Apparatus for sampling of streams for chemical quality and sediment

D.B. VAN WYK
Jonkershoek Forestry Research Station, Department of Environment Affairs, Private Bag X5011, Stellenbosch 7600

Abstract

This paper describes an apparatus designed to automatically collect samples from streams during spates. The system enables stage samples to be taken during both the rise and recession of spates and functions on natural hydraulic pressures created by changes in stream level. A system for the measurement of bed load deposits that has been in use since 1978, is also described. These techniques have proved effective and cost is low when compared with other equipment marketed for similar purposes.

Introduction

The influence of catchment management measures, such as veld protection, prescribed burning, afforestation and clear-felling, on water chemistry and sedimentation is researched in a number of forest regions in South Africa (Wicht, 1967). There is, however, a need to obtain an unbiased estimate of the chemistry and sediment loads of stream water. Manual sampling is efficient during baseflow but during stormflow some form of automatic sampling is necessary.

In the past stormflow had to be sampled manually in remote research areas, for example after prescribed burns were carried out (Van Wyk, 1981). Because of constant uncertainty about whether it would rain or not, many fruitless trips were made and unnecessary costs incurred. In addition to this, high cost of available apparatus precluded its extensive use. This led to the development of the system described in this paper which provides for three separate apparatuses viz. for stage sampling in the stilling pond of a streamgauging weir of the rise and fall of the spate, and for the measurement of bed load.

Gilmour (1976) stated that single stage sampling and manual sampling should be combined to obtain the maximum amount of information.

Materials and Methods

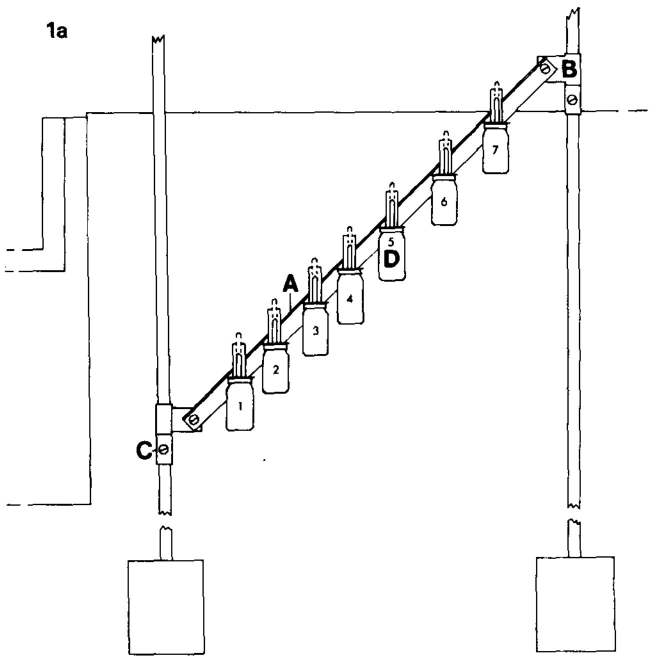
Rising flood stage sampler

This apparatus is based on the apparatus used by Gilmour (1975) in so far as the inlet and outlet controls are concerned.

The apparatus consists of two vertical standards mounted parallel on the weir within the stilling pond. A beam 'A' (Fig. 1a) slides up and down the poles by means of two sleeves 'B'. The lids of the sample containers are fixed to this beam, thus only the containers need be removed to collect samples.

The sleeves rest on stops 'C' held in position by locking bolts. The stops enable the height at which stage samples are taken to be adjustable, depending upon baseflow conditions. The stage intervals between samples remain constant.

The polyethylene sample containers 'D' have two curved tubes 'E1' and 'E2' let into their screw tops (Fig. 1b). Tube 'E1' is the water inlet and 'E2' the air outlet. When the water level in the pond rises above the opening in the air outlet tube an airlock is formed in the bend of the tube, effectively sealing off the sample and preventing further movement of water into or out of the container and hence precluding any mixing and adulteration of the sample. The influence of debris was to a great extent excluded by cutting a 'V' into the inlet (Fig. 1b).



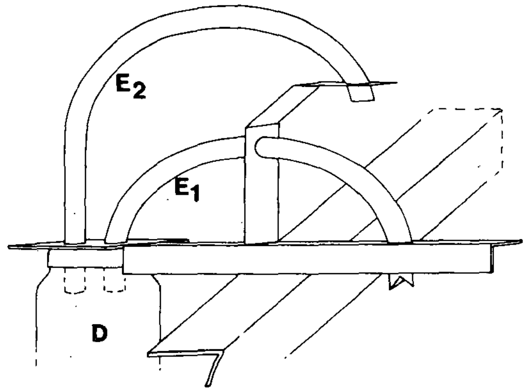


Figure 1
Rising stage sampler

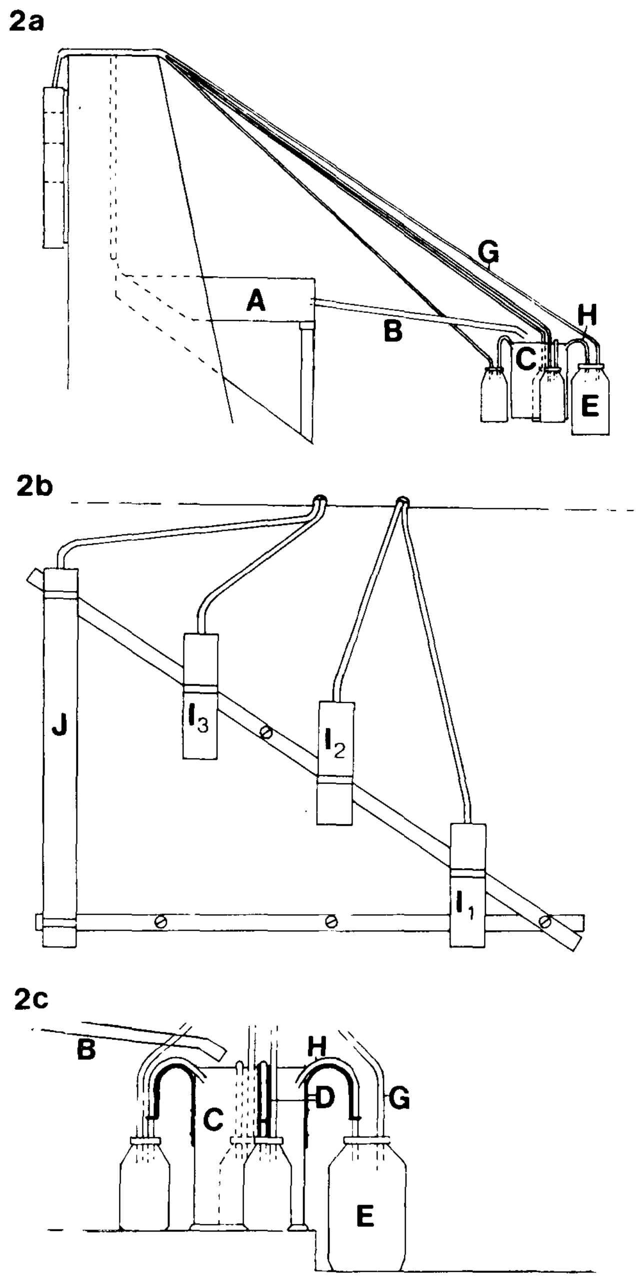


Figure 2
Spate recession sampler

Spate recession sampler

This system samples the stream as it falls from the notch of the weir. It consists of (Fig. 2a) a diverter 'A' by means of which water is diverted into and flows constantly through a tube 'B' into a polyvinyl chloride (PVC) bucket 'C'. The PVC bucket overflows constantly. Thus the diverted water is a sample of the water flowing from the weir at the time of diversion. The bucket has a hole in its base through which accumulated silt is cleared.

Sample containers 'E' are connected by plastic tubes 'G' to a series of PVC cylinders 'I' and 'J' (Fig. 2b) mounted on the inside of the weir wall, and 'H' to the water in the bucket 'C'. Each sample container is connected to a separate PVC cylinder. The tubes from the bucket to the sample containers are led over a tube holder 'D' (Fig. 2c) to position the inlet tubes and to avoid kinking. This tube holder can be adjusted upward or downward to alter the sensitivity of the sampler. These cylinders are fixed vertically at different predetermined heights on the inside of the weir, open end downward and the sample tubes 'G' entering though an airtight cap at the top.

Three short PVC cylinders 'I' are installed so as to sample spates at different stages over the whole possible spate range. One long PVC cylinder 'J' serves to sample the whole spate range. This is a control for the short cylinders. The volumes of these cylinders are such that the sample containers are filled in the sampling process.

The principle of this sampler is that as the water level rises in the weir pond a corresponding rise in the cylinders takes place and forces air out of the sampling system through the tubes 'G' and 'H'. When the water level recedes a partial vacuum is created in each cylinder in turn causing a series of samples to be drawn from the bucket 'C' into the sample containers. The adjustment of the sensitivity of the sampling process, by means of the tube holders 'D', is very important. If the sampler is made too sensitive, waves on the stilling pond can cause sampling to take place. If the sampler is adjusted too far in the opposite direction, so that the difference in height between the cylinder and the sample container is too great, air may escape or be sucked in at the cylinders in the stilling pond. This will break the vacuum and prevent a sample from being taken.

The two apparatuses described above are used to sample the rising and falling legs respectively of stream spates for both mineral content and suspended sediments.

The sampling of a maximum (1 m) spate by means of the apparatus is illustrated in Figure 3. The sampling ranges and positions on the rise and recession of the spate for this specific example are explained in this figure.

Bed load measurement: apparatus and method

The apparatus consists of two booms 'B', made from 50 mm galvanized steel tubing, fixed parallel to each other, one on either side of the stilling pond behind the weir. Rings 'A' are fixed to each tube one metre apart, each ring being exactly opposite a corresponding ring on the opposite boom (Fig. 4a).

A 1,5 mm steel cable 'C' with a coil spring 'D' at one end, is attached by means of a hook 'E' fitted to the spring to the first ring 'A1' on one boom, taken across the stilling pond and over a pulley 'F', which is hooked onto the corresponding ring 'A2' on the opposite boom, and then to a small portable winch 'G' mounted on a concrete block with bolt 'H' positioned near the wall of the weir. The cable is drawn taut by means of the winch to a standard degree of tension as measured by expansion of the spring (D1 to D2). A premeasured scale 'I' is fixed to the one side 'D' of the spring and expanded to 'D2' (see also Figure 4c). The winch 'G' (Fig. 4b) consists of a drum 'J' with enough cable available to allow for maximum required distance. After initial slack has been taken up on the cable, the drum is locked with pin 'L' at the socket 'K'. The final tension is taken up on the fine tension adjuster 'M'. This system enables one cable to be used for all measurements at all weirs and eliminates problems caused by varying inter-ring distances across the stilling ponds. The same tension can be put on the cable at all measuring points.

The distance between the cable and the bottom of the pond is measured at one metre intervals by means of a light-weight measuring staff 'N' the base of which is fitted with a 150 x 150 mm foot-piece to prevent it from penetrating the bed of silt. By taking these readings when the pond has been cleaned and again after a period of silt deposition an estimate of the sediment deposit may be obtained. The measurement with the staff is explained in Figure 4d with a side view of Figure 4a. An enlargement of the premeasured scale 'I' also appears in Figure 4c.

Samples of the sediment are taken from the weir and the relationship between wet volume and oven-dry mass is calculated. This relationship is applied to the sediment volume in the weir to calculate the mass of oven-dry sediment in the weir. Percentage mass loss on ignition is used to correct for organic matter content.

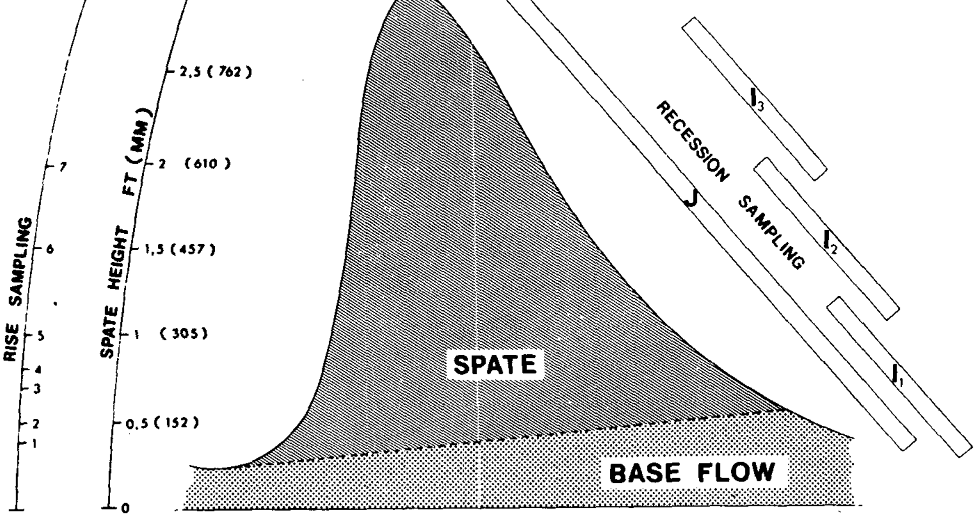


Figure 3
Schematic representation of stage sampling method

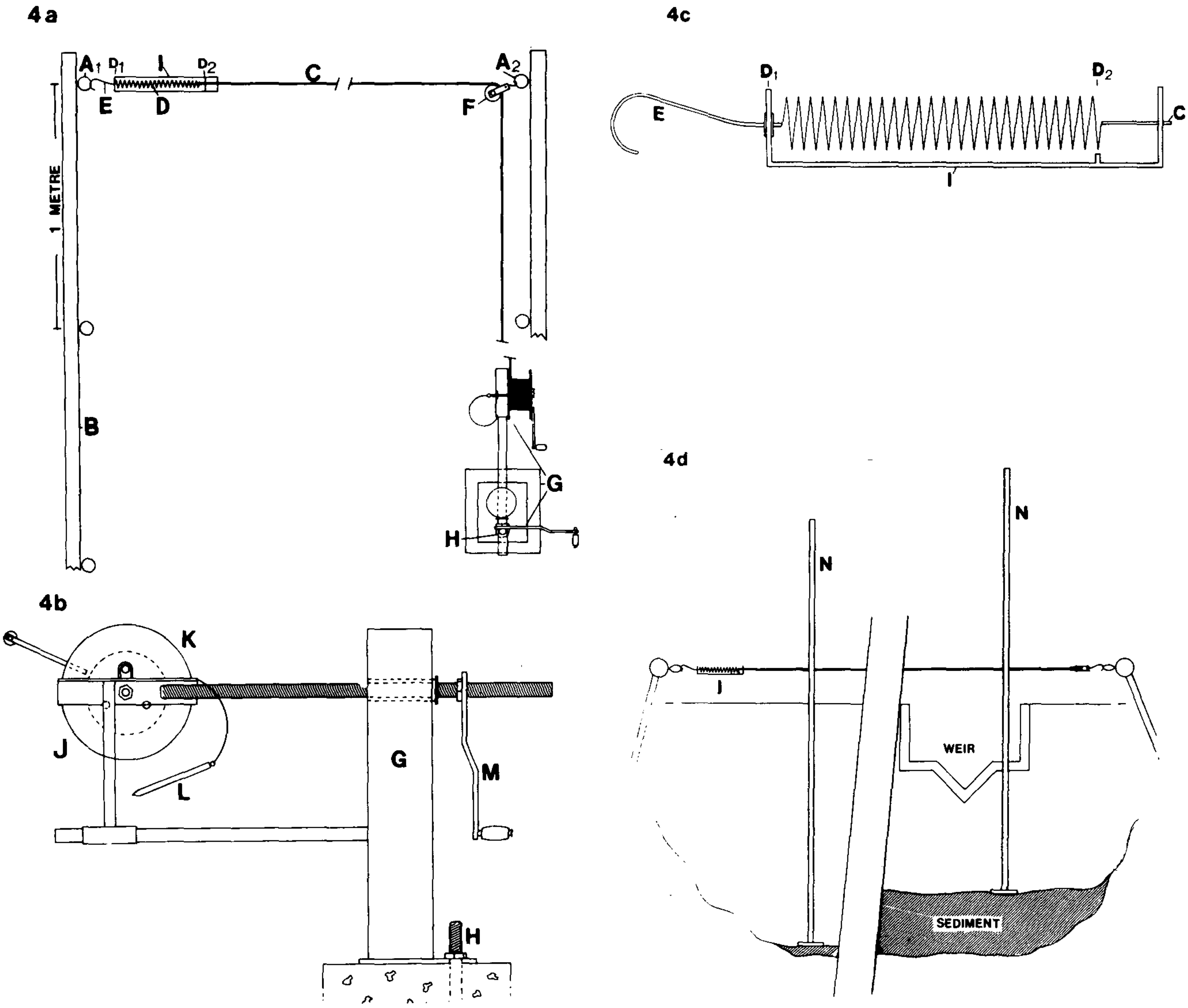


Figure 4
Bed load measurement

Results and Discussion

Results to date have shown the equipment described to be highly reliable. The sampling record shows a success rate of 95% over two rainy seasons in the Western Cape. In Table 1 the success/failure rate is reported for 5 catchments where the apparatus was well maintained.

Hewlett (1979; 1980) achieved a 30% sampling success over two years in an experiment where water quality is investigated after harvesting and regeneration of a piedmond forest. However, as the apparatus described here relies on natural pressures and not on mechanical or electric means of sampling, the failure rate is low.

Blockages caused by debris, and air leaks are the only factors that cause sampling failure. The system does not require much maintenance, but it is essential that the apparatus remains airtight. Where components such as plastic tubing or containers are not protected against the ultraviolet rays of the sun, replacement is often necessary.

The maximum sediment concentrations collected by means of the sampler at the different research sites are presented in Table 2.

The figure for Cathedral Peak gives an indication of the very high concentration that may be sampled. This was an exceptional situation where a wild fire destroyed a pine afforested catchment. With every rainstorm after the fire, the sediment concentration was extremely high.

Gilmour (1976) and Douglas (1967) stated that erroneous

TABLE 1
STATISTICS SHOWING THE NUMBER OF OCCASIONS DURING WHICH THE STAGE-SAMPLING APPARATUS FAILED TO SAMPLE THE STREAM WATER WHEN THE GIVEN LEVEL WAS REACHED

	RISING STAGE																FALLING STAGE										
	Level 1		Level 2		Level 3		Level 4		Level 5		Level 6		Level 7		Level 8		Level 1		Level 2		Level 3		Level 4		Total No. of Spates	Total No. of Spates Sampled	% Failure
	n	% Failure	n	% Failure	n	% Failure	n	% Failure	n	% Failure	n	% Failure	n	% Failure	n	% Failure	n	% Failure	n	% Failure	n	% Failure	n	% Failure			
BOSBOUKLOOF	52	5,8	37	8,1	26	15,4	6	0	—		—		—		—		47	10,6	21	14,3	4	0	46	8,7	56	52	7,1
ABDOLSKLOOF	29	6,9	11	0	—		—		—		—		—		—		—		—		—		—		30	29	3,3
LAMBRECHTS-BOS B	51	0	49	2,0	12	8,3	3	0	—		—		—		—		40	5,0	1	0	—		40	2,5	54	51	5,6
BIESIEVLEI	42	4,8	17	0	1	0	—		—		—		—		—		32	6,3	3	33,3	—		35	8,6	47	46	2,1
LANGRIVIER	52	0	49	2,0	31	9,7	25	0	16	0	12	0	9	0	2	0	—		—		—		—		54	52	3,7
MEAN % FAILURES	3,5		2,4		6,7		0		0		0		0		0		7,3		15,9		0		6,6				4,4

TABLE 2
MAXIMUM SILT LEVELS OF SAMPLES COLLECTED IN DIFFERENT REGIONS

	g/m³
WESTERN CAPE	
Jonkershoek	3 246
NATAL	
Cathedral Peak	647 058
EASTERN TRANSVAAL	
Witklip	980
NORTHERN TRANSVAAL	
Westfalia	1 057

conclusions may be drawn if intermittent hand sampling is the only method used. Stage sampling enables a more complete picture to be obtained of changes in for example nutrient concentration and sediment load which may occur during the course of a spate cycle.

The bed load measuring apparatus can also be used in erosion studies where profiles are measured. Precision is maintained wherever the cable is set up – subject to certain practical span limits – by applying a standard degree of tension.

The apparatus has operated successfully since 1980 in 17 research catchments in the Western Cape, Natal Drakensberg, Eastern and Northern Transvaal.

In comparison with other samplers on the market the apparatus developed locally is inexpensive and has proved very reliable in operation.

All three pieces of the equipment are easily constructed from readily available and inexpensive components. Use of the samplers results in considerable savings in both costs and man-hours when compared to manual sampling, particularly for sampling points in remote mountain catchments. The rising stage sampler was manufactured at a material cost of about R70, the recession stage sampler R60 and the bed load sampler R150.

Acknowledgements

The author wishes to thank Messrs F. Prinsloo and H.J. Barnard for construction and installation of the equipment, Prof Hiemstra for his valuable advice, Mr J.H. Janse van Rensburg for the drawings, Mrs I. Eygelaar for typing this script and Mr D. Bands, Mr F.J. Kruger and Mrs I. Gouws for checking the final draft. This work forms part of the conservation forestry research programme of the Directorate of Forestry of the Department Environment Affairs and is published with its permission.

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