I N S T I T U T E
O F
H Y D R O L O G Y

SELECTED MEASUREMENT TECHNIQUES IN USE AT PLYNLIMON EXPERIMENTAL CATCHMENTS

ABSTRACT

The nature of the Plynlimon experiment and the physical conditions prevailing have led to the adaptation of standard instruments and the design of new ones. This report deals with measuring devices for rainfall at both ground and canopy level, throughfall and stemflow beneath the forest canopy, snowmelt, and streamflow from small sources. The emphasis is on instrument design and operation, not theory

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PREFACE

Few experiments in the environmental sciences are ever conducted throughout with 'off-the-shelf' instrumentation. Since good instruments should not interfere with their environment, those commercially-available suited to 'average' conditions need adaptation to be harmonious with specific conditions.

The design and construction, or modification, of an instrument (even a 'coarse' one) involves much time and labour. If the instrument works satisfactorily, the experience of the designer should be passed on quickly to those faced with similar instrument problems, except of course where he wishes to turn his experience to commercial advantage!

The Institute is frequently consulted on the topic of instruments for research on the water balance of upland catchments, haven trodden new ground in many respects with the Plynlimon project. It has hitherto shared its expertise by correspondence. The report gathers together a compendium of techniques used at Plynlimon, some for routine measurements, others for the study of hydrological processes. The authors are those individuals who have spent considerable time patiently developing the techniques; thus theoretical background is very much subordinate to practical details. Where suppliers of materials are quoted this does not mean official endorsement by the Institute; prices quoted are for the rapidly changing financial period 1974-75.

M D Newson

August 1977

I: RAINFALL

Two research raingauge installation procedures from the Plynlimon catchments

A. J. Bucknell, P. J. Hill and A. J. Newson

Introduction

The following account is designed for those confronted with rain-gauging for research projects involving exposed sites with short vegetation (ground-level gauge), or sites of any exposure with dense forest cover. Both are suitable at either plot or catchment scale but in the latter case obviously network considerations also need to be evaluated before gauges are chosen. For the theoretical background to the selection of the gauges and to results from them the reader is referred to published sources (section 4).

1. The ground-level raingauge

Systematic errors in rainfall measurements from exposed locations using the standard raingauge (which protrudes 30.5 cm above ground level) have long been suspected. Use of a turf wall surrounding the gauge or careful choice of a more sheltered raingauge site have both been advocated as solutions to the problem. However, following the work of J. C. Rodda, the Institute of Hydrology has adopted a ground-level gauge, the orifice of which is set parallel to the surrounding ground surface, even if sloping (see Plates 1 and 2). The raingauge itself is the standard period gauge (Octapent) and only if a recording gauge is substituted (either siphoning or tipping bucket-types) will the so-called stereo arrangement be needed; i.e. the gauge set vertically to permit normal siphoning or tipping actions but the orifice tilted.

A corollary of the ground-level configuration for raingauge networks in catchment experiments is that, since the sample catch is made parallel to ground slope, the use of rainfall 'domain' theory, in which all significant combinations of slope, aspect and altitude over a catchment area are sampled becomes obligatory. Domain theory was used at Plynlimon as a deterministic guide to raingauging networks, although subsequent statistical analyses have shown that fewer gauges are required for monthly totals than suggested by domains (Clarke, Leese & Newson, 1973)

The raingauge pit and frame

Perhaps the most problematic aspects of the choice of ground-level gauging are those concerned with digging the large pit to surround the gauge, the drainage of this pit, the protection of its walls and the surrounding of the gauge orifice with an anti-splash grid.

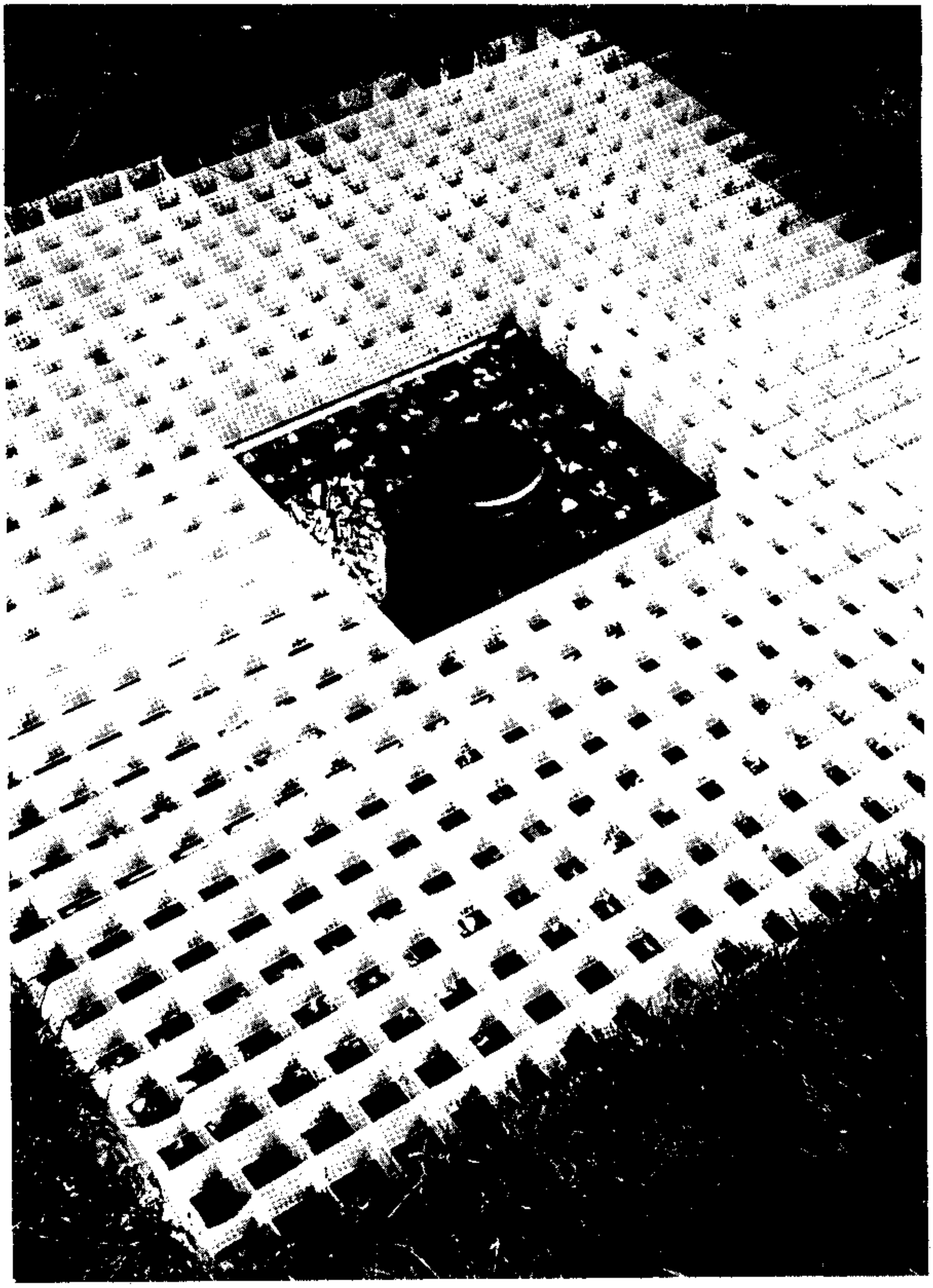

PLATE 1 Ground-level raingauge, showing anti-splash grid

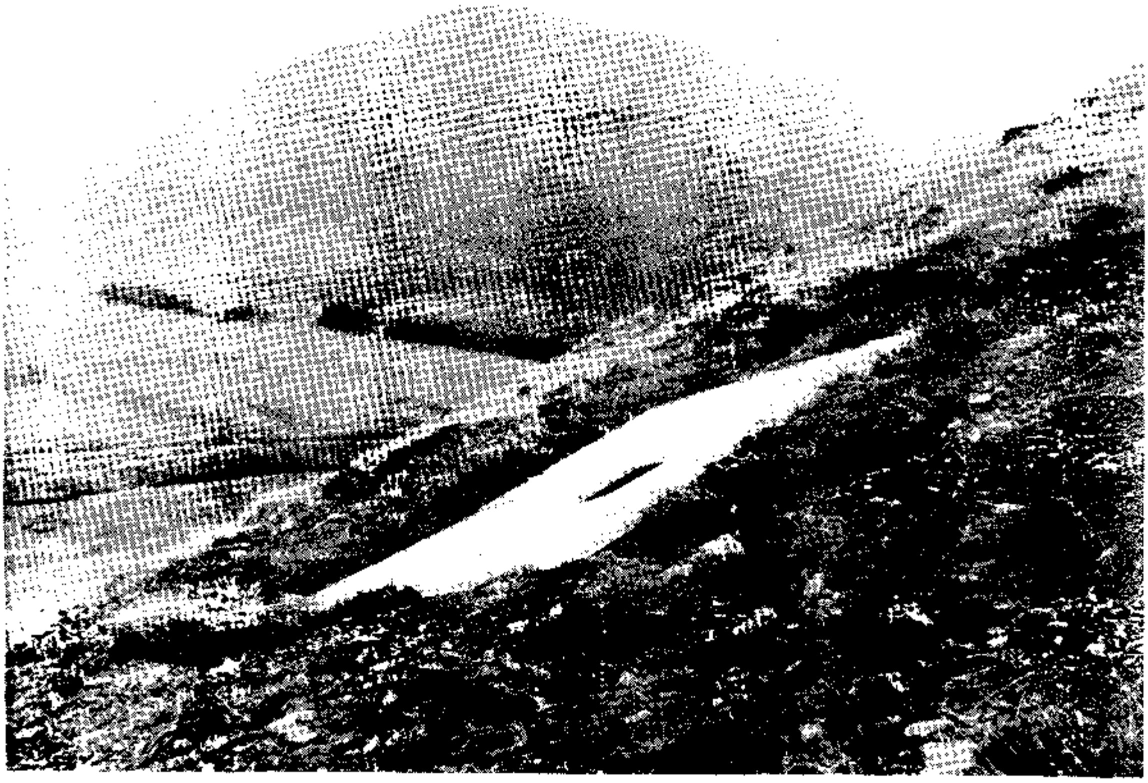

PLATE 2 Ground-level raingauge installed on steep incline, Wye catchment, Plynlimon

The gauging site is chosen at a random point within the domain to be sampled, using a grid on a detailed field map (1:5000 at Plynlimon). (In the case of small field studies or plot studies, where only one or two gauges are required, obviously some more subjective location procedure can be employed). The slope and aspect of the chosen site are checked in the field with compass and Abney Level. The exact location of the site is where the domain criteria are fully met - the nearest position to that chosen randomly from the map should be adopted but if access for vehicles and materials is difficult, or the site itself is solid rock or boggy, an alternative random location can be selected from the map.

The pit is excavated by hand, or mechanically if feasible, to a depth of 80 cm and 130 cm square, with one diagonal aligned to the slope aspect (in other words pointing downslope). Next, a wooden frame, whose dimensions are illustrated in Figure 1, is assembled on the site and inserted to prevent the sides of the pit from collapsing (alternatively a ready-made frame can be taken to the site by vehicle if access is good). Protection with the frame has been found essential in the organic or poorly cohesive mineral soils of Plynlimon. The raingauge is then installed to meet the criteria of slope, aspect and ground-level at its orifice. It is fixed by screwing small blocks of wood

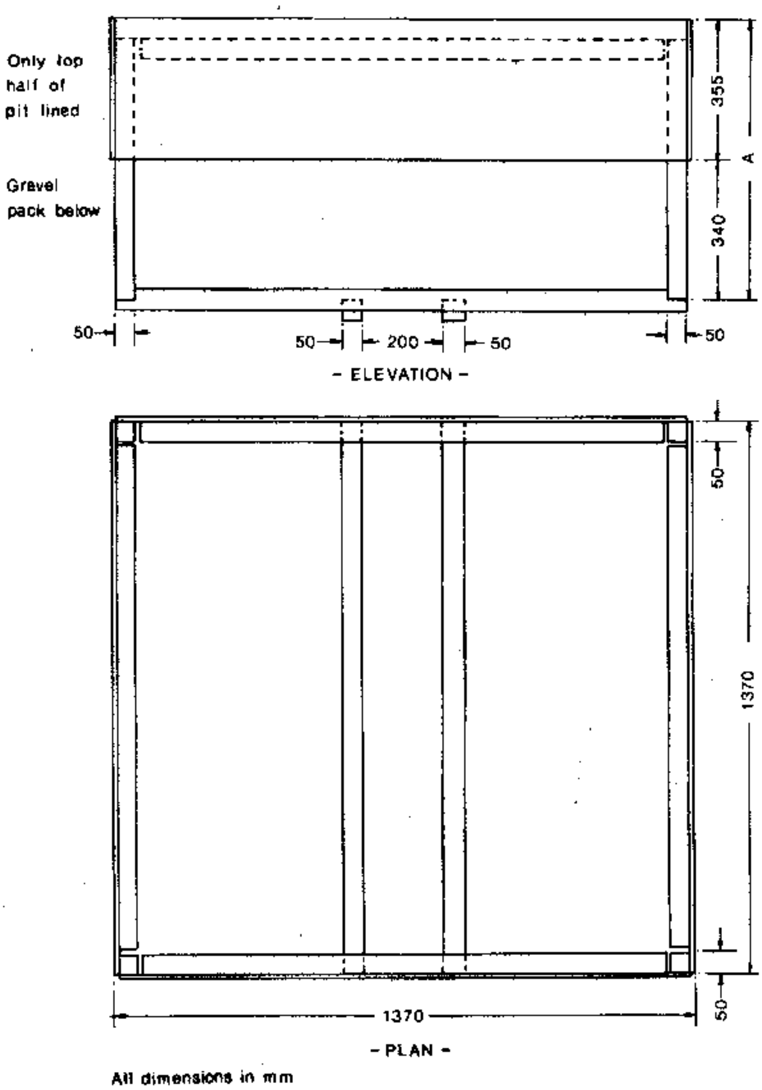

FIGURE 1 Ground-level raingauge frame

to the basal cross members of the frame, across the basal lip of the raingauge outer container (See Figure 1). Thus, care in constructing the frame is needed to make sure that these cross members accurately bring the gauge orifice into correct alignment once the base of the gauge is fixed to them; this is a good reason for frame construction to be completed before field installation. In many locations drainage of the pit through its downslope corner is essential, using plastic downpipe. The pit surrounding the gauge is now filled to 30 cm from the ground surface with gravel. Experiments in which the gravel was replaced with a plywood 'false floor', 30 cm below the anti-splash grid were conducted in an effort to prevent corrosion by acid soil water but the void gave less insulation to the gauge than the gravel packing and the gauge contents often froze in winter. The problem of corrosion, which particularly attacks the solder of the raingauge seams, has largely now been solved another way by painting with Dulux chlorinated rubber paint (thick coat, brushing) before installation.

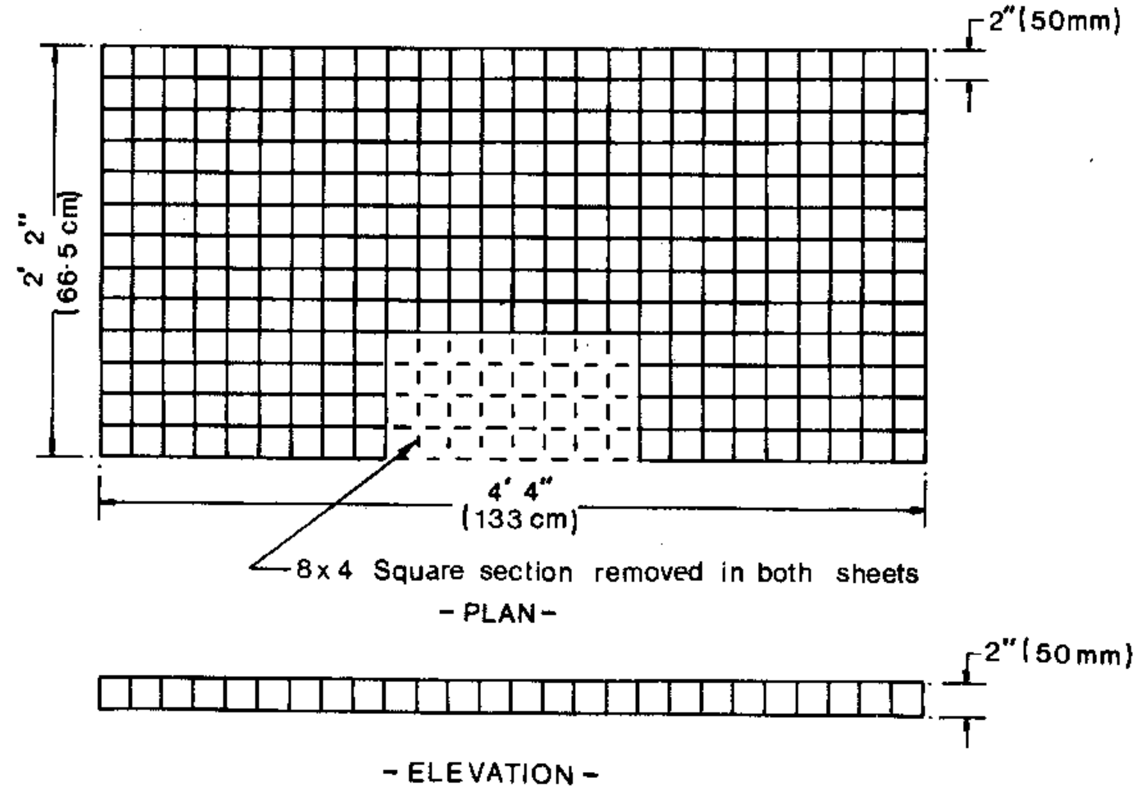

FIGURE 2 Ground-level raingauge anti-splash grid (one half)

The anti-splash grid

This was originally workshop-constructed in metal, but is now made of a proprietary material, namely plastic egg-crate louvring designed for interior lighting (see list of suppliers, Section 3). Two sheets are needed and the gap for the gauge orifice is created by sharply tapping the grating; dimensions are shown in Figure 2. The grid is supported by two lengths of wood across the full width of the pit; support is essential, especially in snow.

Marking the site

As a further precaution against snow, the position of the gauge is marked with a post, five paces to the north of the gauge (or some other strict relationship). Even when snow does not completely cover the gauge such a post is very helpful to find the gauge in moorland country, or in fog.

Routine maintenance

This is absolutely necessary. Leakage of the outer container may require pumping and eventual soldering, re-painting or replacement. The growth of vegetation in the pit should be prevented by weeding the gravel, at least annually.

PLATE 3 Ground-level raingauge - installing frame

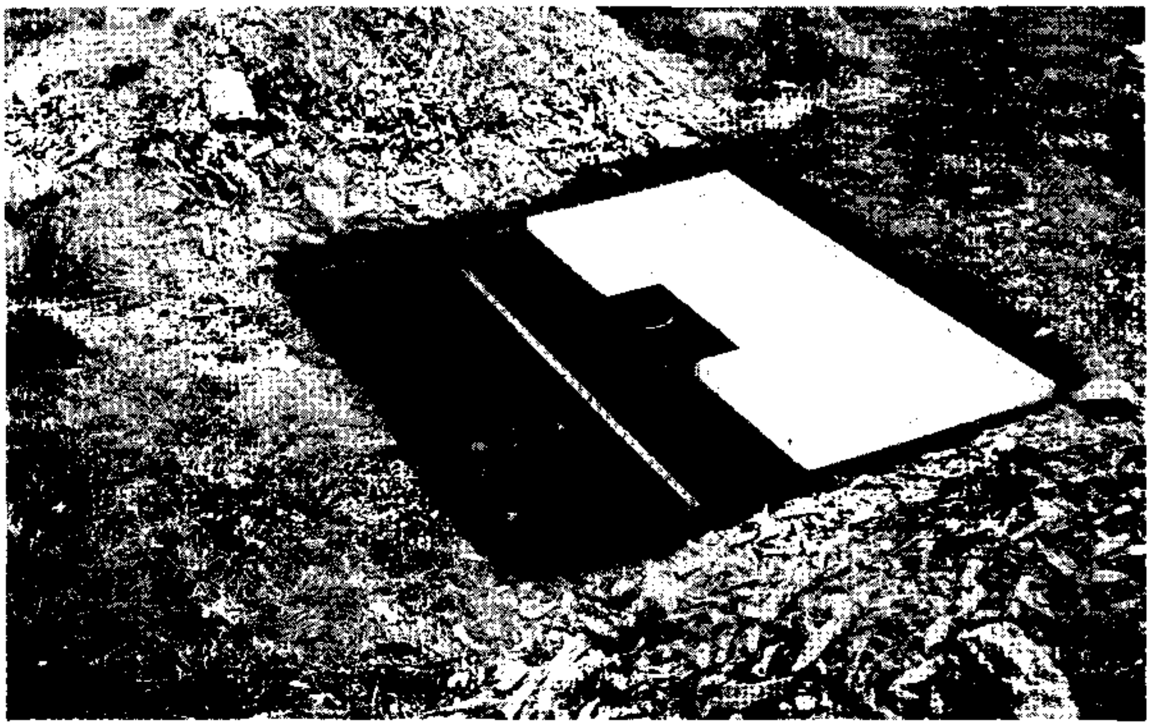

PLATE 4 Ground-level raingauge with half the anti-splash grid in place

2. The canopy-level raingauge

In studies of rainfall interception by forest canopies and in less detailed catchment investigations where insufficient clearings exist in the forest for ground-level raingauging, the canopy-level (or mast-head) gauge is essential. It consists of a funnel with its orifice horizontal mounted on a scaffolding mast just clear of the canopy, Plate 5. The sheet copper funnel has the standard 5 inch (12.7 cm) diameter, with slant length 3.5 inches (8.9 cm), feeding into 0.5 inch (1.3 cm) copper tube. The funnel is held horizontally in place by a metal cap which fits the top of the scaffold tube, screwing against it and giving some scope for level adjustment. Both funnel and cap are made in the Institute's workshops. Polythene tubing (1.0 cm internal diameter) connects the funnel to the collector at the base of the mast; this is a storage gauge, modified so that the removable top of the conventional gauge is replaced with a firmly fitting copper lid, penetrated by a tube which links polythene tube and inner container. The mast has a concrete base block and three guy wires, secured to concrete blocks with pre-cast reinforcing hoops, form additional supports. Metal rings need to be welded to each of the steel scaffold poles used for attachment of guys at the mast end. The safest way of securing the base of the mast is by casting a piece of angle iron into the base block and connecting the mast to it with U-bolts. Experiments have indicated that highest rainfall catch occurs with the funnel well clear of the forest canopy rather than at 'mean' canopy level, where turbulence may influence catch. This matter is not yet fully resolved.

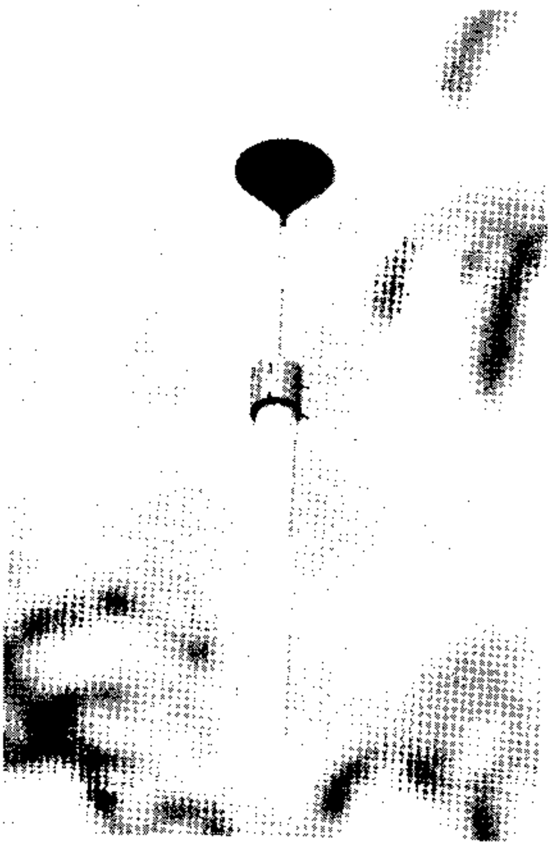

PLATE 5

Canopy-level raingauge funnel

Funnel height is a problem, especially in a rapidly-growing tree crop such as conifers. The scaffolding and guy construction is difficult to assemble in the first place and even more difficult to raise in order to keep pace with the trees' growth. The initial joins in the mast etc should be well-greased; this helps when raising the mast. Available pump-up telescopic masts do not reach far enough for the highest canopies and are very expensive. The highest gauge so far constructed according to the description above (see also Figure 3) is 15 m, comprising two 6 m steel poles surmounted by part of a 6 m alloy pole.

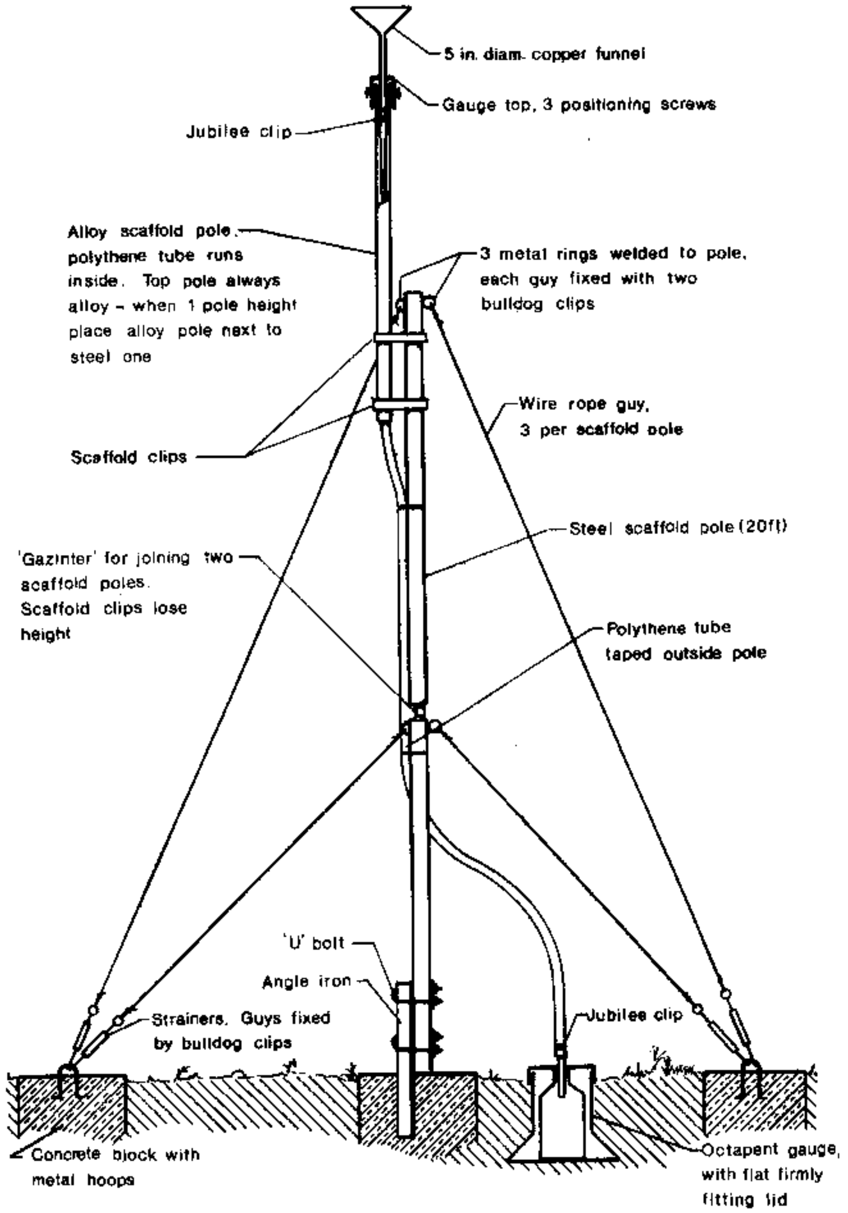

FIGURE 3 Canopy-level raingauge

Maintenance

Routine maintenance for the canopy-level gauge consists of keeping a check during readings of the gauge that the trees have not overtaken it, that the funnel is not damaged by strong winds and that there are no blockages. As with all rainfall data, early inspection and quality control of the data helps field workers detect instrumental error.

3. Materials and Costs

Ground-level gauge installation

Wooden frame - 9 mm exterior grade ply-wood. Approximately 50 sq ft is required for full protection of pit walls or half this area if the walls are terminated at the gravel surface, i.e. only the exposed upper part of the pit is protected (see Figure 1).

Supports and strengtheners - 2 in x 2 in sawn timber, total length 55 ft (1 in timber is sufficient to support the plastic grid - 9 ft required).

Screws - 50 x 2 in, No. 8

Creosote to protect the wooden frame.

Two plastic egg-crate louvres, supplied by Elco Plastics Ltd.,
High Wycombe, Bucks
High Wycombe 22164

Canopy-level gauge installation

Funnel

Gauge top (cap to fit scaffold)

Modified rain collector

Polythene tubing, 10 mm i/d

Scaffold poles (20 ft 6 m lengths) and junctions ('Gazinters')

Wire rope and bulldog clips to attach to strainers

Galvanized barrel wire strainers (8 in, with hook and eye)

Jubilee clips (two for top and bottom polythene tube connections)

U-bolts and angle iron or scaffold base plate.

Note

During installation it is advisable to wear safety helmets and to take a 30 ft (9 m) ladder, pulley and rope, spirit level, wire-cutters etc. The installation is much more involved than that for ground-level configurations.

Total costs for one installation (1975 prices)

Ground-level raingauge:	8' x 4' ⅛" plywood	£10.00
	2" x 2" rough sawn timber	7p per foot
	1" x 1" " " "	3p " "
	50 No 8 2" screws	60p
	1 gallon creosote	1.00
	2 egg crate louvres	10.00
	total cost, one pit liner	£ 25.50
Canopy-level raingauge:	Scaffold poles steel 20'	6.00 each
	alloy 20'	9.50 each
	clamps	1.50 each
	polythene tube	30p per metre
	strainers	1.50 each
	wire rope (6mm) 50 m coil	12.00
	total cost, one two-pole assembly	£35.00

4. Relevant publications:

General and ground-level

Robinson A. C. & Rodda J. C. 1969 Rain, wind and the aerodynamic characteristics of raingauges. *Met. Mag.* 98, 113-120

Rodda J. C. 1967 The rainfall measurement problem. *Proc. Berne Assembly, IASH Pub.* 78, 215-231.

Rodda J. C. 1971 Report on precipitation. *Bull. IASH,* 16(4), 37-47

Rainfall domains and analyses

Clarke R. T., Leese M. N. & Newson A. J. 1973 Analysis of data from Plynlimon raingauge networks April 1971 - March 1973. *Inst. Hydrol.* Rept. 27.

Canopy-level gauges

Clarkson L. S. 1973 The performance of a mast-top raingauge in the field. *Met. Mag.* 102, 82-85.

Newson A. J. & Clarke R. T. 1976. Comparison of the catch of ground-level and canopy-level raingauges in the Upper Severn experimental catchment. *Met. Mag.* 105, 2-7.

II: NET RAINFALL - BELOW THE FOREST CANOPY

Plynlimon through-fall troughs and stemflow gauges

I. R. Wright

Introduction

In the study of rainfall/runoff relationships in a mature forest the process of interception of rainfall by the forest canopy means that inputs to the slope runoff and soil moisture regimes need to be measured to compare with inputs at canopy level (see Section I). There are two main routes by which the net inputs from canopy-level rainfall reach the forest floor: throughfall and stemflow. The former occurs by raindrops finding a direct path through the canopy or by dripping from the branches; it is consequently a variable amount and needs more than a conventional raingauge on the forest floor to sample it adequately. Consequently, rather than operate batteries of raingauges (although these are used to discover the pattern of through-fall) large troughs, integrating throughfall over a large area, are used for routine through-fall measurements at Plynlimon. Stemflow is, of course, localised by the tree trunk and must be caught and lead away to a measuring device.

1. Design considerations for throughfall troughs

Two types of trough are used at Plynlimon, metal and glassfibre (see Plate 6). Initially, one trough made in resin-bonded glass fibre was installed at each of six interception sites and the work contracted out. The design of these troughs is the same as the more recent metal troughs (see Figure 4) except in the finer constructional details associated with the material.

When the number of troughs was expanded (six more troughs at each site, plus an extra site with six and a more intensive main site with eighteen) the sixty extra troughs required were produced by the Institute's workshop at Wallingford. They were constructed of prefabricated mild steel sheet, spot-welded together and finally galvanized.

The most important dimensions of the troughs are the internal length and internal width; these dictate the effective collecting area. They need to be deep enough to allow the storage of snow which can then melt in the gauge and run out for measurement. Further, if the gauge becomes blocked at its outlet by conifer needles there is a certain volume of storage: the catch is not entirely lost. The troughs should be kept as clean as possible to minimize evaporation loss from damp trash in the trough and the diameter of the outlet should be large enough to prevent frequent blockage.

The troughs are tilted for rapid transfer of the water to the measure-

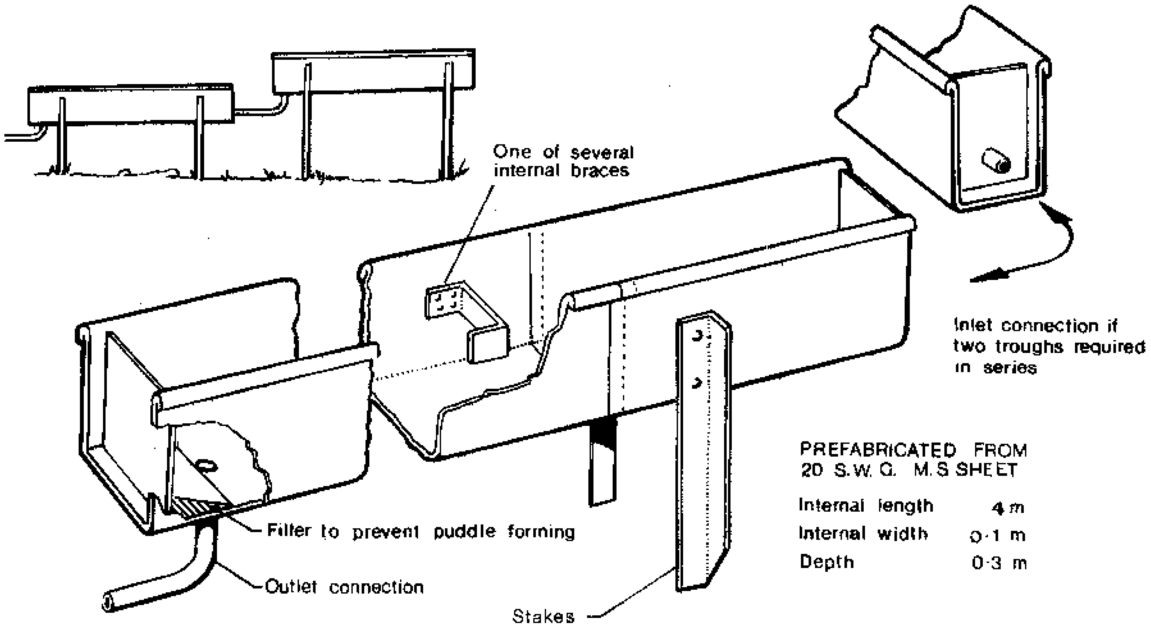

FIGURE 4 Construction details of metal throughfall troughs

PLATE 6 Throughfall troughs, Severn catchment, Plynlimon

ment device. The gradient at which the trough is installed is a compromise to suit individual requirements. A shallow tilt increases the response time of the gauge and increases evaporation loss. A steep tilt means that the flow is fast enough to wash any trash towards the drain hole. If trash from the tree is not a problem then the steepest limit is reached when the plan area of the trough is significantly reduced.

The troughs are supported by steel angle-iron stakes to which they are bolted. The method of support should not of course hinder the collecting area of the trough.

2. Design considerations for stemflow gauges

Two main types of stemflow gauge can be used: the collar type and the spiral type. The spiral type diverts the water from the tree trunk into a spiral gutter and the water is led away from the bottom. These are not now used at Plynlimon because of the problem of tree litter. The slanting channel catches litter and the water washes it into the outlet measuring-system causing inaccuracy and blockage.

The collar type has a collecting collar concentric with the tree in which the water is trapped (Plate 7 and Figure 5). Although these also collect tree litter, they are much less liable to suffer as the needles are not so easily washed into the gauge (slower moving water).

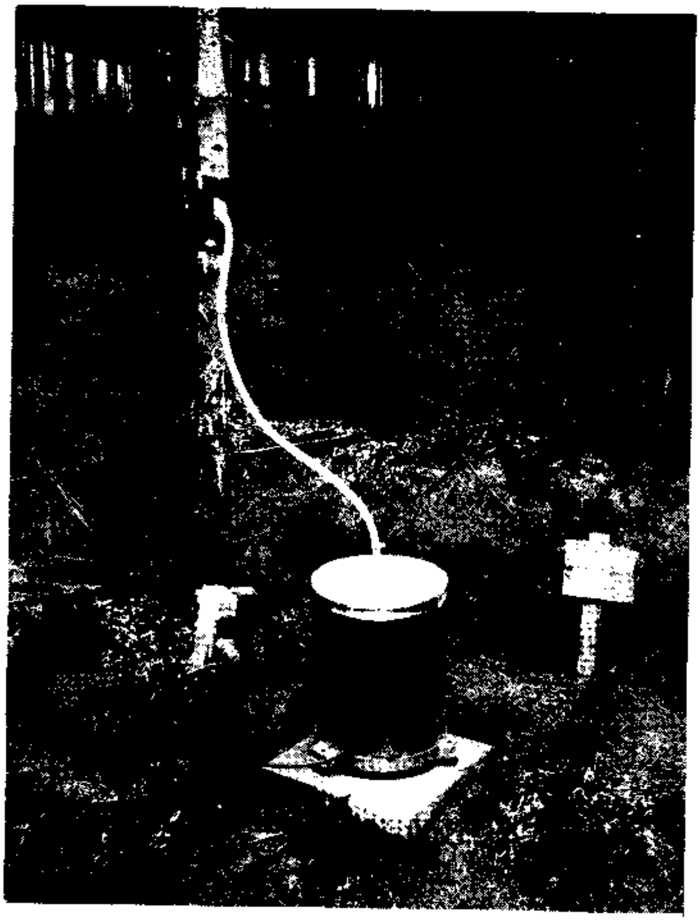

PLATE 7

Collar-type stemflow gauge and measuring device

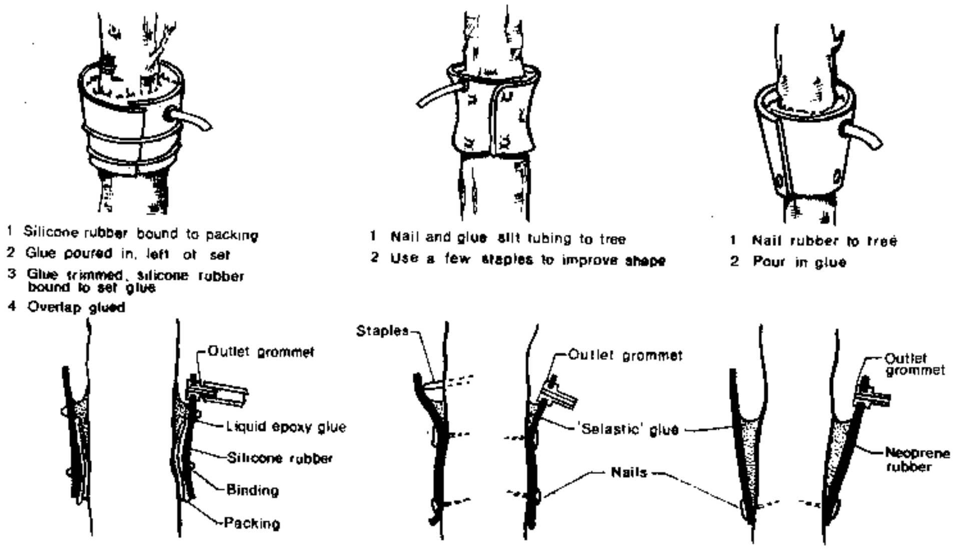

FIGURE 5 Types of stemflow gauge used at Plynlimon

The critical dimensions for these gauges are the internal depth of the collar and the distance of the collar from the bark. The internal depth provides a head of water above the outlet to overcome any minor blockages. The depth from the outlet to the internal floor acts as a small sediment trap. For an intensive study this trap would be undesirable because of the lag in response when wetting up, but otherwise there is no disadvantage. (For accurate measurements of canopy capacity, the volume of water needed to fill the trap can be easily measured.)

The distance of the rim of the collar from the trunk is a compromise between catching a minimum of throughfall and still leaving a practical gap for water travel. If the gap is too small it will close up as the tree expands its girth. This can be helped by making the gauge from elastic materials, (especially if the gauge is required for more than a year - the tree can become significantly 'ringed' in the second year).

The materials needed for the gauges depend on the number required, functional life and tree sampling technique. If a large number of gauges are needed it is worth getting a design that is quick to build and easy to maintain. Sheet Silicone* rubber is good for easy maintenance, being soft and easily bent away from the tree for brushing the dirt from the gauge. With a stiffer material the gauge tends to deteriorate with successive cleanings. This rubber will resist perishing by sunlight or age and is easy to work with, but is difficult to bond to anything. Glue is available for sticking silicone rubber to itself, but will not adhere to the tree very well.

*Silicone Rubber Engineering Ltd., Brookhouse, Blackburn, Lancs.

If a small number of gauges are required, 1 in - 1½ in diameter red rubber tubing, slit along its length provides a more readily-available source of sheet rubber. This is more easily bonded, but will perish with age (about a year) and is more difficult to manage during construction and maintenance. Silicone rubber is better for a lot of gauges or for durability but is more expensive. Neoprene rubber is also useable but is very stiff and prevents easy maintenance. It can be used on trees without a litter problem.

So far, this description has favoured a more durable gauge but tree sampling techniques affect the construction and materials. It may be more desirable to have, for example, five randomly 'moved' gauges, rather than twenty randomly 'fixed' gauges. The latter is less labour intensive but the former ensures better sampling if a large variance is suspected. A 'moved' gauge is built and used for a short period and then taken down and attached to another tree for the next period. Thus sampling many trees in a year is possible. Here durability is unimportant and a cheap gauge, quick and easy to construct, is necessary. If the material is cheap enough a new gauge could be built each time. Gauges modelled from plasticine have disadvantages, but are obviously suited to this situation.

3. Through-fall and stemflow measurement sites

Apart from work at the main interception site, (an independent, process investigation), the placing of the auxiliary gauging sites was coordinated with the existing raingauge network (see Section I.4) to get a measure of the canopy-level precipitation input.

A central point was chosen at each site and the throughfall troughs were arranged around this point, aligned at random radial angles relative to magnetic north and at random distances (up to an aribtrary maximum) from the central point. Stemflow gauges were placed on the nearest five trees in a circle of arbitrary radius around the central point.

4. Calibrations for net rainfall

At the main interception site water from throughfall and stemflow collectors is piped into Rimco tipping bucket raingauges and the information is logged on Microdata loggers.

At the auxiliary interception sites the water is piped into large, low-density PVC bins where the cumulative level of water can be measured. These bins* hold over 200 litres of water, are about 1 m tall by 0.6 m in diameter and are slightly conical, making the relationship of water level to input non-linear. Originally, the level was measured with a metre rule, hung from a screw in the side of the bin, viewing the water through the translucent plastic. The volume of water collected was calculated from the change in level over the previous reading, using an equation incorporating the bin's dimensions.

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*WBC CONTAINERS LTD., Stalybridge, Cheshire.

With more bins in use and with more frequent measurements, this method became very time-consuming and error-prone. Direct input graduations were painted on the side of the bins to speed up measurement and to reduce the operations on the data to a mere subtraction of the new level from the old.

The calibration was achieved by weight, rather than by volume, on cantilever-type sack scales because volumetric calibration introduces an increasing error each time the measuring device is filled, which in this case would have been 100 times two litres. Although calibration by weight is subject to the accuracy of the scales, the error is constant over the whole range. On the other hand, the volumetric method requires only a measuring cylinder whereas the weighing method needs fairly accurate heavy-duty scales.

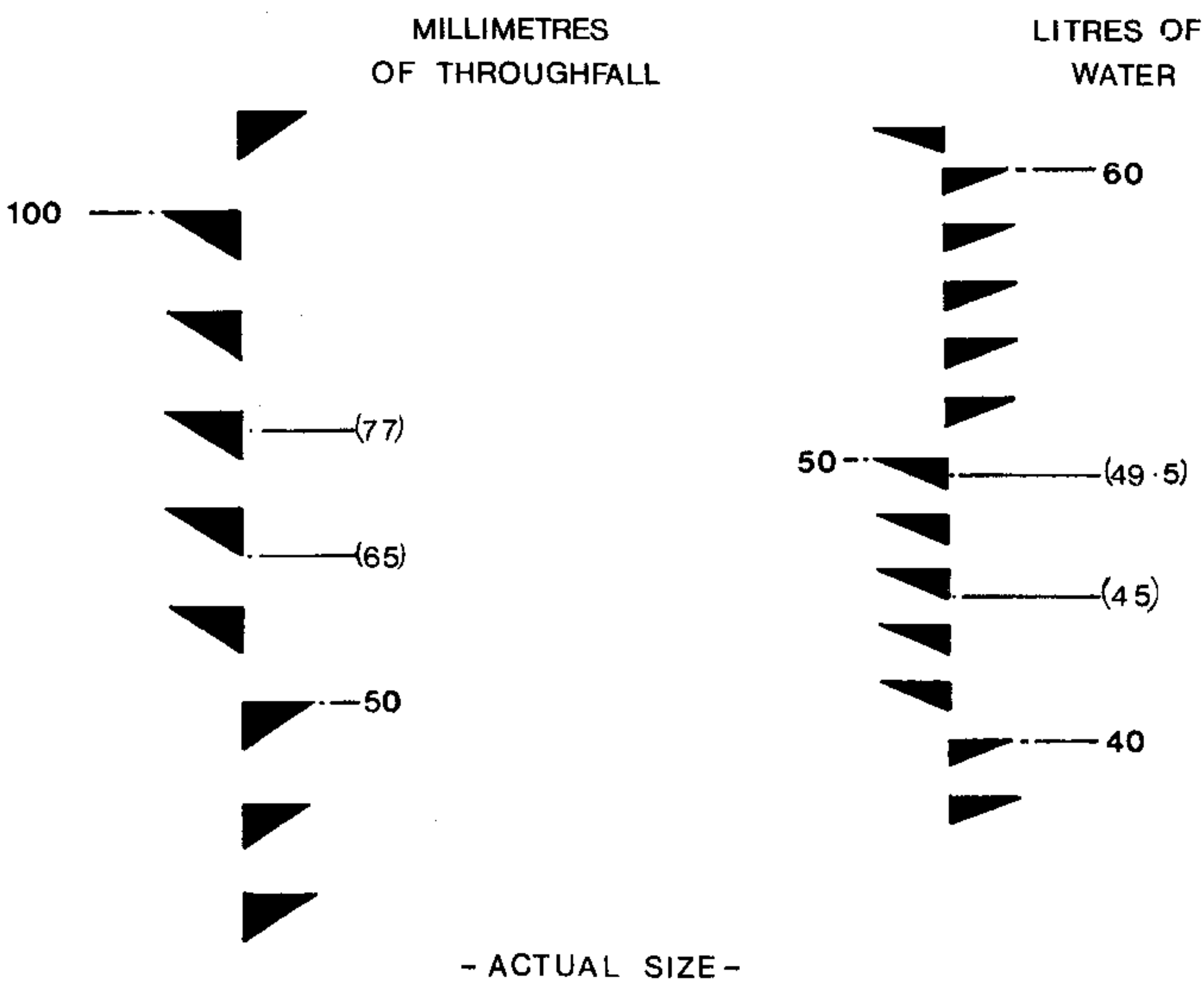


FIGURE 6 Examples of graduations on collecting bins

The stemflow bins required calibration in litres, easily achieved by marking the bin directly in ten intervals, i.e calibrating in 10 kg increments. After three bins had been marked, the graduations were compared for consistency by linear measurement from the base and then a steel tape template produced from these for marking the rest of the bins. The graduations between the 10 litre marks were interpolated linearly, giving an accuracy well within that required. It is advisable to make a new template for each new batch of bins as small differences in shape and thickness of materials can occur, presumably from different mouldings at the factory.

With the throughfall bins it was obviously convenient to calibrate directly in millimetres of throughfall, related to the particular collecting area. This relies on a successful check that the troughs have a consistent collecting area. The conversion of the scale was done while making the template so that the first three bins were calibrated in litres and then re-marked in millimetres of throughfall. The actual graduations were painted on to the side of the bins using black enamel paint and a fine brush.

Plastic-Sheet Net-Rainfall gauges

P. T. W. Rosier

Introduction

In previous interception experiments where the throughfall and stemflow components have been measured separately, Reigner (1964) has shown that calibration of throughfall trough gauges for splash is difficult, and Leyton *et al* (1967) showed that large numbers of throughfall troughs and stemflow gauges, randomly situated are required to give a statistically adequate sample. To overcome these factors, a single, large net-rainfall gauge consisting of a plastic sheet, suspended below the forest canopy by a rope network, has been used in more detailed studies of the interception process in the Hafren forest (see Calder, 1976; Calder and Rosier, 1976).

1. Construction

The location of the site for the plastic-sheet gauge is determined by several factors. Firstly the site must be representative of the area with respect to tree planting density and tree girths. Secondly the site should have a sufficient gradient for runoff from the sheet to occur. (In a flat area this could be provided by inclination of the ropes used in suspending the sheet beneath the forest canopy).

All branches between ground level and approximately 1.75 m in height are removed as close as possible to the trunk on the trees that are going to be encompassed by the plastic sheet and this region is then brushed clean of any loose material and bark scales. The ground over the area to be covered by the sheet is smoothed to allow unhindered flow of net-rainfall.

With the site prepared, the rope network can now be constructed as shown in Figures 7 and 8. The rope is stapled to an anchor tree standing outside the area of the plastic sheet, at about 0.25 m from the ground and then pulled taut, wound round the second tree, pulled taut and stapled. This method is continued until all the trees in a row are connected. On the second and subsequent trees the rope height is 1 m (see Figure 7). In some cases rows of trees will be incomplete and a fence post driven well into the ground with the top stapled to the top will be a satisfactory substitute for a tree at any point (Figure 7).

As no water will reach the soil beneath the plastic sheet an irrigation system to prevent the death of the trees is provided by laying lengths of plastic garden hose perforated with holes. The lengths of hose are connected to a large tank, fed by a nearby stream if convenient, which acts as a reservoir. Roofing felt is laid over the lengths of garden hose to act as a barrier between the ground and the sheeting, thereby avoiding punctures from litter on the ground.

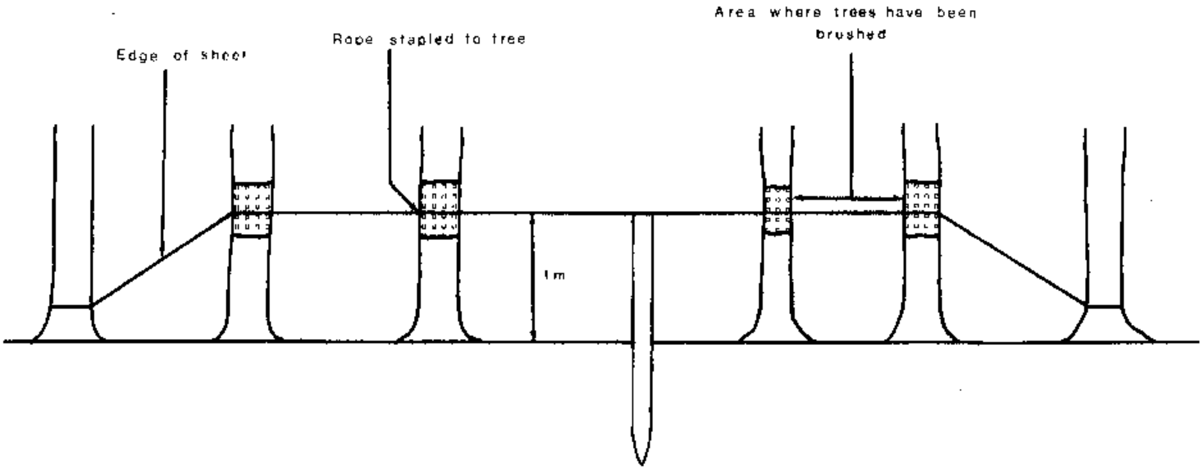


FIGURE 7 Constructional details for plastic-sheet net-rainfall gauge

This method of measuring net-rainfall does not differentiate the throughfall and stemflow components. Since the correct proportion of stemflow to throughfall should be measured, the sheeting has to lie with its outermost edges either midway between tree lines or along tree lines; midway <u>between</u> the tree lines is the most practical position as this avoids the difficulty (with an edge <u>along</u> a tree line) of separating stemflow coming down one side of the tree from that on the other (Figure 8).

Over the area of the plastic sheet a configuration of ridges and valleys is formed (Figure 9a). The individual plastic sheets are overlapped along the ridge lines (i.e. over the rope between the trees) and pegged with longitudinally slit hosepipe. The overlapping edges

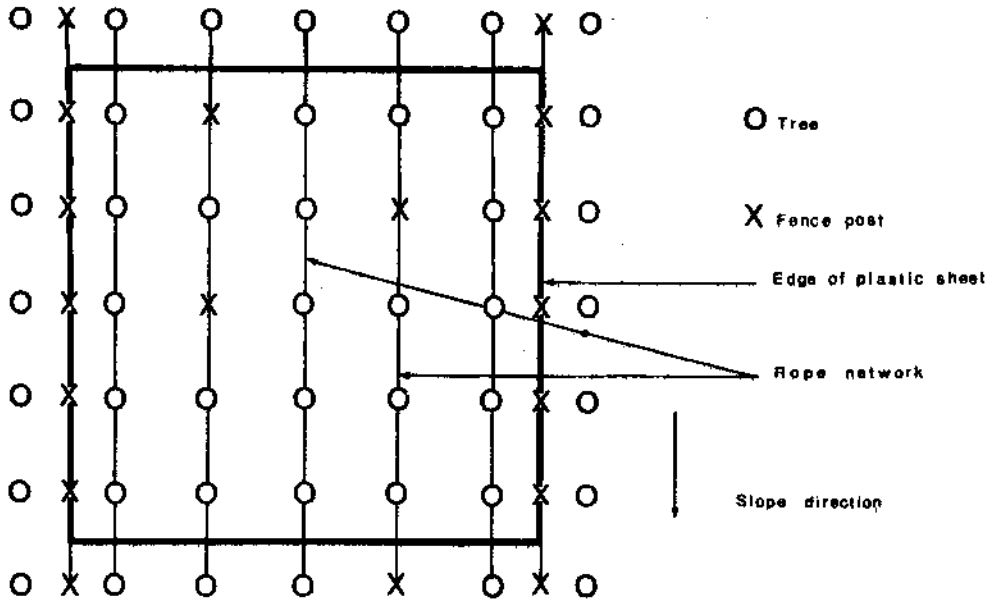


FIGURE 8 Plastic-sheet net-rainfall gauge - plan view

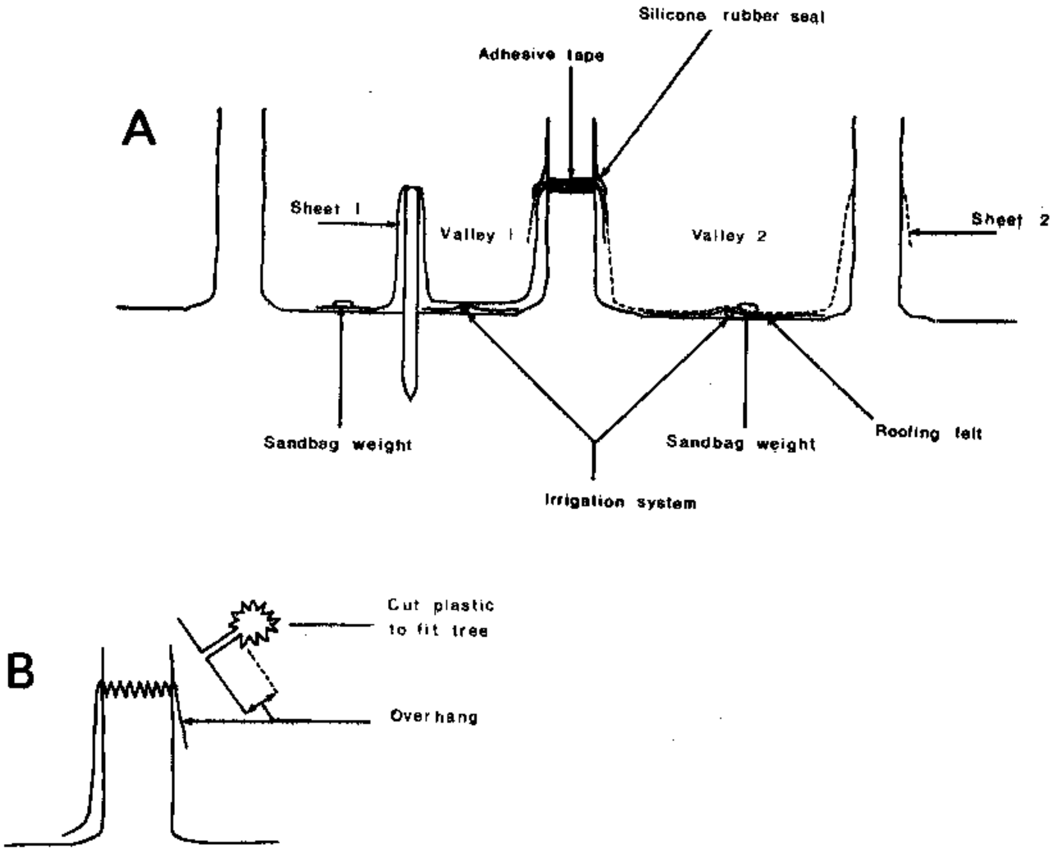


FIGURE 9 Arrangement of plastic sheet

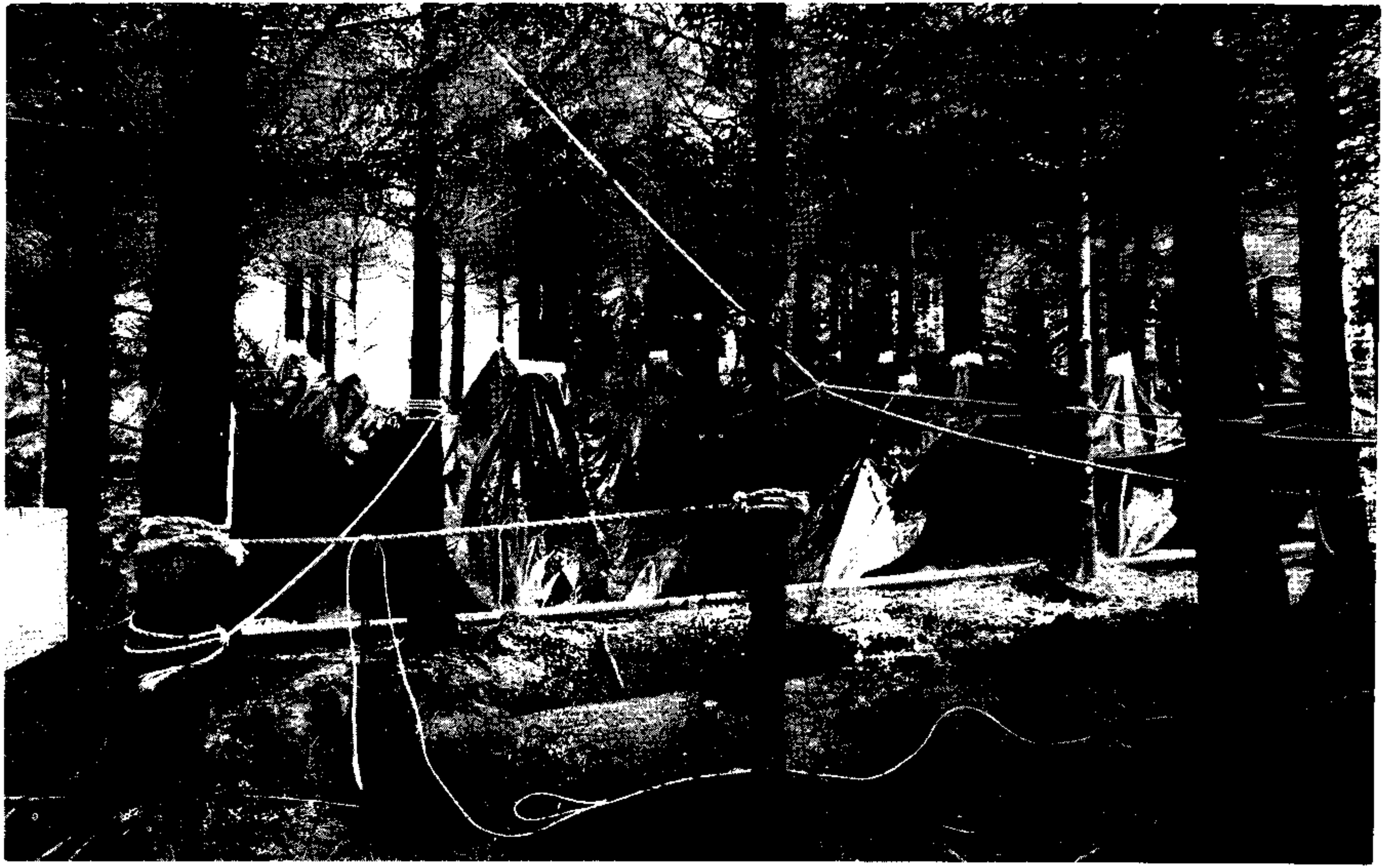


PLATE 8 Plastic-sheet net-rainfall gauge, Hore site

of the plastic sheets are cut to fit round the trees allowing plenty of overlap (Figures 9 a & b). The sheeting is secured to the trees by adhesive tape and silicone rubber adhesive using a plastic gun applicator to spread the rubber evenly over the sheeting and the tree. The rubber will form a skin in about 1 hour and is cured in 24 hours. This will make a watertight yet flexible seal.

Runoff from the sheet is channelled by pieces of roofing felt into a length of plastic guttering which feeds into a tipping bucket flowmeter. It may be necessary to dig a hole for the tipping bucket to allow sufficient depth for the inlet pipe to be level with the gutter from the plastic sheet. The bucket is mounted on a block of wood, levelled, screwed down to avoid movement and then embedded in concrete. This gives added stability and enables *in situ* static calibrations to be made on the bucket. Each time the bucket tips it operates a mechanical counter and reed switch whose pulses can be stored on magnetic tape. (With two counting systems loss of data from the bucket is small).

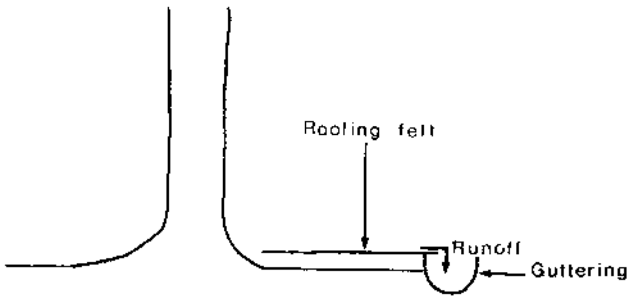


FIGURE 10

Plastic-sheet net-rainfall gauge - details of runoff measurement

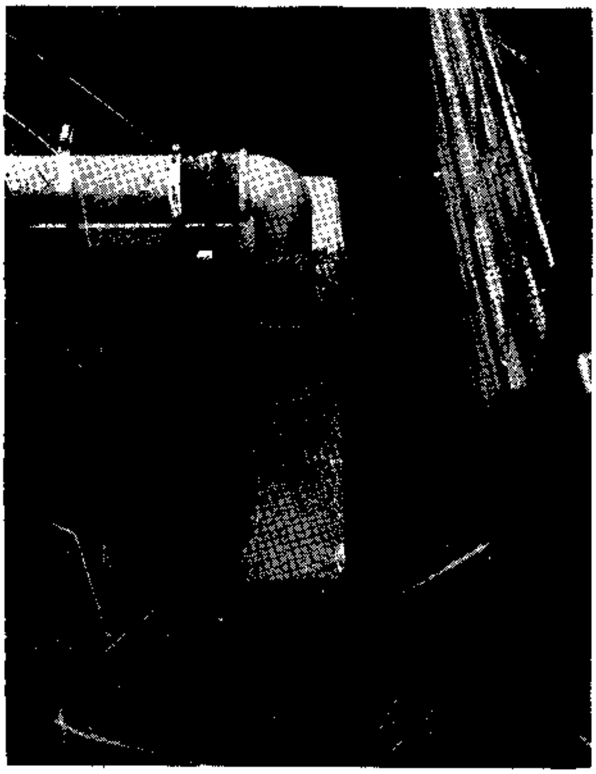


PLATE 9

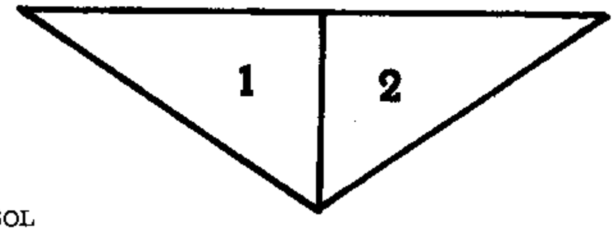
Plastic-sheet net-rainfall gauge - tipping bucket flow meter

2. Calibration of tipping-bucket flowmeter

Static calibration

In situ static calibrations of the bucket can be carried out when the concrete has firmed. Water is poured into one side of the bucket until it just starts to tip; the volume poured is noted. This is repeated until sufficient values of reasonable accuracy are achieved. The operation is repeated for the other side of the bucket. Varying volumes for the bucket can be obtained by adjusting the stops beneath the bucket.

EXAMPLE



Side 1	Side 2
1. 1.226L	1. 1.230L
2. 1.219L	2. 1.244L
3. 1.222L	3. 1.230L
4. 1.220L	4. 1.230L
Mean = 1.222L	Mean = 1.234L

Overall mean calibration = 1.228L

Dynamic calibration

I R Calder

Introduction

Both high resolution and accuracy can be achieved with tipping bucket flowmeters if these devices are calibrated dynamically. In general a non-linear relation exists between flow rate and the tipping rate of a tipping bucket flowmeter. This non-linearity arises even though a constant quantity of water (V) is normally required to initiate a tip because a variable quantity of water (depending on the flow rate) is lost during the time (t) taken for the bucket to move from rest to the position at which the central bucket division is beneath the inlet stream of water. If the time between tips of the bucket is denoted by T the flow rate is given by:-

$$Q = \frac{V}{T-t}$$

At low flow rates, when T is large compared with t the above equation reduces to the static flow rate equation: =

$$Q = \frac{V}{T} \qquad T >> t$$

Method

Values for V and t can be most easily derived from measurements of the tipping rate of the bucket at known flow rates. If T, the time between tips, is plotted graphically against the reciprocal of the flow rate the volume of the bucket (V) is given by the slope of the line and the tipping time (t) by the intercept on the T axis.

Typical Results

Two types of tipping bucket gauge which may require dynamic calibration are the Institute of Hydrology's 1.2 litre flowmeter, which has been used for measuring runoff from large plastic-sheet net rainfall gauges, drainage from small plots etc., and the Rimco 0.1 mm recording raingauge. Typical calibrations for these instruments are shown in Figures 11 and 12.

Ideally tipping bucket gauges should be individually calibrated for both V and t as these parameters will depend upon a number of variables, principally the height of the bucket stops and the resistance of the bearings. In practice, however, it has been found that if the volume, V, for the large tipping bucket gauges is set to 1.2 l the tipping time, t, will be close to 0.48 s and for many purposes this estimate of t is acceptable.

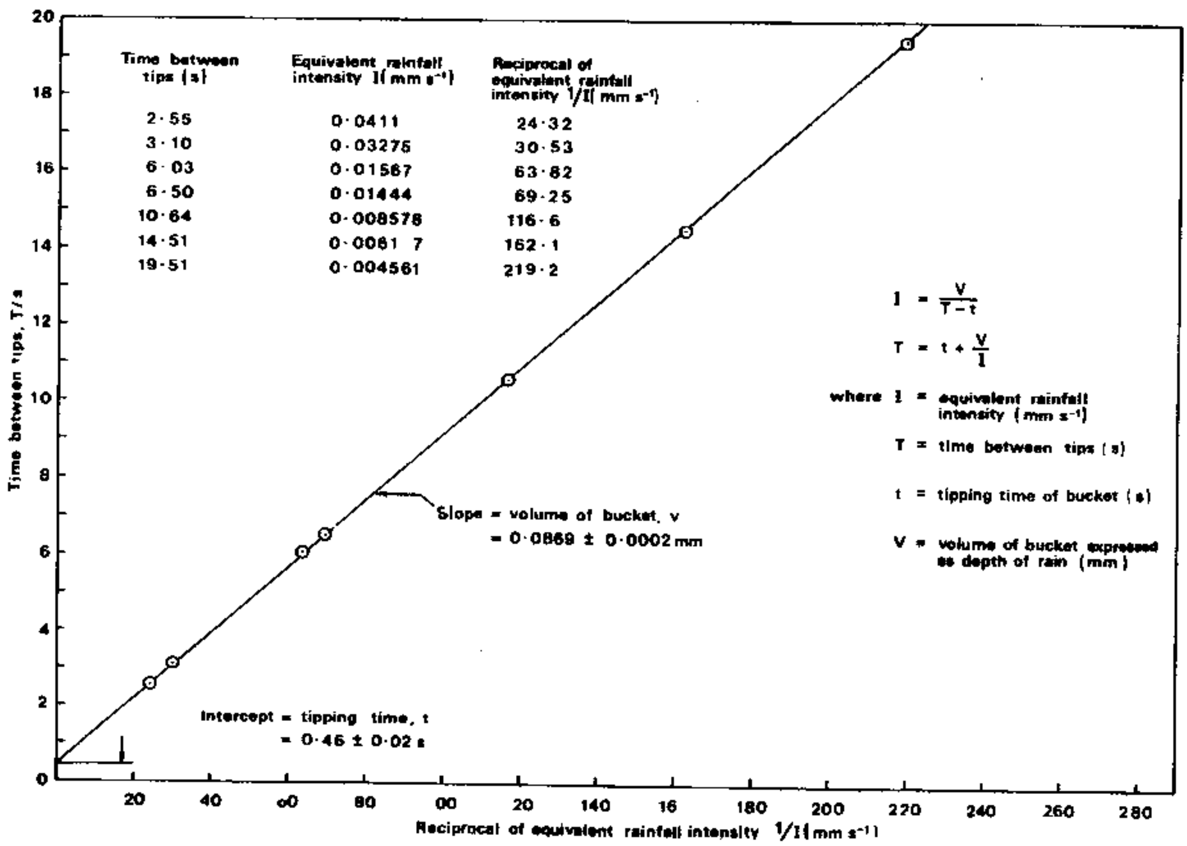


FIGURE 11 Rimco 0.1 mm raingauge calibration

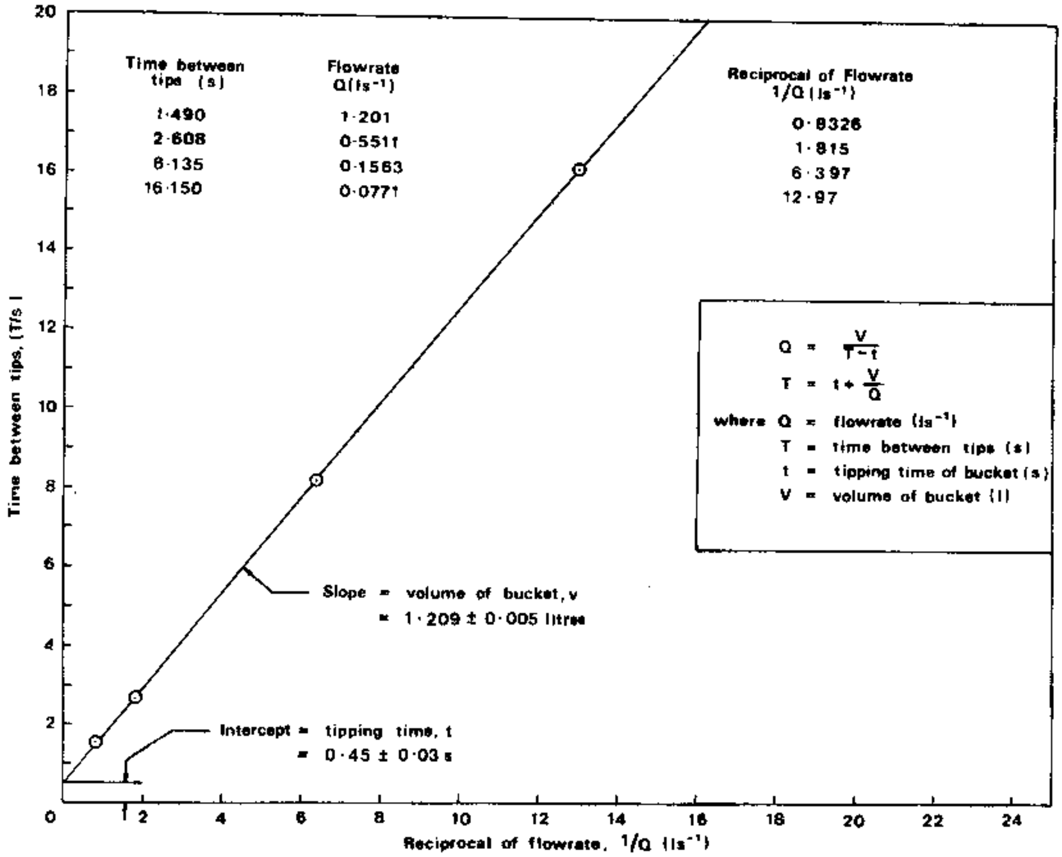
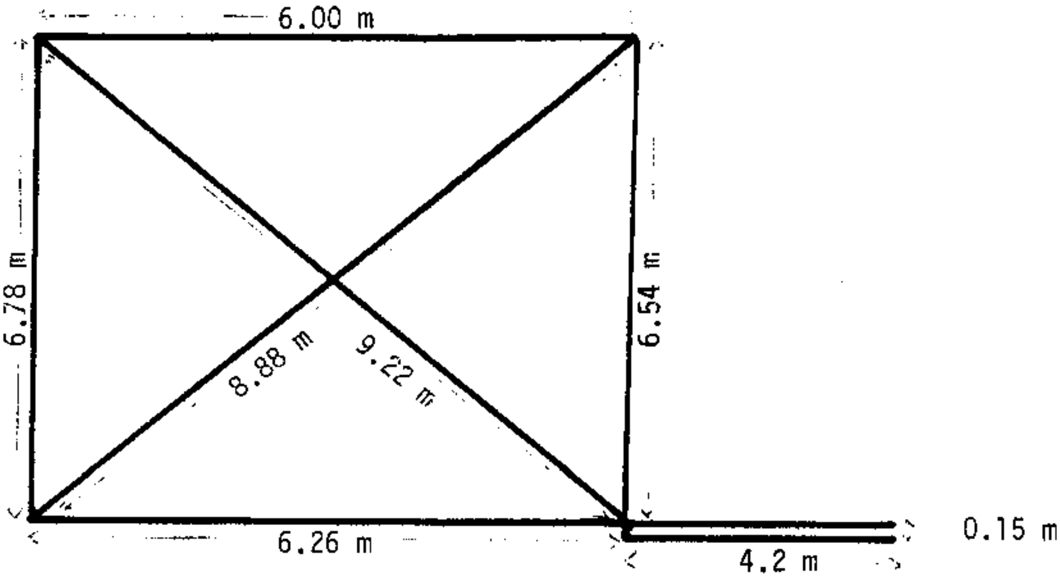


FIGURE 12 IH 1.2 litre tipping bucket flow meter calibration

3. Calculation of collection area of sheet

Superfluous material is trimmed off the plastic sheet and by measuring the lengths of the four edges and two diagonals the effective collection area can be calculated. It may be necessary to know the area of the plastic gutter if the distance between the tipping bucket and the sheet is large.

EXAMPLE



Area of gutter = 4.20 x 0.13

= 0.546 m^2

To calculate area of sheet use the following formula:-

$$\text{Area} = \sqrt{S(s-a)(s-b)(s-c)}$$

where a, b and c are the lengths of the three sides of a triangle and

$$S = \frac{a + b + c}{z}$$

Triangle 1

a = 8.88

b = 6.54

c = 6.26

S = 10.84 m

$$\text{Area} = \sqrt{10.84\ (10.84-8.88)\ (10.84-6.54)\ (10.84-6.26)}$$

$$= \sqrt{10.84\ (1.96)\ (4.30)\ (4.58)}$$

$$= \sqrt{418.42}$$

$$= \underline{\underline{20.455}}$$

Triangle 2

a = 8.88

b = 6.00

c = 6.78

S = 10.83

$$\text{Area} = \sqrt{10.83\ (10.83-8.88)\ (10.83-6.00)\ (10.83-6.78)}$$

$$= \sqrt{10.83\ (1.95)\ (4.83)\ (4.05)}$$

$$= \sqrt{413.11}$$

$$= \underline{\underline{20.325}}$$

Area of sheet = 20.455 + 20.325 + 0.546

= 41.326 m^2

By knowing the mean volume of the bucket and the area of the sheet a calibration factor can be employed.

Mean volume of bucket = 1.2281

Area of sheet = 41.326 m^2

$$\text{Calibration factor} = \frac{1.228}{41.326}$$

= 0.0297 per tip

Example

For a total of 100 tips (ie. 50 to left, 50 to right)

net rainfall = 100 x 0.0297

= 2.97 mm

The above examples have used reasonable values for the tipping bucket flowmeter and plastic sheet in real situations (the bucket volume is about 1.25 litres and sheet size is approximately 40 sq metres).

Several of these gauges have been in operation for a period of two years and have required minimal maintenance. Replacement of the seals may be necessary to accommodate tree growth if a gauge is to continue in operation for more than a couple of growing seasons.

4. Equipment and materials

Tipping bucket flowmeter

This was made specially for the Institute of Hydrology by:-

Clark Instruments Ltd
91a High Street
Camberley
Surrey

Cost: £306 (February 1975)

Plastic sheet

Builders' quality black polythene, twice heavy quality, nominally 1000 gauge. Rolls 12 ft x 75 ft.

Transatlantic Plastics Ltd
Garden Estate
Ventnor
Isle of Wight

Cost: £18 per roll (October 1976).

Silicone rubber adhesive

738 RTV adhesive sealant in 340 gm tubes.

Dow Corning Ltd
Barry
Glamorgan

Cost: £30 + VAT per carton (a carton contains 12 tubes).

All the following items can be purchased from builders' merchants, agricultural stores, etc.

Rope Polypropylene, 1½" circumference, cost £3.00 per 20 metres.

Adhesive tape Any general purpose plastic tape.

Roofing felt Heavy weight, cost £2.00 per roll.

Plastic gutter 4 metre length, 150 mm wide, cost £2.00 per length.

Plastic garden hose ½" dia. Cost £15.00 per 100 metres.

Large Tank 100 litre osmaglass tank. Cost £35.00

5. Relevant Publications

Calder I. R. 1976 The measurement of water losses from a forested area using a "natural" lysimeter. *J. Hydrol.*, 30, 311-325.

Calder I. R. & Rosier P. T. W. 1976 The design of large plastic-sheet net rainfall gauges. *J. Hydrol.*, 30, 403-405.

Leyton L., Reynolds E. R. C. & Thompson F. B., 1967 Rainfall interception in forest and moorland, In: W. E. Sopper and H. W. Lull (Editors), Forest Hydrology, Pergamon, Oxford, pp. 163-178.

Reigner, I. C., 1964 Evaluation of the trough-type raingauge. *U.S. For. Serv. Northeast For. Exp. Stn., Res. Note, 20,* 4 pp.

III: SNOWMELT

Melt-water gauge (snow gauge)

J. A. Hudson

Introduction

The main problem of snowfall from a hydrological point of view is that of spatial variation of depth. This is overcome in the Plynlimon experiment by terrestrial photography (Blyth *et al*, 1974). A further problem is the water-equivalent of the snow, tackled at Plynlimon by manual density-sampling linked to photographic surveys of depth. The final topic for investigation during snow periods is the timing and rate of snow-melt, information on which is only grossly acquired by the depth and density surveys. It is required for three reasons:

(1) To understand the meteorological and topographic factors controlling snow-melt.

(2) To get realistic time increments of catchment input for runoff studies during snow periods.

(3) Snowmelt flood warning, at present only a possible future development.

Snow melt-water collects in the conventional raingauge; however, even the ground-level gauge does not allow snow to gather evenly prior to the melting process and the metal funnel has different thermal properties to vegetation and soil. The gauge described here attempts to create an unobstructed pattern of snow accumulation and a natural melt process by using an artificial grass surface, punctured with holes, melt-water from which is gauged by a tipping-bucket.

The assembly is pictured in Plates 10 & 11 and Figure 12. The tipping bucket gauge is set in a pit covered by the grass, with an extension funnel flush with the ground surface. The immediate ground surface around this funnel is perforated plastic grass and a circle of this material also rests in the funnel itself.

1. Assembly

The pit should be dug with the base of the hole horizontal. It should be deep enough in the middle to allow for the height of the gauge plus at least 6" of P.V.C. tubing; this gives flexibility and makes alignment of the two funnels less critical. The pit should be drained with a pipe long enough to reach from the bottom corner of the hole to the ground surface and lie with a downhill gradient (see Figure). On shallow slopes one may need to drill holes in the pipe and rely on natural drainage along its length.

The ground at the edge of the pit is rebated for the plastic grass

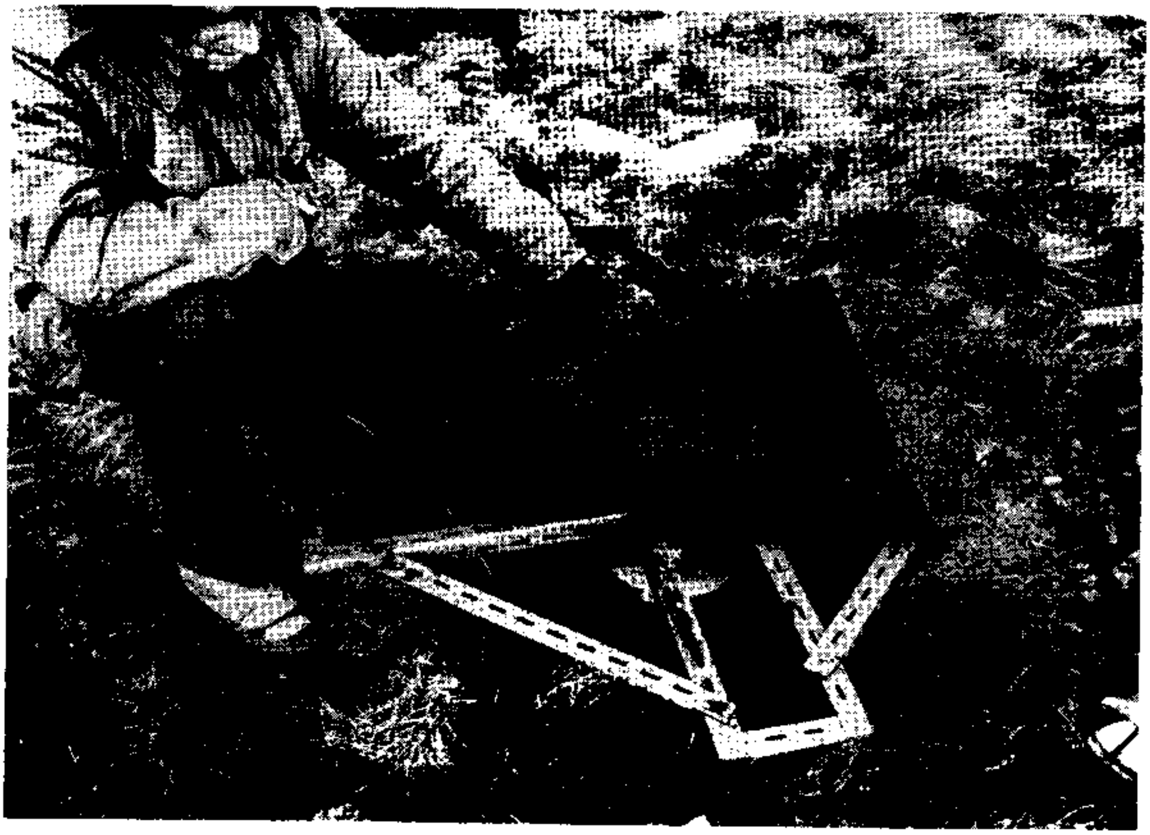


PLATE 10 Melt-water gauge construction; artificial grass cover lifted to reveal Rimco raingauge

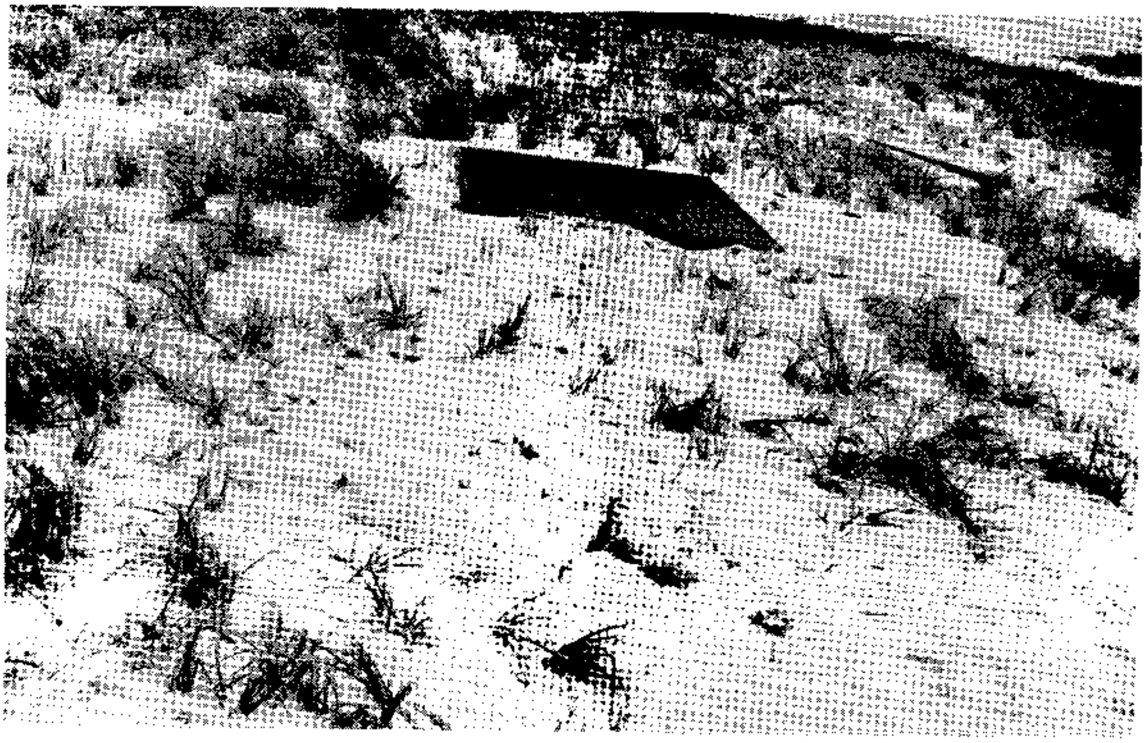


PLATE 11 Melt-water gauge in foreground, covered by snow. Conventional Rimco and ground-level raingauges in background

to lie flush with the natural sward. This is done by putting the plastic grass-covered frame in position over the hole as a template and marking the extent of the rebate with a spade. After fitting the frame, backfill up to the plastic grass with turfs.

The Rimco gauge and concrete block is installed and levelled before the frame is fitted. The top funnel is roughly lined up with the brass ferrule on the Rimco gauge and the P.V.C. tube cut to length, securing with jubilee clips. Leaks should not occur if the P.V.C. tubing and jubilee clips make a tight fit on the funnel and ferrule and if the ferrule/polythene disc joint is waterproofed with silicone rubber mastic.

All wires should be buried to prevent damage by sheep.

It must be stressed that it is quite feasible to alter the materials used and still retain the essential characteristics of the gauge.

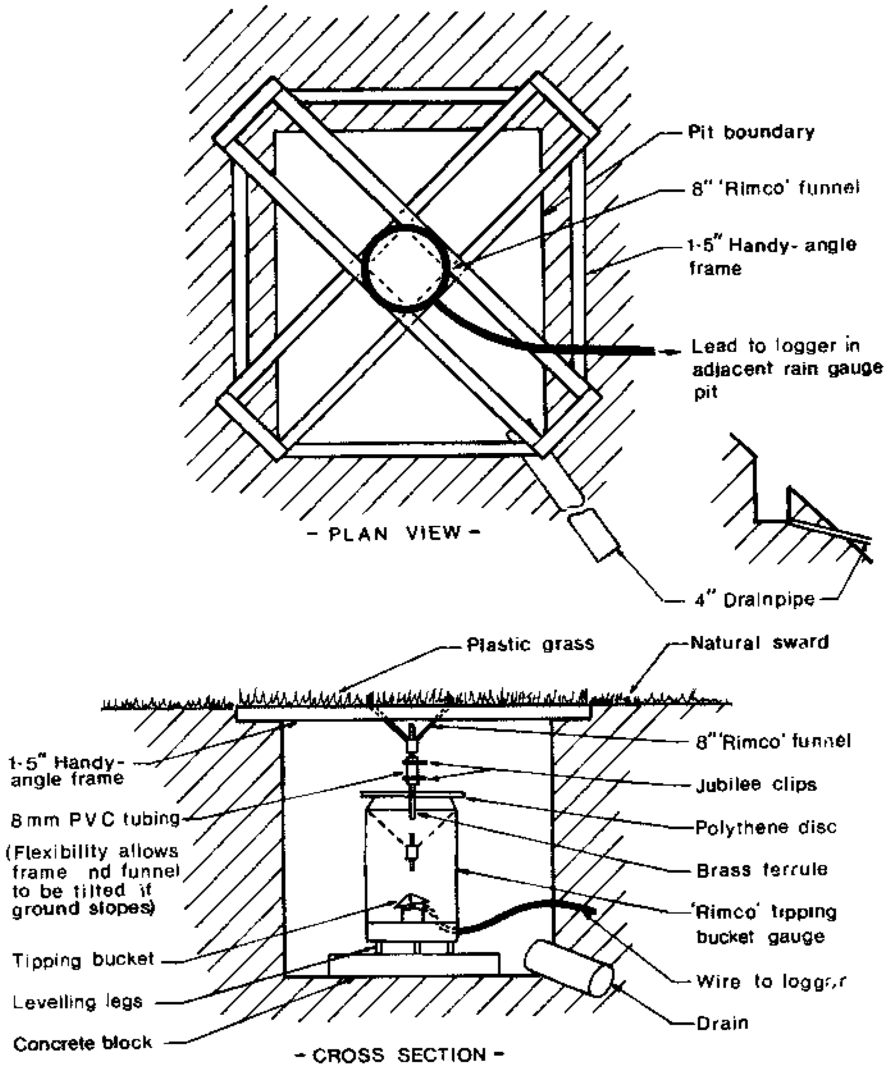


FIGURE 13 Diagram of melt-water gauge construction

2. Materials and costs

NO.	DESCRIPTION	COMMENTS
1	8" 'Rimco' raingauge Funnel	or equivalent
4	4' lengths 1½" handy-angle	
4	2' lengths 1½" handy-angle	
4	8" lengths 1½" handy-angle	
1	8" Rimco raingauge Tipping Bucket	or equivalent
1	greater than 8" diameter polythene disc	8" diameter groove to take funnel rim plus hole to take brass ferrule.
1	c4" brass ferrule	
1	smaller than 2' length P.V.C. tubing	
2	Jubilee clips	for tight fit on P.V.C. tubing
Numerous	Handy-angle nuts & bolts	
9	1' square plastic "Evergrass" tiles	From:- W. ARMES & SON LTD., CHILTON MILLS, SUDBURY, SUFFOLK, CO10 6XB. This grass has holes to allow water to percolate.
1	c15" square x 2-3" thick concrete block	
1	length 4" pitch pipe	Or equivalent, length depends on slope of ground.
1	Logger	
1	Battery	
1	Logger cover	Wooden or plastic - can be made to fit 2 loggers if rain-gauge adjacent
6-8	pieces of wire c12" long	To hold grass onto frame

Prices are not quoted in detail since the gauge can basically be made from 'odds', the most important item being the Rimco raingauge and spare funnel, against which expense the remainder is very small. At the time of writing 'Evergrass' tiles are £0.50p each and 'Handy Angle' £35 per 100 ft.

3. Relevant publications

BLYTH K, COOPER M. A. R., LINDSEY N. E., & PAINTER R. B. 1974. Snow depth measurement with terrestrial photos. *Photogrammetric Engineering*, XL(8), 937-942.

BLYTH K & PAINTER R. B. 1974. Analysis of snow distribution using terrestrial photogrammetry. in: "Advanced Concepts and Techniques in the Study of Snow and Ice Resources", National Academy of Sciences, Washington D.C. 679-687.

IV MEASUREMENT OF SMALL FLOWS

Introduction

A fundamental advantage of the comprehensive permanent stream gauging network at Plynlimon (see IH Report No 42) is that, within it, smaller scale catchments and plots can be instrumented for short periods. The permanent network provides reference information for spatial and temporal extrapolation from these shorter reconnaissance studies.

The measurement of outflow from plots and small catchments generally requires less attention to the initial design than in the case of permanent gauging stations but is equally, if not more demanding of accuracy, maintenance and routine attention. The sheer number of flow gauging sites used by process studies has meant a high input of labour in spite of the lower capital outlay for each individual gauge. At least fifty sites at Plynlimon have so far been gauged for process study purposes using the techniques described below.

Whilst the channel characteristics of the major Severn and Wye tributary catchments demand the use of the novel steep stream flumes described in Report 42, there are locations, on smaller tributaries still, which are more suited to the use of weirs. Consequently, rectangular and a variety of 'V' notch sharp-crested weirs have been used, with or without an artificial stilling pool tank. A corollary of the extensive use of these weirs has been the development of a simple and relatively cheap water level chart recorder.

Two types of digital flow recorders have been used, velocity meters within enclosed pipes and the open tipping bucket system. The latter has been described earlier, as part of the net precipitation measurement system in use on natural lysimeters. The velocity meter principle was adopted for measurements of flow in natural soil pipes.

1. Water level recorder and weir tank

V W Truesdale and J M Howe

There were no suitable instruments available for the measurement of relatively low flows (0.8 l sec^{-1}) when studies began of the chemistry of run-off water from small catchment areas (of the order of 1 hectare). As the sites in question are very exposed, it seemed that a V-notch weir and water level recorder would be most suitable because simplicity and reliability are all important.

V-notch weirs of varying angles have been used for measuring low flows but, generally speaking, have not been used below a head of 50 mm (British Standard 3680; 1965). However, it was considered that V-notches of varying angles to give different flow ranges, could be rated successfully and a minimum accurate head could be ascertained. Accordingly, prototype recorders were constructed in the Institute's workshops*.

Weir box

The weir tank consists of an Osmaglass C25 cistern with a square hole cut in one end, slightly smaller than the V-notch plates. The plates are attached to the cistern by small BA nuts and bolts set in a standard pattern. "Half-ninety" degree plates are used mostly but on occasion, 20^{o} plates are also used. A white plastic ruler is mounted vertically to act as a staff gauge, slotted for easy adjustment of the zero using a reference mark inscribed on the V-notch plate. A plastic debris screen is fixed to the bottom and sides of the box by P.V.C. strips. The screen does not reach to the top of the tank to allow overflow in case of blockage. A union (Osma 126) for the pipe which links the weir tank to the stilling well is fixed to the tank after the lip of the holding nut has been removed. A fibre washer is used to ensure a good seal. A sediment trap is made from an Osmaglass C7 cistern containing three plywood baffles, two descending half-way from the top of the cistern and one in the middle fixed to the base and reaching approximately half-way up the walls. The weir tank and sediment trap are connected by 90 mm diameter P.V.C. flexible ducting. Standard P.V.C. plumbing unions are used to join the flexible ducting to the sediment trap.

Water Level Recorder

The complete assembly consists of the intake pipe for the stilling well, the framework and base recorder assembly (Figure 14). The stilling well consists of a 600 mm length of 155 mm diameter P.V.C. pipe with an Osma 126 fitting glued in near the base and connected to the weir box by short lengths of 38 mm diameter pipe. The base is sealed with a P.V.C. end cap.

The stilling well is suspended by three pieces of Dexion 140 below a a platform made from 6 mm thick, fibreglass sheet. The platform is supported on a framework of aluminium Dexion 225. A plastic dustbin with a clip-on lid is used as a cover, inverted and clipped directly to the platform. Slots are cut in the base and rim of the bin to allow rain to drain away from its uppermost surface when it becomes inverted.

The recorder assembly, shown in Figure 14, consists of a float, float rod, bearing cylinder, stops, pen assembly, chart drum and clock. The float is a plastic Dec-computer tape-container with its lid sealed on and a perspex threaded boss glued on top. The float is 110 mm diameter and 30 mm deep. The float rod is a 900 mm long aluminium rod,

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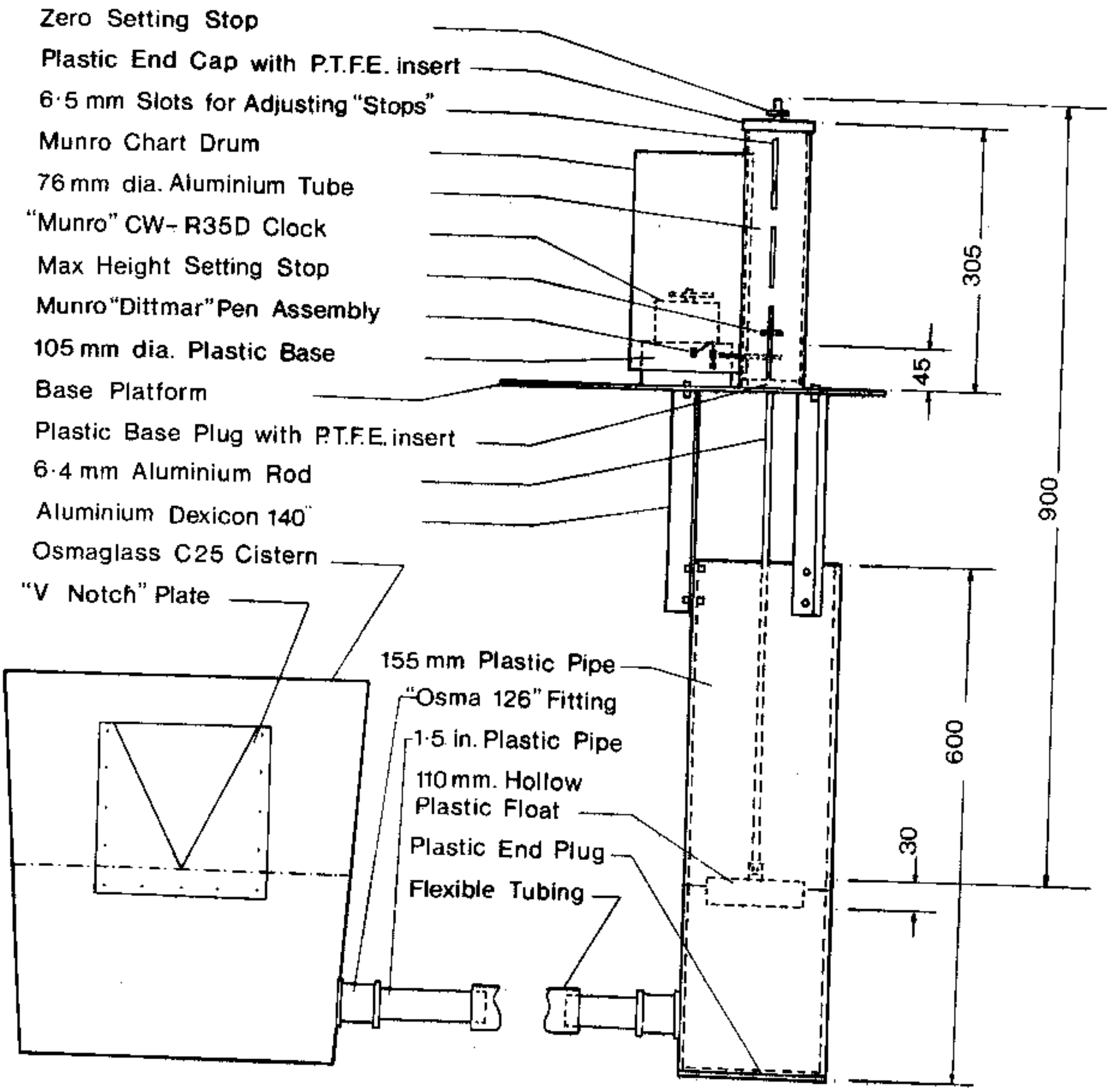
* Grateful thanks to Mr P D R Andrews and his staff.



Note:- Flow range adjusted by replacing "V Notch" plates

FLOW RANGES

V Notch	Flow
10°	0-1·5 l/sec
20°	0-3·0 l/sec
½ 90° (53°8	0-8·0 l/sec

FIGURE 14 Water level recorder assembly

6.4 mm (¼") diameter, threaded at its lower end to fit the perspex float boss.

The bearing cylinder is a 305 mm long, 76 mm (3") diameter aluminium tube fitted with P.V.C. end plugs with PTFE bearings which takes the float rod. A longitudinal slot, 230 mm long and 6.5 mm wide is milled to take the pen arm, while a series of three lateral slots are milled to allow adjustment of the pen arm and maximum height stop. The cylinder is fixed to the platform by three BA nuts and bolts through the lower base plug.

The pen arm is made from aluminium sheet 6.4 mm (¼") thick with a clamp for the float rod and a holder for the Munro Dittmar pen assembly placed at the other. The screw holding the pen assembly in position also holds a small retainer against which the pen rests when not in use. Near the clamp end of the arm a collar is formed to enable the clamp end to be inserted through the slot in the cylinder and then turned and slid into its correct position. A small PTFE plug is inserted through the arm to allow smooth running up and down the cylinder slot.

A standard Munro vertical chart drum taking Munro 28A/176 natural scale charts is mounted on a Munro CW-R35D. Clocks with different speeds can be obtained. The clock is mounted on a cylindrical P.V.C. base, 105 mm in diameter and 47.5 mm thick, which is fixed to the platform by three BA screws.

Assembly

The following parts were manufactured in the Institute's workshop: V-notch plate; stilling well with base plug and inlet pipe junction; float and float arm; pen arm and stops; bearing cylinder with end plugs and bearings; clock base.

The following parts were bought: Weir tank (Osma-glass C25 cistern); sediment trap (Osmaglass C7 cistern); plastic rulers; Munro Dittmar pen assembly; Munro CW-R35D clock; Munro vertical chart drum.

The whole assembly was positioned in the field in one man day following the same sequence as that used in the description of the equipment.

Design limitations

It was found that whereas the 20° V-notches blocked easily the half-90° did not; probably a range of V-notch plates with angles of 90°, 53°8' (half-90) and 28°4' (quarter-90) would suit most purposes. The Osmaglass C25 weir box probably held too small a volume of water for accurate measurement of high flows through the half-90° V-notch, because too much turbulence was set up. Also, the C25 was too small to allow a 90° V-notch to be installed. Larger tanks in the Osmaglass range are obtainable and would be more suitable for these higher flows.

During storms it was noticed that wind blowing both on the water discharging from the weir box and on the water surface created a surge effect through to the stilling well. This effect could be considerably damped by installing removable covers on the weir box and a wind shield around the discharging water.

Greater heads could be measured by manufacturing longer float rods (with bigger floats to give more buoyancy), longer chart drums and longer bearing cylinders. Larger charts and a taller weatherproof housing would have to be obtained.

The sediment trap used here could well prove unsuitable or unnecessary at other sites. It was found that at high flows sediment was generally carried straight through both the baffle and weir boxes. Newly installed traps were often left cleaner than they had been before the storm!

The system could be adapted so that two (or three) weir tanks were connected to two (or three) float chambers recording on the same chart drum with different coloured inks. For greater low and high flow accuracy, a 90° V-notch weir tank could be mounted so that it discharged into a quarter-90° V-notch weir tank. The latter could be fitted with a longer stilling well and float rod and be connected up to the same chart drum. The quarter-90° pen would always be (except at zero flow) well above the 90° pen, so little confusion would arise.

Field Experience

The prototype has been in operation for three years. No problems have been encountered other than those set out above and the instrument has proved extremely reliable. It also has other attributes. Once the stops have been set, the zero of the recorder and the maximum height are permanent unless the recorder moved in relation to the weir box. The zero stop was very useful in setting the pen. If a good seal was obtained between the base platform and the weatherproof cover, there was no means of access into the recorder from outside by external agents, such as insects, wind or rain.

In the form described (Figure 14) the weir/recorder assembly has been used to measure flow from soil pipes and surface runoff. The recorder and stilling well have, however, been widely used in connection with more conventional weirs on open channels such as forest drains, agricultural ditches, and also with some success on boreholes exhibiting a narrow range of water level

2. Instrument system for natural pipe flow

K Gilman

The discharge of a typical natural pipe at the height of a rainstorm is of the order of one litre per second. Most pipes have no baseflow, and to gauge a pipe during a storm, an instrument must be capable of measuring flows from zero up to a maximum of ten litres per second.

The simple instrument system described here combines a siphoning tank for low flows with a propeller meter for high flows.

The propeller meter

Flows above 0.2 litres per second are measured by a Braystoke propeller meter (Valeport Developments Ltd, Dartmouth) mounted in a perspex or uPVC tube. The meter must be arranged so that it runs completely immersed, and also must be protected from debris, as the small clearance between the rotor and the tube is easily blocked. A suitable sediment trap is shown in Figure 15.

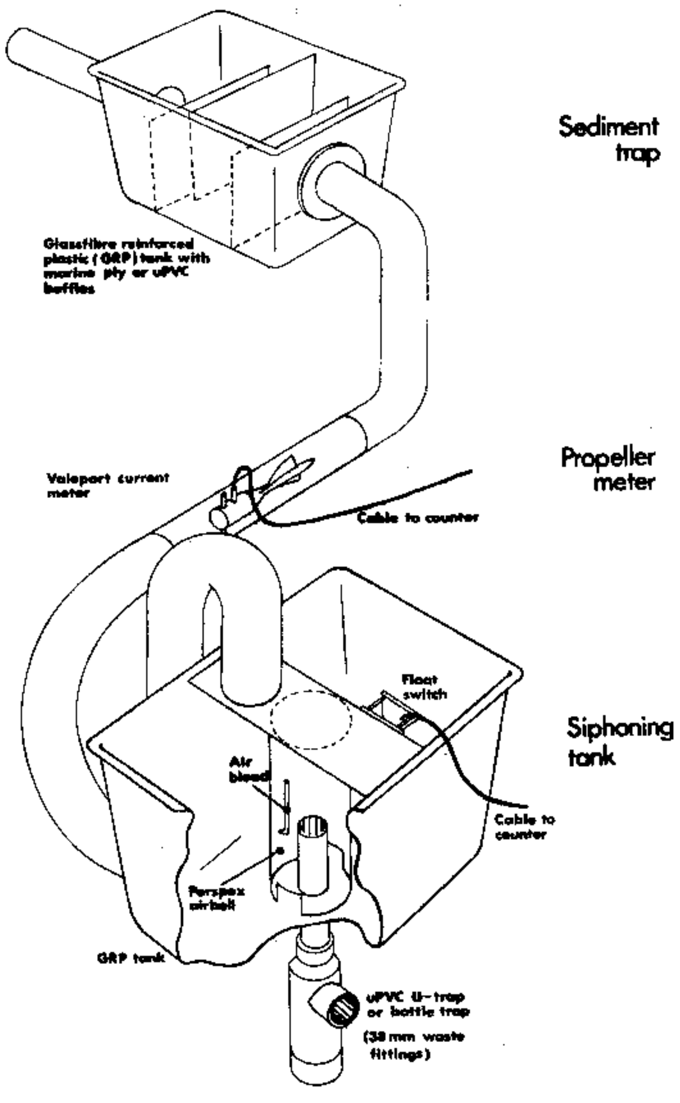


FIGURE 15 The combined instrument. Water entering the sediment trap is forced to flow over and under the baffles, depositing much of its sediment load in the base of the tank. Both sediment trap and siphoning tank are based on 7-gall. domestic GRP cisterns. The airbell in the siphoning tank must be airtight.

The siphoning tank

The propeller meter has a starting velocity of 0.07 ms^{-1}, corresponding to a pipe flow of 0.3 litres per second. For lower flows a siphoning tank tank is used, which operates as follows:

(i) as the water level in the tank rises, the level in one limb of the U-trap is depressed, until air starts to pass through the trap (Figure 16a, b).

(ii) the air escapes in large bubbles, and the water level in the air bell rises in steps. When the water level in the air bell rises above the rim of the inner tube, the siphoning action starts, draining the tank. (Figure 16c).

(iii) to ensure a constant final water level, an airbleed is fitted to the air bell, allowing air to enter through a vertical tube. (Figure 16d).

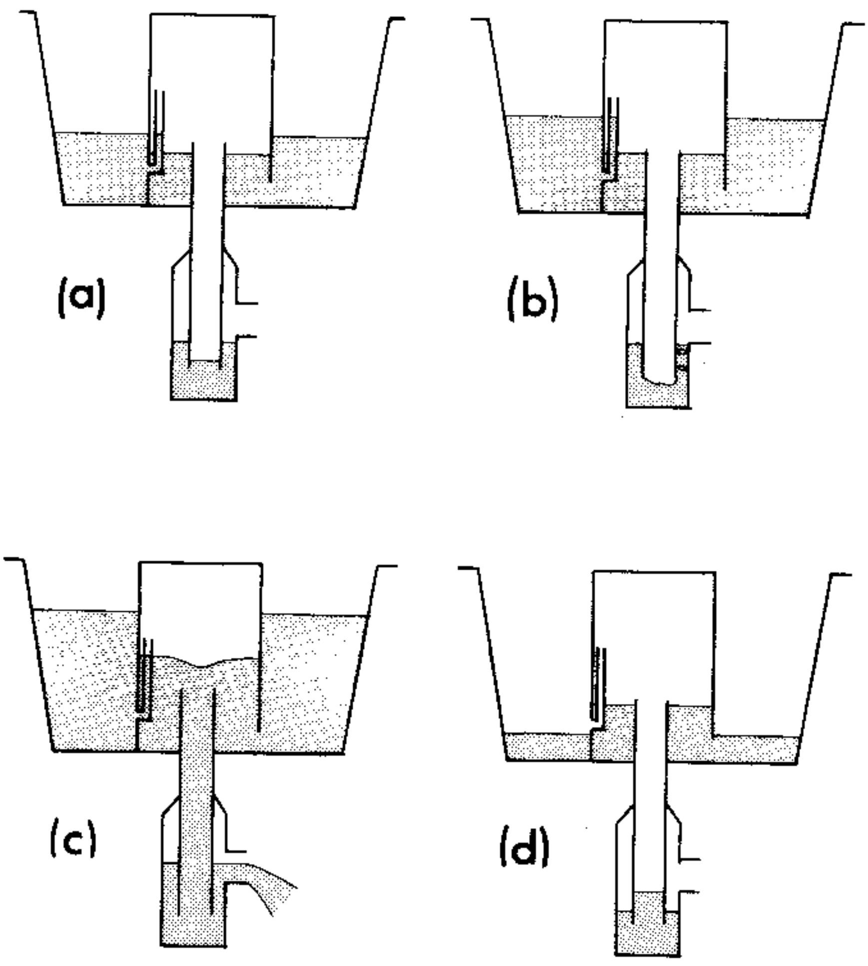


FIGURE 16 Principle of the siphoning tank. (a) water level rising, level in U-trap depressed. (b) air escaping through U-trap. (c) siphoning action. (d) siphoning completed, airbleed functioning.

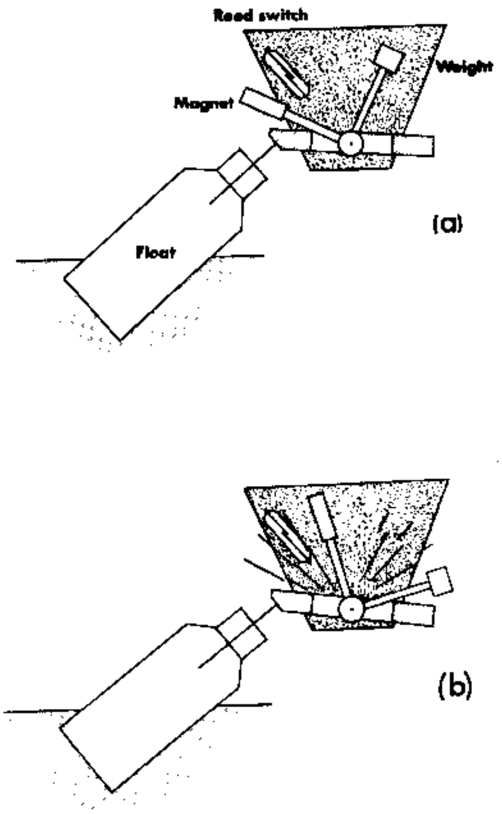


FIGURE 17

Principle of the float switch. (a) water level rising, magnet carriage approaching unstable equilibrium position. (b) magnet carriage flips over, taking magnet rapidly past reed switch. On a falling water level, the magnet moves more slowly past the reed, and the carriage then tips back into its initial position.

The float switch

As the tank fills, the water level rises slowly until the siphon action starts, and the water level falls rapidly. Typically, a flow of 0.25 litres per second would mean a rise taking about 50 seconds, and a fall taking about 25 seconds.

The float switch used to record the operations of the tank is designed to have a quick throw on the rising level, and a slow throw on the falling level, ensuring that the switch remains closed for the shortest possible time (about 5½ seconds for each operation of the tank). Figure 17 shows the principle of the switch: the magnet carriage and float carriage are pivoted independently, and the magnet carriage tips when its centre of gravity is vertically above the pivot.

The combined instrument

The instrument, comprising sediment trap, propeller meter and siphoning tank, is connected into the source of water using flexible ducting. This ducting is also used to connect the components of the instrument.

Signals from the propeller meter and the siphoning tank are on-off pulses, which may be registered on a counter or event recorder, using a simple transistor circuit to protect the reed switches in the instruments from spark discharges caused by the counter solenoids.

For flows up to 0.3 litres per second the results from the siphoning tank are used, for flows above 0.3 litres per second the propeller meter must be used, as the siphon ceases to function efficiently at 0.35 litres per second.

Calibrations depend on the exact dimensions of the instrument and must be determined for each instrument. The propeller meter is approximately linear, but the theoretical equation for the siphoning tank is

$$Q = \frac{V}{T-t}$$

where V is the volume of water defined by the maximum and minimum levels in the tank, T is the period of the operating cycle, and t is the time of emptying. V and t are approximately constant for any given tank.

APPENDIX I (September 1979)

A revised canopy-level raingauge

P J Hill

The revision of the previous canopy-level raingauge construction was necessary for the following reasons:

It is difficult and dangerous to construct the old type raingauge to heights greater than 11 metres;

Regular maintenance with close inspection of the funnel is impossible using only a scaffold pole support.

The new canopy-level gauge consists of a 5" copper funnel, cap and alloy (as on the previous type) but this is now situated at the tope of a commercially-available triangular section mast (Plate 12). The pole is

PLATE 12

Revised canopy-level raingauge

fitted to the mast by clamping collars (designed to allow maximum extension) made in the Institute's workshops. The mast has a steel frame foundation that is set in concrete (Plate 13). The first section is lifted over the protruding bolts on the base and the nuts are tightened; the erection boom supplied with the masts is lifted near to the top of this 10 ft section and hooked on to the side (Plate 14); the rope through the pulley is used to lift the next section on to the first and it is bolted on (Plate 14). This manoeuvre is continued until the final section remains to be fixed. The bottom fixing collar for the alloy tube is then fitted to come between the penultimate and the top section. Once the top section is bolted in place, the five-foot clamp tube is inserted into the collar; the top collar is then bolted in place. The mast sections are used until the top is just below canopy level as this leaves the maximum amount of alloy pole available for future extension as the trees grow.

PLATE 13

The steel frame foundation of the mast before cementing into the ground

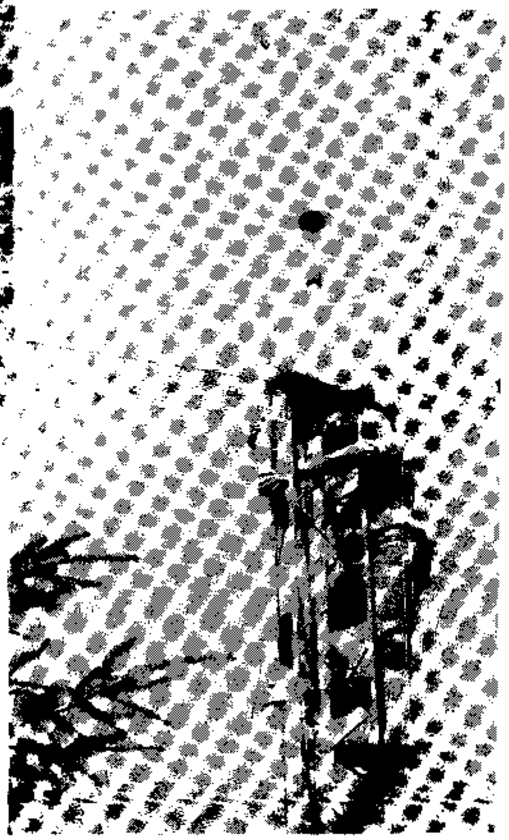


PLATE 14

Erection boom in place (on completed gauge - for demonstration purposes

The erection boom is used to lift the alloy pole for the funnel above and down through the collars and it is then held in position by the clamping screws. The funnel with polythene tube connected can now be fitted. The polythene tube is taped down the inside of the mast until just above the collector (a modified Octopent raingauge as in the previous type of canopy gauge).

Masts with more than three sections need to be guyed. Wire rope guys are fitted to the guy holes on the mast using shackles; the lower ends are secured with shackles to screw-in ground anchors and tensioned with strainers. It is recommended to guy at the first 30 ft and then every 20 ft thereafter.

During construction, the person on the mast is secured by an erector's belt leaving hands free for bolting, etc. When the mast is completed, a bar and pulley is bolted at the top which enables a rope to be passed through the pulley and attached to the belt of a person climbing the tower. The lower end of the rope is run through a pulley at the base, belayed and payed out as the person ascends, as a safety precaution against the person slipping while ascending, descending or when the erector's belt is unattached. A draw string is left through the pulley at all times enabling the safety rope to be connected before starting to climb. The highest gauge completed by this method is 60 ft, but much higher masts can be built simply.

Maintenance

Routine maintenance is carried out at the top of the mast; the funnel can be lowered for close inspection and raised as appropriate before locking into position. Many years' extension is available on the alloy pole without the need for a further mast section.

Materials

Funnel with cap to fit scaffold	
20 ft alloy scaffold tube	
Polythene tubing, 10 mm i/d	
Clamping collars) Safety bar)	IH workshops
Triangular mast sections	manufactured by Painter Bros. Ltd Hereford
Erection boom	marketed through Balfour Beatty (01 684 6922)
Wire rope, bulldog clips, shackles, barrel strainers	
30" screw-in ground anchors	Tirfor Ltd Halfway, Sheffield (482266)
Erector's belt	Barrow Hepburn Ltd Stewarts Road London (01 622 9900)

A revised stem flow gauge

J D G Smart & H R Roberts

Section II described the types of stem stem flow gauges used at Plynlimon on spruce trees. After three uears of use the gauges required refurbishment and the opportunity was taken to incorporate new ideas.

The guages had performed reasonably well but had exhibited the following faults:

The silicone rubber forming the upstand collar although tough, was liable to tear at the outlet grommet hole;

The outlet grommet, 4 mm bore, was frequently blocked by pine needles;

The 12 mm projection of the grommet over which the collecting tube fitted was too short and often the two parted as the tree moved in the wind;

The rigid collar formed round the tree by using a bonding cement was in conflict with tree growth. This resulted either in 'ringing' or splitting the collar.

The replacement gauges used neoprene rubber throughout. The outlet grommet was replaced with a moulded flanged tube 14 mm bore, 140 mm long, with the tube set at 30° to the vertical flange. The flange extended 25 mm around the tube.

The width of the trough was built up with successive layers of soft non-intercellular (NIC) rubber strip, 100 mm wide and 2 mm thick.

The upstanding collar was constructed of commercial quality (CQ) rubber strip, 150 mm x 1.5 mm.

The construction technique was a follows:

1 The tree trunk was cleared of loose bark, lichen and projecting branch stubs using a Surform. This in no way damaged the bark but yielded an unexpected benefit in that resin started to exude from the bark after 12-24 hours providing an extra sealant (Plate 15a).

2 The cleaned section was coated with rubber-based impact adhesive. Neoprene cement and Evostick were both used with no discernible merit exclusive to either. The NIC strip was similarly coated and stuck to the cleaned section under tension. Because of its soft texture, the NIC strip accepted minor irregularities in the trunk. Successive strips were stuck on in this way until the ring was about 12 mm thick (Plate 15b and c).

3 The flanged outlet tube was stuck to the CQ strip and stuck round the outside of the NIC band to form the upstand collar. Adhesion better if the surfaces were roughened with emery cloth (Plate 15d).

PLATE 15

4 String was tied round the outside of the completed gauge in the manner of a tourniquet (Plate 15 e).

It is hoped that the use of the larger bore outlet tube will make blockages infrequent. The use of the CQ strip only 1.5 mm thick makes it possible to turn the collar down for cleaning when required.

The materials used are relatively cheap and easily obtained, no special skills are required but construction is easier if the weather is warm and dry.

Typical costs for a tree 6-8" in diameter are:

flanged outlet	60
3 m NIC neoprene rubber strip 100 mm x 2.0 mm	£1.65
1 m CQ neoprene rubber strip 150 mm x 1.5 mm	£1.00
Adhesives	5
	£ 3.30

Construction time depends on numbers. Two men working on five gauges at a site can complete the work in two hours, as the tasks are done in rotation, but a single gauge would probably take an hour.

All materials were obtained from Moyer Manufacturing, Vansittart Road, Windor.

Dipflash - water sensing unit

J D G Smart

The Institute required an instrument to check the zero settings of its stage recorders at the gauging structures. Dissatisfaction with existing devices led to the prototype dipflash in which the water surface completed a circuit and lit a battery-powered bulb.

The prototype was developed and improved but retained the original basic features:

Contact with the water surface activated a light display;

A self-contained waterproof unit.

The production dipflashes consist of a cylinder some 350 mm long by 45 mm in diameter. The circuitry, dry cell batteries and display bulb are contained in moulded silicon rubber (Plate 16).

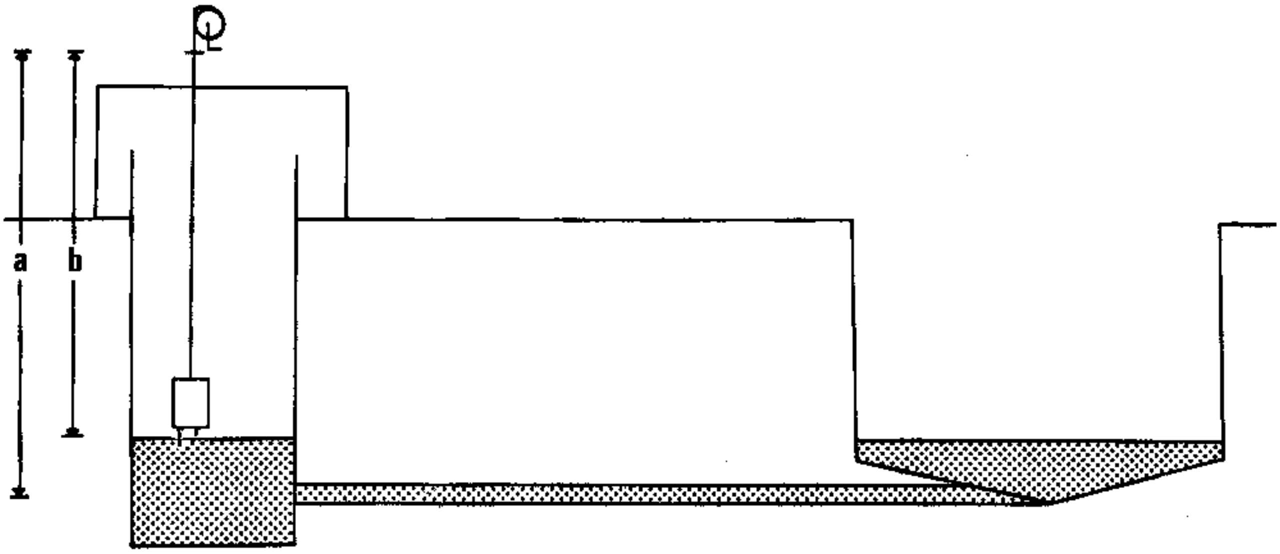
PLATE 16

The unit is suspended by a standard metal tape from a reel mounted on the table over the stilling well of the gauging structure (Plate 17). The tape passes behind a fixed mark scribed on perspex. The scribed mark is levelled to the flume invert and the height of the water surface above invert can thus be derived and compared with the stage recorders (Plate 18).

The dipflash is designed to be thrown away when the batteries are exhausted. Its life is dependent on usage but the first one installed at Plynlimon has lasted 13 months with no sign of failure. Although they are used at Plynlimon as fixed units, they are robust enough to be used as portable instruments, one unit serving many installations.

PLATE 17

PLATE 18



Height of scribed mark above invert **a**
Dipflash value **b**
Depth of water in structure **a – b**

FIGURE 18 Principles of dipflash operation