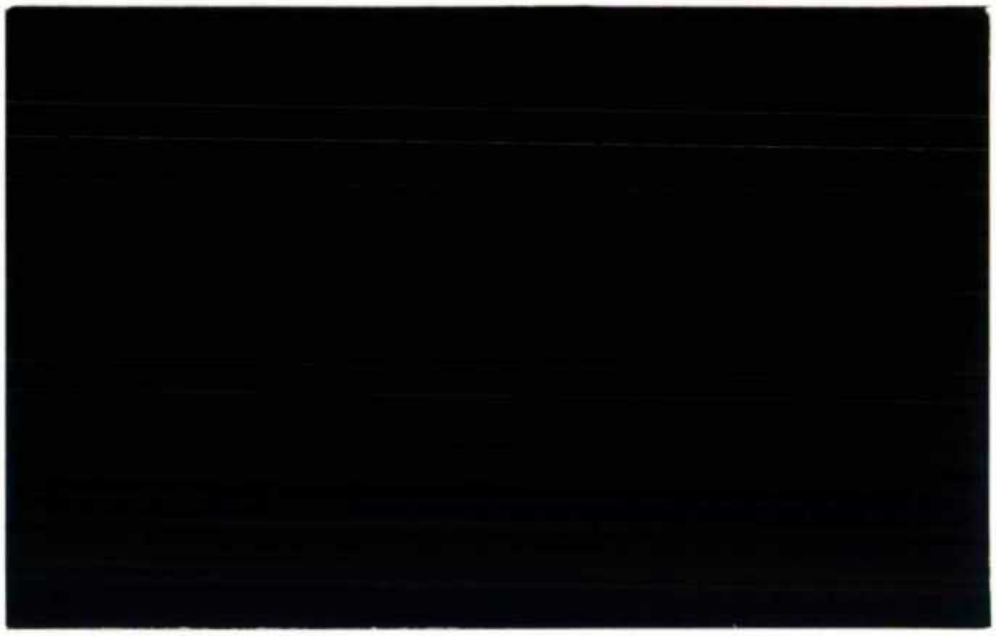
Institute of Hydrology



UPLAND AFFORESTATION AND WATER RESOURCES

Interim Report on the Balquhidder Catchment Studies 1981/82

by

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Introduction

The objective of this study within the overall project is to compare the hydrological responses of a forested catchment with a comparable non-forested one in a geographic and climatic situation typifying the areas of upland Scotland where forestry and water resource interests may overlap. Of the various sites considered the Kirkton and Monachyle Glens near Balquhidder appeared to offer the best compromise between climate, geography and vegetation on the one hand and access, amenable landowners and the feasilibity of instrumentation on the other. They also provided the option of extending the initial 5 year study to include the effects of forest planting on one and of progressive felling of mature timber on the other.

It was recognised from the outset that instrumentation of these catchments to provide data of the required standard may be feasible but would certainly not be easy. Year one of the project has proved the point. The summary of the year's work programme on page 7 and the list of instrumentation installed in Table 1 give some indication of the problems encountered. Many have been overcome but others are taking a little longer, and the cost will probably be rather more than was estimated at this time last year. Nevertheless the IH team and the Working Group stand by the proposition that it is feasible to instrument these catchments and that the resultant data obtained will be of an acceptable standard.

The Catchments

Figure 1 shows the location and relative positions of the two catchments. Whilst not immediately adjacent they are similar in size, aspect and altitude range. Geology and soils are also similar, though there is an area of relatively flat deep peat in the upper basin of the Monachyle which is absent in the Kirkton. The Kirkton (Fig 2) covers approximately 685 ha of which 275 ha is under mature plantations of spruce, larch and pine. The Monachyle (Fig 3) of 770 ha is under a vegetation cover similar to that above the tree line in the Kirkton; it comprises a mixture of upland grasses, heather and bracken. The grasses dominant on the lower slopes, give way progressively to heather as the altitude increases. There are considerable areas of exposed rock in both catchments.

The raingauge network and the weather stations

The storage raingauge networks were designed using domain theory with altitude, aspect and slope as the variables. The theory was translated into practical on-site locations in April and the first phase of installation, using cross-country vehicles, took place in May. The Automatic Weather Stations in Monachyle and on the Western ridge of Kirkton were also installed during this period. In July a helicopter was used to reach the more inaccessible sites and the remaining gauges in the forested area of the Kirkton were installed.

Outside the forested area all raingauges are in grid-covered pits with their funnels at ground level and parallel to the slope. Within the forest, specially modified 1 metre high gauges are sited in suitable small clearings. The aerodynamic effects which could result in serious underestimation of rainfall by such gauges in the open are considered to be negligible in these clearings. Some justification for this has been obtained from a comparison of catches with adjacent ground level gauges in two clearings, as shown in Figure 4. Data from the recording rain gauges attached to the weather stations and from the additional event recorder in the upper Monachyle are used to distribute in time the catches of the monthly storage gauges.

The Automatic Weather Station in the Monachyle is a standard Didcot Instruments type recording, at 5 minute intervals, solar and net radiation, temperature, depression, windspeed, wind direction and rainfall on magnetic tape. Tape and batteries are changed at fortnightly intervals. In view of the potential difficulties of access, the station on the western ridge of the Kirkton has been set to record at 15 minute intervals and battery power is maintained using a solar panel. This station can operate unattended for over two months, though when conditions permit the tape is changed fortnightly.

Assessment of snow input

Whilst ground level gauges give the best measure of liquid precipitation input, they are of little value when input is in the form of drifting snow. Snow input estimation presents particular difficulties in this type of steep uneven terrain. Further constraints arise in this case from the difficulty

of access in snow conditions and the presence of only one observer. The first winter had to be a period of experimentation to assess the performance and feasibility of various techniques.

It was recognised that the best chance of actual snowfall measurement was in the small clearing sites in the forested area of Kirkton, where lateral snow movement would be minimised. Hence in these clearings the 1 metre tall funnelled gauges mentioned above were designed to measure snow as well as rain inputs. As rainfall data accumulate it should be possible to determine the relationships between the ground level gauges and these clearing gauges. A first estimation of snow input at all other sites can then be obtained by assuming that the relationships determined for rainfall are also applicable to snow.

Since it is not feasible to consider systematic depth/density snow coursing after each snow event, other approaches were considered. In November sparse networks of snow poles were installed on a domain basis with the design constraint that they could be read, by tripod mounted telescope, from a few key observation points. The intention was that these, coupled with an altitude range of density measurements, would give some estimate of input for comparison with the extrapolation from the forest gauges.

A third approach adopted was to identify a few 'neutral' sites in key altitude/aspect domains and install snowmelt gauges at these. 'Neutral' in this context implies sites unlikely to be subject to excess accumulation or scouring of drifted snow. The melt gauge comprises a ground level mounted gauge with the funnel covered with porous plastic grass. Three storage and one recording version of these gauges were installed in each catchment in November/December.

Streamflow measurement

From the outset it was recognised that the design and installation of structures to give accurate estimates of streamflow from these catchments would present difficulties. With the agreement of the Consortium the Hydraulics Research Station were commissioned to design appropriate structures. Surveys of the reaches they suggested were carried out by Forth River Purification Board and drawn up by North of Scotland Hydro Board. An

assessment of the likely range of flows in each was carried out by IH. From this information HRS produced hydraulic designs and recommended sites for them in June. Consideration of the engineering problems posed indicated that the HRS sites were not feasible. Alternative sites were identified on which the basic HRS designs could be used and a full engineering drawing of the Kirkton structure was produced by SDD in September. Forestry Commission undertook to build the structure, with IH supplying the steel crests, and site preparation commenced in November. Severe conditions in December and January 1982 delayed the work but completion of site preparation and construction is now scheduled for as early as weather permits in April 1982.

The Monachyle structure presents greater practical problems than the Kirkton one. Whilst an alternative site which will require less concrete than that proposed by HRS has been identified, there is an additional problem in that the present access track will not withstand the passage of the heavy plant and materials required for construction. The first kilometre in particular is a private farm track which would require major reconstruction to take the loads. Negotiations to build an alternative access over the first kilometre are proceeding with Forestry Commission. Assuming that these are successful a target of site preparation and construction in late summer 1982 should be feasible. Because of the delay Forth River Purification Board agreed to install a temporary gauging station and cableway upstream of the structure site to provide some initial estimates of flow.

Meteorological site and the Third Weather Station

The agreed programme of instrumentation included the installation of a manually read meteorological site to be supplied by Meteorological Office and an adjacent automatic weather station. These were to be sited at low level in a position accessible under all conditions by the observer resident in Tulloch Lodge, the objectives being to obtain base level data against which any gaps in the high level station records could be infilled and to provide a comparison of manual and automatic systems. The site originally proposed proved to be fraught with local political difficulties and eventually had to be abandoned. Access to an alternative site was negotiated and planning permission for this site was received in February 1982. Installation is now in hand.

Data Analysis and instrument assessment

In terms of the overall objectives of the project no meaningful analysis is possible yet on the short runs of data accumulated. Nevertheless these data have provided useful indications of instrument performance and suitability for the job. Figure 4, for example, provides some initial justification for the use of the combined gauges in the forest clearings to provide usable rainfall data. Indirectly it also illustrates a problem during snow events. Whilst the main reason for the discrepancy between the A3Y ground level and combined gauge during the snow period was an accumulation of a snow drift over the ground level gauge, part of it was due to 'bridging' of the combined gauge funnel and partial loss of the snow built up on the bridge. This problem was observed to occur on several occasions. Redesign of the funnel rim of the gauge has been done and a revised version is now on test alongside A3Y.

A series of irritating teething troubles with the Monachyle and Kirkton Weather Stations, none of them related to site conditions, delayed the start of usable data until August. Since then they have performed reasonably well, though data were lost for part of January when it proved impossible to reach the Monachyle site to change tape and batteries. The Kirkton station appeared to survive this period reasonably well, though the data suggest that icing may have affected some of the sensors intermittently. December and January temperatures made it abundantly clear that the temperature range of the sensors will have to be extended downwards from the present $-15^{\circ}C$ limit.

No useful information was obtained from the snowpoles during the December/ January snow events. Access to the selected observation sites immediately after some snowfall events was not possible with the equipment required. On other occasions low cloud made it impossible to 'read' the poles from the sites. Clearly some re-thinking of the approach is required during the coming year.

Lessons learned

(1) Reading the storage gauge networks, and the other instrumentation at the required intervals is feasible with one observer during no-snow conditions.

(2) In snow conditions an additional observer on site is essential to obtain a useful return on the investment in instrumentation. Working together they would increase the effective radius of operation in the catchments and, when conditions permit them to work individually, they could increase the possible work load in the short periods of winter daylight.

(3) With increased experience the observer should be able to make greater use of the existing IH cross country vehicle as a means of access to the catchments in deep snow conditions. A suitable tracked vehicle could increase the limits under which access is possible. Within the catchments, skis are the only practical means of travel above the valley bottom in Monachyle or above the tree-line in Kirkton. This limits the observer's ability to carry batteries or other equipment and is a constraint that must be borne in mind when redesigning snow measurement techniques.

(4) Solar cells and wind generators to sustain battery power have proved practicable in the environment of the catchments; these, together with long duration logging equipment, should be used for winter data collection whenever possible.

1982/83 Programme

Following the anticipated installation of the meteorological site and the third weather station in March the next priority for the coming year is the construction and instrumentation of the Kirkton Weir in April.

Decisions on improving access to the Monachyle must be made in March if that structure is to be completed in the summer.

Beyond that, a decision must be made on whether to proceed with the proposed second structure in the Monachyle (Figure 3) and appropriate action taken.

During the summer the snow measurement systems must be modified to give a better return of data consistent with the difficulties of access. With minor modificiations the combined clearing gauges in Kirkton have proved adequate but the snow pole system must be modified. No judgement can be made on the snowmelt system until the readings have been recovered and examined.

With the completion of the streamflow structures accumulation of full hydrological data will begin.

Thereafter sediment loads can also be measured using the structures as bedload traps. Observation suggests that suspended sediment loads are very low but a systematic sampling programme will be initiated following completion of the structures.

JRB/JVP

Catchment Studies

Work programme
summary

1981

January - March	Site investigations at Balquhidder. Access agreements with landowners. Surveys of streamflow structure sites. PR work with local residents. AGREEMENT TO PROCEED WITH BALQUHIDDER CATCHMENTS.
April	Raingauge network design completed. Sites identified and flagged in catchments. Sites for weather stations identified.
May	Tulloch Lodge made available to IH. Phase 1 of raingauge network installation. Kirkton and Monachyle AWS installed. Site meeting - Consortium working group.
June	Structure designs received from HRS.
July	Mr Johnson took up post as observer, based on Tulloch Lodge. Phase 2 of raingauge network installation. Site visits to examine alternative structure sites on Kirkton and Monachyle.
August	Surveys of alternative structure sites (FRPB). Drawings of structures prepared (SDD). Routine rainfall and weather station data collection initiated.
September	Combined snow/rainfall gauges installed in clearings in Kirkton. Design of additional snow networks.
October	Temporary gauging station installed in Monachyle (FRPB) Neutron probe networks under heather (Monachyle) and spruce (Kirkton)
November	Installation of snow poles and snowmelt gauges. Rock blasting at Kirkton structure site (FC).
December	Installation of snow throughfall gauges in Kirkton forest site. Planning applications submitted for Met site and streamflow structures.

1982

January	Heavy drifting of snow created severe access problems for resident observer.
February	Wind generator installed to power snowmelt gauge in Kirkton. Site meeting (SDD, IH, FC) to finalise construction plans for Kirkton structure and to consider Monachyle site and access problems.
March	Third weather station and manual met. station installed on Tulloch farm site.

Table 1

Instrumentation installed on the Balquhidder catchments.

Item	KIRKTON (Forested)	MONACHYLE (Control)
Automatic Weather Stations (incorporating recording raingauge)		
Ground level storage raingauges	6 (+ 3*)	
Rainfall event recorders		(+ 1†)
Combined snow/rainfall storage gauges		
Recording snowmelt gauges		
Snow poles		12
Streamflow structures	1 (Spring 82)	1 (Summer 82) 1 (Autumn 82 provisionally

In addition, one site under heather (Monachyle) and 1 under spruce (Kirkton) have been instrumented for soil moisture studies and a site under spruce (Kirkton) has been instrumented to measure snow throughfall.

* These are located alongside 3 combined gauges for comparison purposes.

† This is a Met Office MTER alongside the Weather Station.

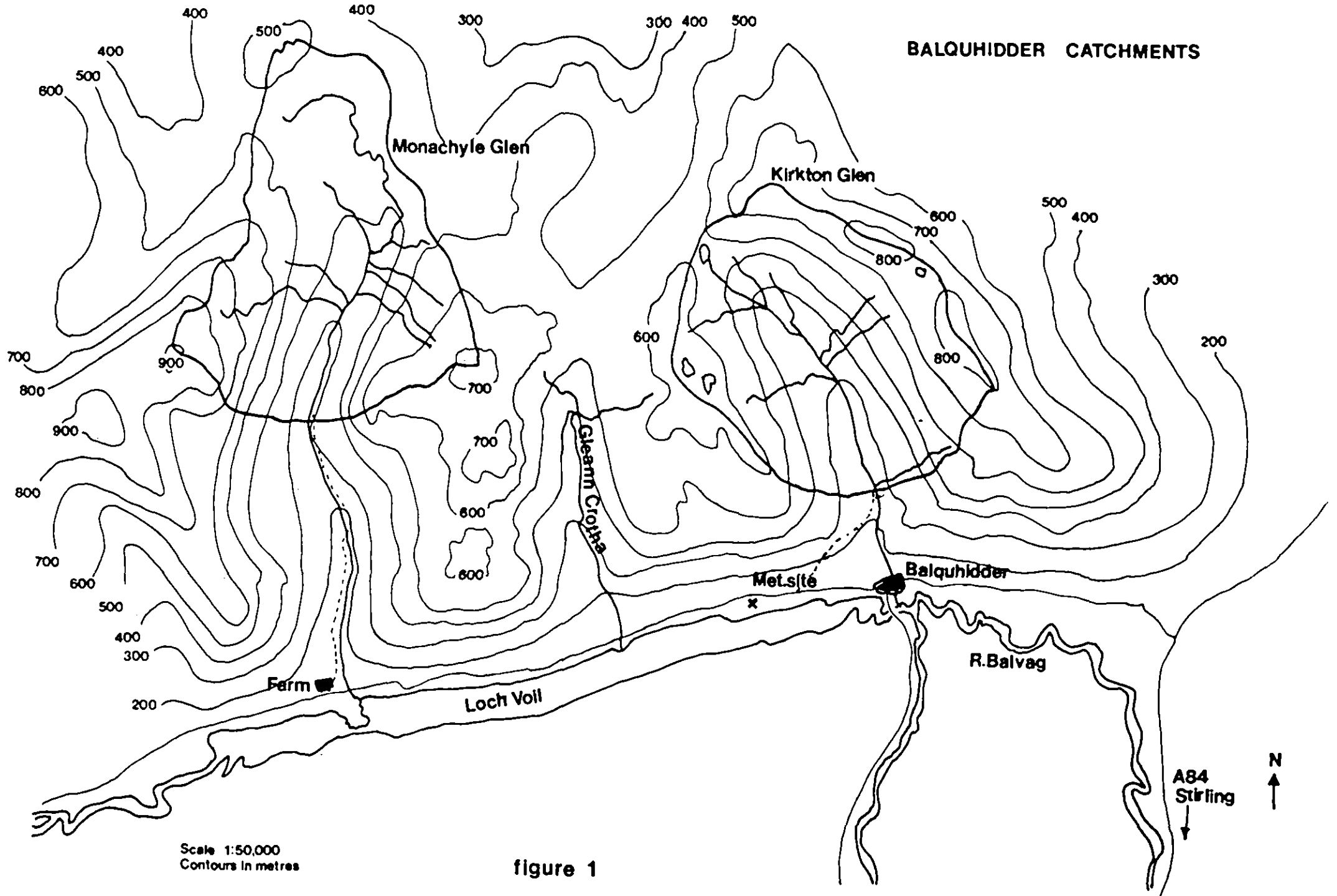
BALQUHIDDER CATCHMENTS
Monachyle Glen
Kirkton Glen
Gleann Croitha
Met.site
Balquhidder
R.Balvag
Farm
Loch Voil
A84
Stirling
N
Scale 1:50,000
Contours in metres

figure 1

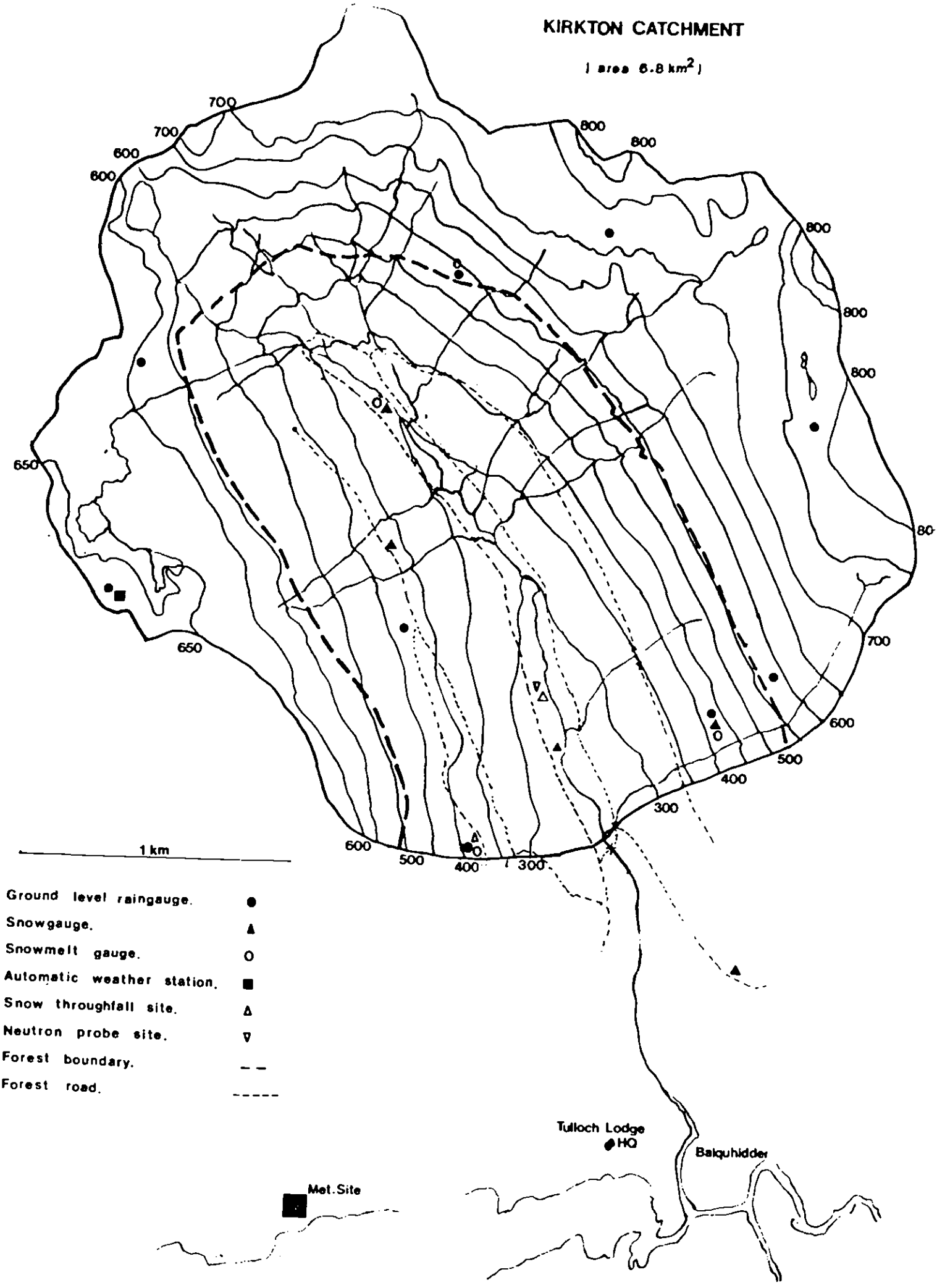
KIRKTON CATCHMENT
(area 6.8 km²)
700
700
600
600
800
800
800
800
800
650
650
700
600
500
400
300
600
500
400
300
1 km
Ground level raingauge.
Snowgauge.
Snowmelt gauge.
Automatic weather station.
Snow throughfall site.
Neutron probe site.
Forest boundary.
Forest road.
Tulloch Lodge
HQ
Balquhidder
Met.Site

figure 2

MONACHYLE CATCHMENT (area 7.7 km^2)

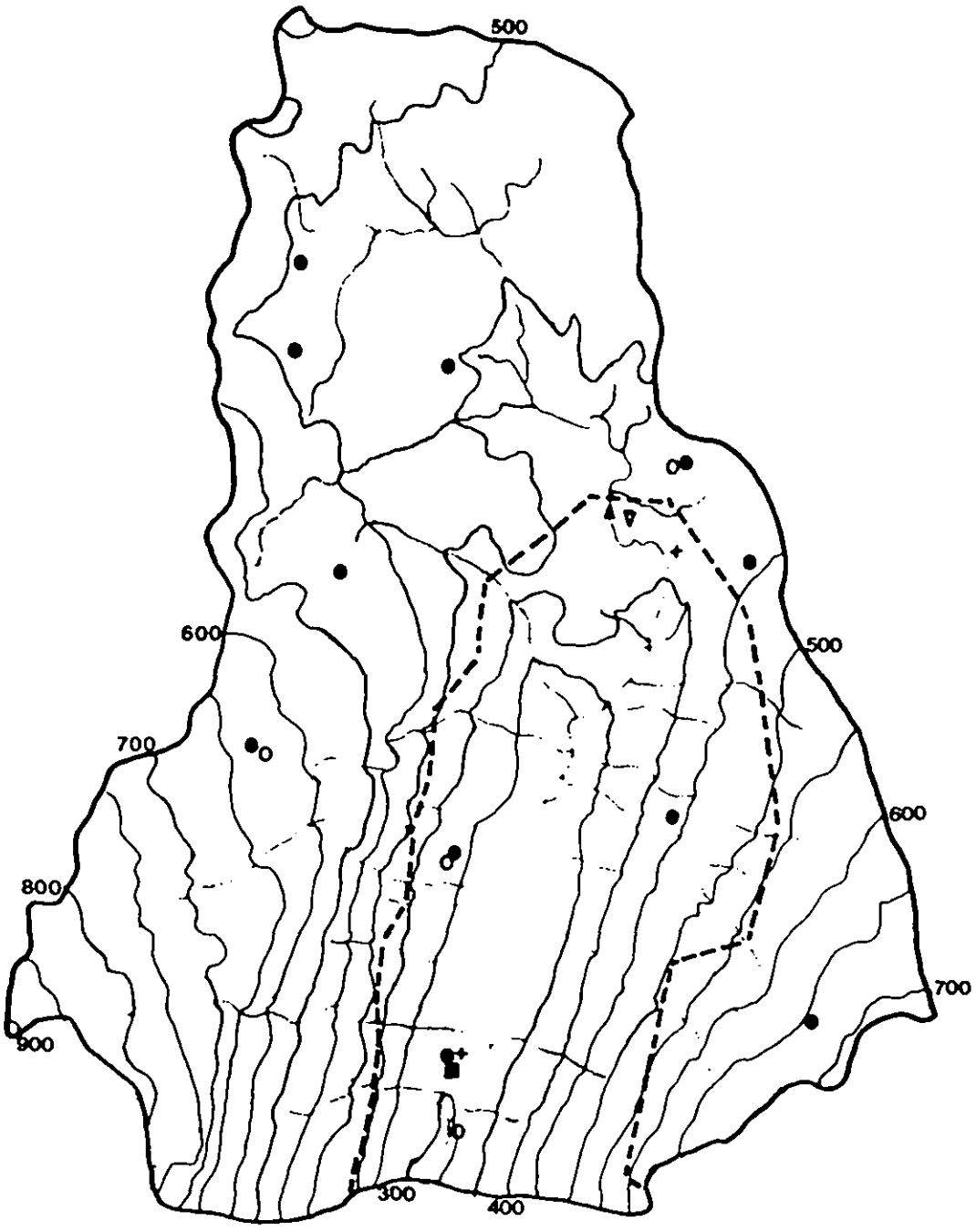

figure 3

KIRKTON RAINGAUGE COMPARISON

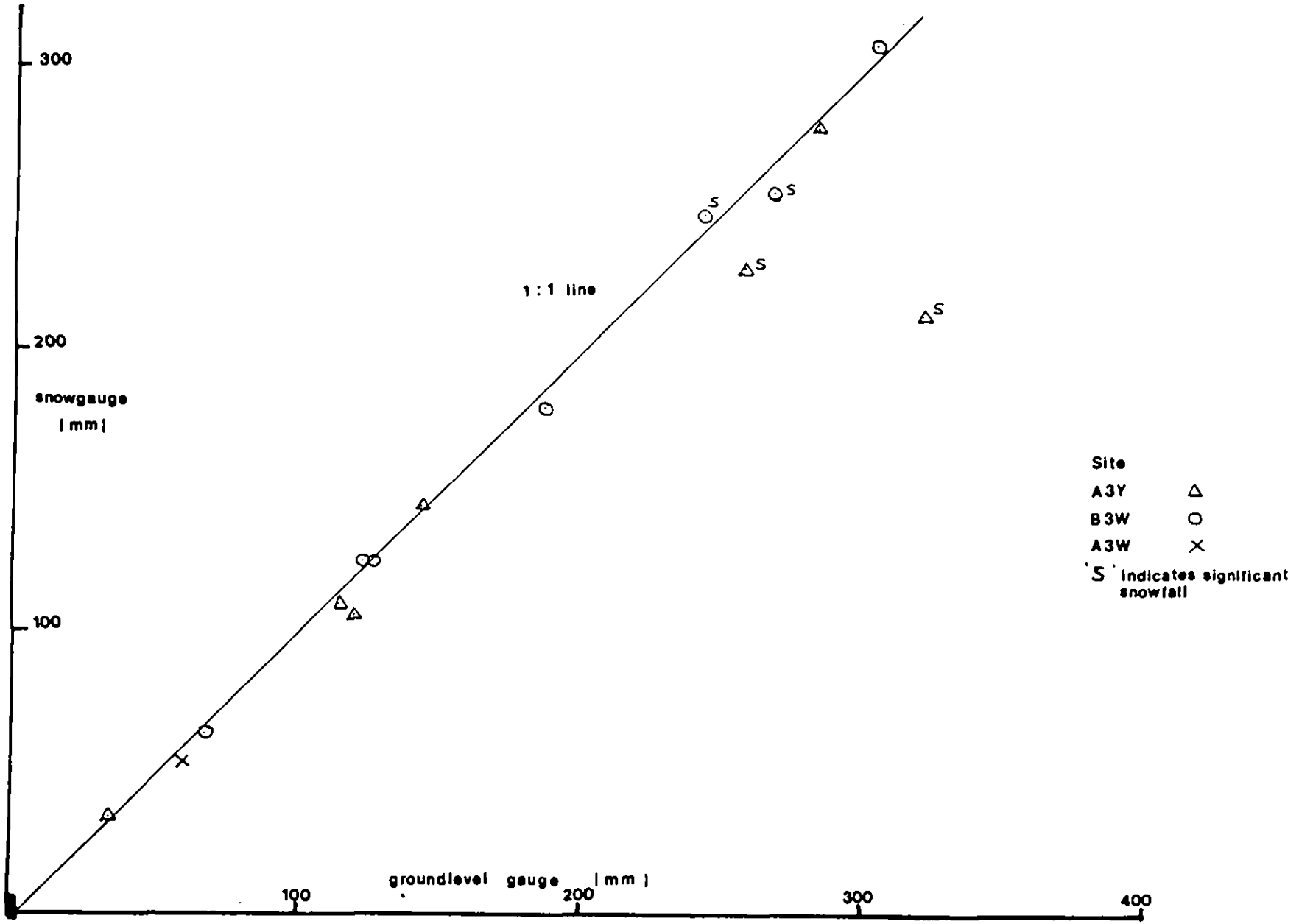

figure 4

Natural
Environment
Research
Council