STREAM DISCHARGE ESTIMATION

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ABSTRACT

A method that minimizes the amount of field and laboratory work when measuring the three discharges at the junction of a main stream and a tributary is described. A comparison between discharges calculated from actual measurements and estimated from an electrical conductivity analysis is made.

INTRODUCTION

A dilution gauging technique to measure discharges up stream and down stream from the junction of a main stream and its tributary usually involves two discharge measurements and one estimation. The amount of field and laboratory work involved can be considerably reduced by making only one discharge measurement and using three electrical conductivity measurements to estimate the remaining two discharges.

FIELD STUDY

Study Area

This study was carried out in the upper reaches and tributaries of Broken River in the Craigieburn Range, South Island. The area drained is predominantly greywacke with low mineral content, and hence the waters have low conductivities. It has been pointed out by Durum (1953) that studies of this nature are normally applicable only to the location studied. However, as no attempt was made to obtain a relationship between conductivity and discharge — tentatively suggested by Keller (1967) — the technique can be universally applied.

Dilution Gauging Technique

The dilution gauging technique is based on the injection of sodium dichromate solution at a constant rate, and the measurement of the subsequent dilution. This method is described in detail by Keller (1969). Operation of the equipment in the field normally takes about 20 minutes per gauging; laboratory analysis takes about one hour.

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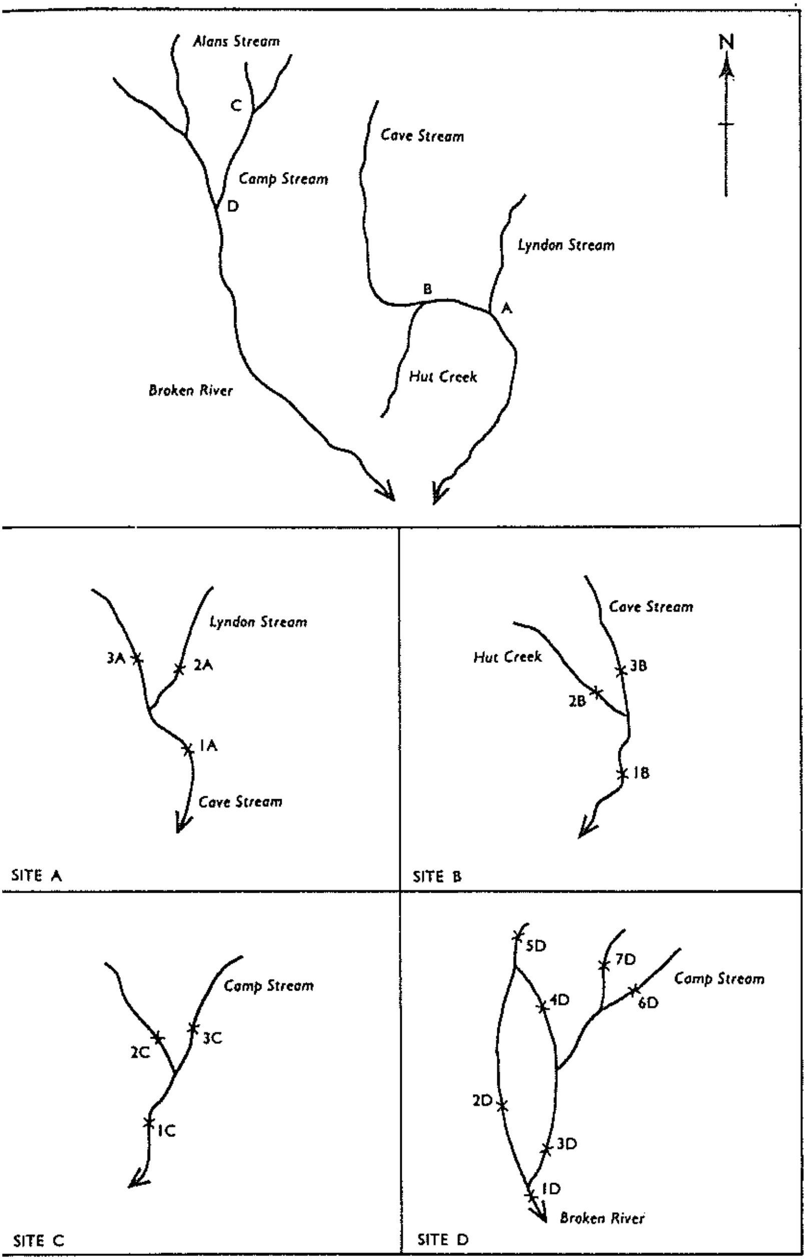

FIG. 1 — Site location sketch map.

Sampling and Gauging

Sampling and gauging were carried out at the four sites shown in Fig. 1. Sites A, B and C consisted of the simple confluence of a tributary with a main stream. but site D was at the confluence of two tributaries and a braided main stream.

At each site duplicate samples for conductivity analysis were collected at each point. followed by dilution gaugings commencing at the down-stream section. The stream discharges and conductivities were determined as soon as possible on return to the laboratory. The conductivity values were converted to the equivalent value at 25°c.

THEORY

If at any junction of a tributary and a main stream:

q_1 is the discharge of the main stream below the tributary,

κ_1 is the conductivity of the main stream below the tributary,

q_2 is the discharge of the tributary,

κ_2 is the conductivity of the tributary,

q_3 is the discharge of the main stream above the tributary,

κ_3 is the conductivity of the main stream above the tributary,

then, at any instant of time. from continuity:

$$q_1 = q_2 + q_3$$

and from mixing:

$$q_1\kappa_1 = q_2\kappa_2 + q\ \kappa_3.$$

In terms of q_1, this gives

$$q_2 = q_1(\kappa_1 - \kappa_3)/(\kappa_2 - \kappa_3)$$

and

$$q_3 = q_1(\kappa_1 - \kappa_2)/(\kappa_3 - \kappa_2).$$

Hence. by knowing one discharge measurement and the three conductivities it is possible to calculate the other two discharges.

RESULTS

At present no information on the comparative values of discharge obtained by this and other stream gauging techniques is available.

The results of consecutive dilution gaugings under steady flow conditions on 12 occasions gave some indication of the reproducibility of the method. The maximum percentage variation (expressed as a percentage of the mean of the two measurements) was of the order of $\pm 5\%$. Extreme care was taken on every occasion. and there seems to be no way of reducing this variation with the present method.

Table 1 lists the measured conductivity and discharge values for all sites. The conductivity value is the mean of the duplicate samples (differences were very small).

TABLE 1 — Measured conductivity (micromhos/cm at 25°c) and discharge (cusecs) for all sites

Site	*Date*	*Point*	*Conductivity ($\mu mho/cm$)*	*Discharge (cusecs)*
A	10/12/68	1A	40.8	6.80
		2A	41.8	1.14
		3A	40.3	5.52
	28/12/68	1A	44.5	3.70
		2A	47.4	0.92
		3A	43.0	2.38
	10/ 1/69	1A	43.9	3.16
		2A	46.5	0.64
		3A	43.0	2.13
B	11/12/68	1B	37.9	4.03
		2B	26.8	0.31
		3B	39.4	3.40
	11/ 1/69	1B	46.4	1.68
		2B	40.6	0.11
		3B	46.6	1.64
	12/ 1/69	1B	46.4	1.41
		2B	39.6	0.12
		3B	46.7	1.21
C	28/12/68	1C	23.3	0.71
		2C	28.5	0.16
		3C	22.5	0.47
	10/ 1/69	1C	23.3	0.54
		2C	26.7	0.24
		3C	24.4	0.34
	12/1 /69	1C	25.1	0.62
		2C	28.6	0.20
		3C	24.1	0.46
D	27/12/68	1D	29.7	11.39
		2D	28.4	1.14
		3D	29.8	10.71
		4D	28.2	8.76
		5D	28.4	8.47
		6D	33.1	0.93
		7D	39.1	0.93

From the theory it is known that $q_1 = q_2 + q_3$. Fig. 2 shows the variation of the measured q_1 from the q_1 calculated from the measured q_2 and q_3 discharges. The regression line should be $Y = X$ and the deviation from this is very small. The correlation is significant at the 1% level, and this means that a measurement of two discharges will yield a good estimate of the third discharge by this dilution gauging technique.

The upper limit of discharge that can be measured without modification to the technique has not been ascertained, so that it is impossible at this stage to give a likely percentage difference.

To test the conductivity method of estimating discharges it was assumed that the down-stream discharge q_1 was measured and the other two discharges q_2 and q_3 estimated from the conductivity measurements. Fig. 3 compares the estimated discharges with their respective measured values for all streams. There is a high degree of correlation, and deviation from the theoretical $Y=X$ line is very small.

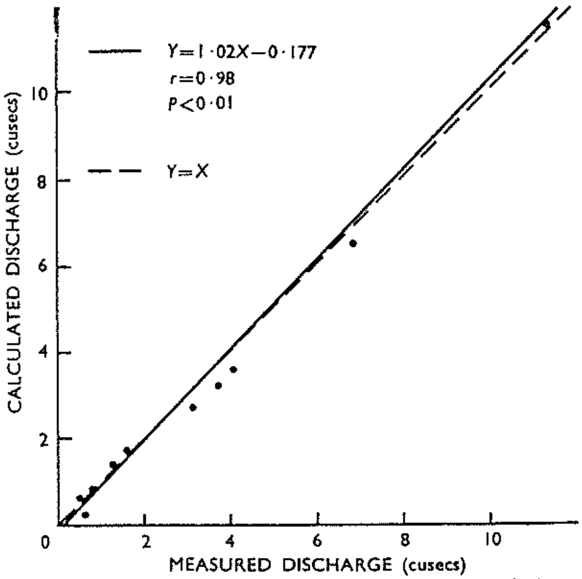

FIG. 2 — Comparison of measured and calculated discharges.

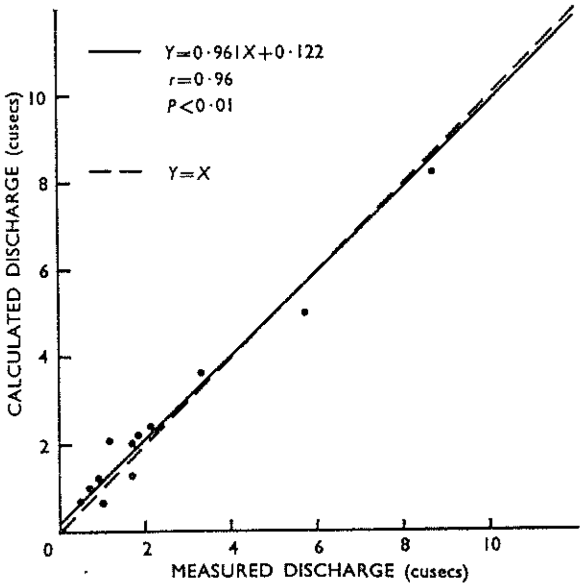

FIG. 3 — Comparison of measured and estimated discharges for all streams.

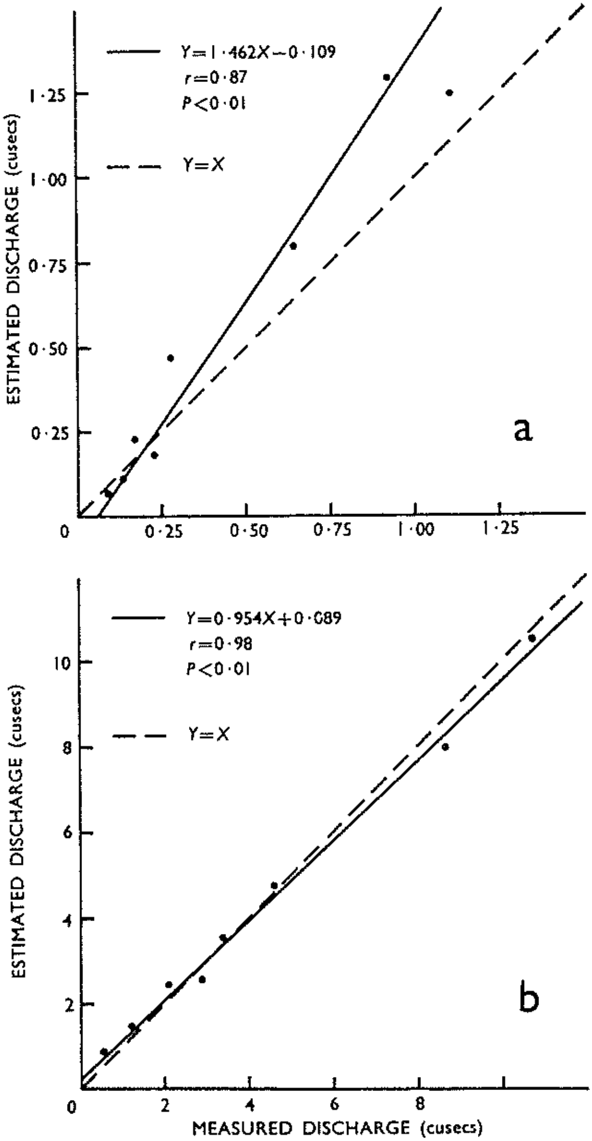

FIG. 4 — Comparison of measured and estimated discharges.
(a) Tributary streams.
(b) Main streams above the confluence.

Figs 4a and 4b separate the comparison into discharges from tributary streams and discharges from the main stream up stream of the confluence, respectively. Again a high degree of correlation is found in both cases, although deviations are greater from the 45° line in the case of the tributary streams.

Part of the variation in all cases can be attributed to the inaccuracy in gauging technique, but the remainder results from inadequacies in methods of field sampling. The range of conductivities is small and a slight increase or decrease in the conductivity value would cause a large variation in the discharge estimate. The smaller value of the two discharges would be more susceptible to this error, as shown by the variations in the values for the tributaries.

The method assumes that adequate mixing of the tributary and main-stream waters takes place below the confluence before sampling. Heterogeneous sampling sections may account for some of the differences in the work described here.

The assumption is made that only mixing occurs between the waters and that there is no chemical reaction. It is unlikely that there is any reaction of such a magnitude as to influence the results significantly.

CONCLUSIONS

A good estimate of two discharges at the confluence of two streams can be made by one discharge and three conductivity measurements. Less than half the time is involved compared with the conventional method using a dilution gauging technique, measuring two discharges and calculating the third. In small high-country streams where no gauging stations exist and a quick estimate of many stream and tributary discharges is required, this method is a great time saver.

Johnson (1968) found that relationships between chemical parameters and stream discharge in some instances was more pronounced when using estimates of specific minerals present in the water rather than of conductivity. This possibility is under examination with a view to applying it to this technique.

ACKNOWLEDGMENTS

This project formed part of the work undertaken by the author whilst a recipient of a New Zealand National Research Advisory Council Post-Doctoral Fellowship.

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