A P.O.E.M. ON THE WAIHO
(Electronic gauging of rivers)

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ABSTRACT

A Pressure-Operated Electronic Monitor, using the Pitot principle, was used to gauge the swift, gravel-bed Waiho river. The gauging system measures the velocities along vertical profiles every few metres across the river and stores water velocity and depth on a data logger. These results are available to the operator at the time of gauging. During gauging tests velocities ranging up to 5 m/s were recorded. The flows calculated with this system were indistinguishable from those obtained using a conventional propeller meter.

INTRODUCTION

Drag, snags and equipment damage are common problems when gauging fast rivers with conventional propeller or bucket-wheel current meters. To overcome these problems, the Hydrology Centre of the Department of Scientific and Industrial Research, New Zealand, has investigated a new gauging system comprising an instrumented Pitot tube, a static pressure sensor and a hand-held data logger. The instrument is known as a Pressure-Operated Electronic Monitor or POEM (NZ Pat. Appln. No. 240494). The weight of the prototype POEM is approximately 20 kg. A schematic representation is shown in Figure 1.

With conventional meters the revolutions per second/velocity relationship is linearly extrapolated beyond the range of calibration. With the Pitot principle, water velocity is proportional to the square root of the velocity head, and the higher the velocity the lower the influence of any errors in velocity head determination.

Pitot tubes have proven reliable and robust as airspeed indicators in aircraft. The Reynold's number of a POEM in the Waiho river is similar to that of

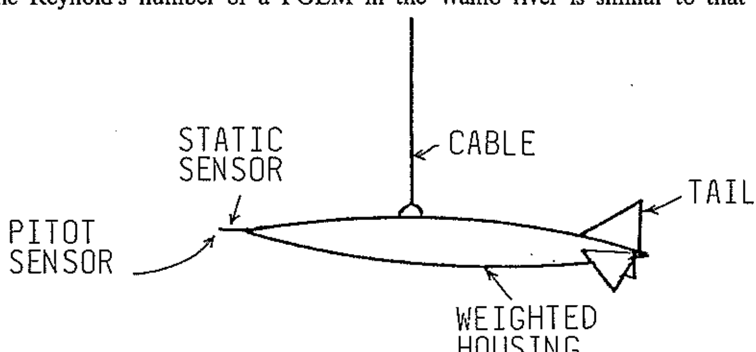

FIG. 1—Schematic drawing of POEM

TABLE 1—Summary of test gaugings, Waiho River, 13 September 1991

Gauging method	Start time	Elapsed time (min)	Stage change during gauging* (mm/h) left bank	right bank	Average stage (m)	Calculated flow (m³/s)
1 Large Ott, with 90 kg weight	0930	80	−32	−18	3.702	278
2 POEM	1115	29	−1	−5	3.684	229
3 POEM	1200	60	+29	+1	3.690	220
4 Large Ott, with 45 kg weight	1735	75	−22	−25	3.607	185

* +ve and −ve numbers signify rising and falling stage respectively.

a Boeing 737 at cruising speed. Pitot tubes have been used to determine point velocity measurements in hydraulic laboratories for many years. The advent of miniature pressure transducers and microelectronics allows this technique to be attempted in the field. The instrument is deployed in a similar manner to a conventional current meter, i.e., it is lowered from a bridge or cableway at intervals across a river. As the POEM is lowered to the river bed it continuously measures the depth and velocity; these values are transmitted up the winch cable to a decoder and data logger. The operator is warned if the POEM is lowered or raised too quickly, and a software algorithm checks the standard deviation of the turbulence signal for a short period during each vertical profile to identify any sediment blockage of the Pitot tube.

The POEM system logs nine mean velocities, each representing a vertical interval of one tenth of the water depth. Velocities in the top and bottom twentieth of the profile are not recorded. This system contrasts with conventional gauging in which the velocity is normally measured at the surface or at 0.6 of the flow depth, or at 0.2 and 0.8 of the flow depth.

Because of the streamlined shape of a Pitot tube, and the absence of moving parts, the drag on a POEM is much lower than that on a conventional meter. When the POEM is carried downstream by drag on the cable, the instrument's static pressure sensor still indicates the correct depth of water above the probe and no vertical angle correction is necessary. The absence of moving parts should increase the operating life of the device before recalibration is necessary. Factors which could affect calibration are erosion of the pitot tube tip, and drift or deterioration in the pressure transducer linearity (transducer offsets are recalibrated automatically during each gauging).

Conventional meters are difficult to operate effectively at water velocities higher than about 5 m/s. However, the POEM is designed to operate at velocities between 0.5 and 9 m/s. Rating tank tests showed the instrument to give correct readings at velocities of 1, 2 and 3 metres per second in clean, non-turbulent water.

FIELD TEST

The Waiho river in south Westland was selected for field trials of the POEM because:

(i) surface velocities of 7 m/s have been measured with floats;

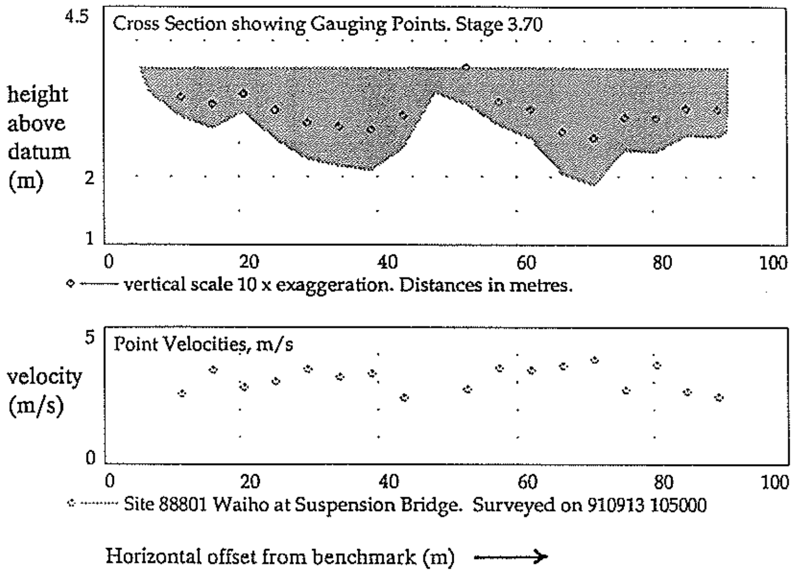

FIG. 2—Conventional gauging 13 September 1991, 0930 to 1050 hrs, 278 m^3/s. (Dates and times in the figure legends are given as YYMMDD HHMMSS, where Y denotes year, M month, D date, H hours, M minutes and S seconds, respectively.)

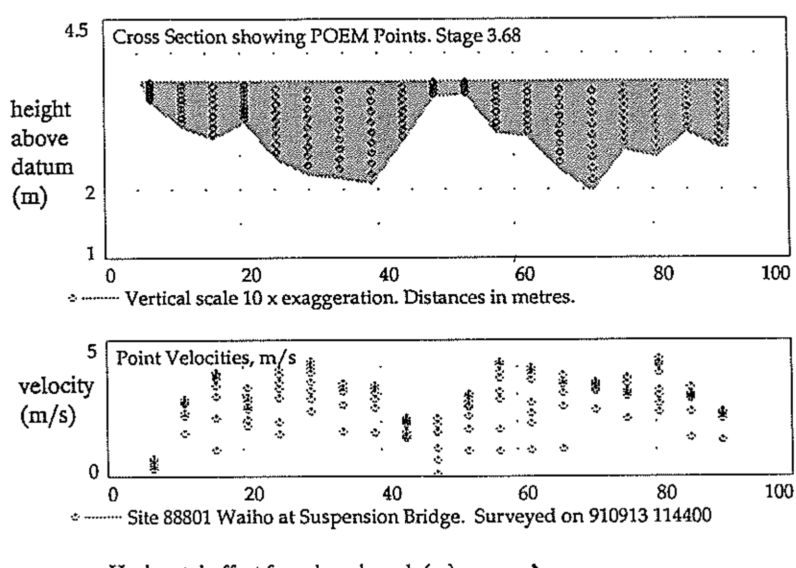

FIG. 3—POEM gauging 13 September 1991, 1115 to 1144 hrs, 229 m^3/s.

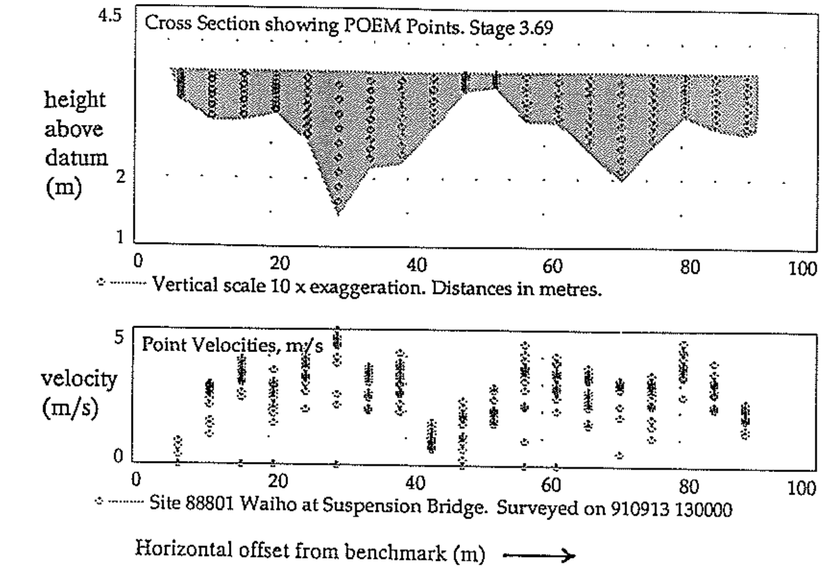

FIG. 4—POEM gauging 13 September 1991, 1200 to 1300 hrs, 220 m³/s.

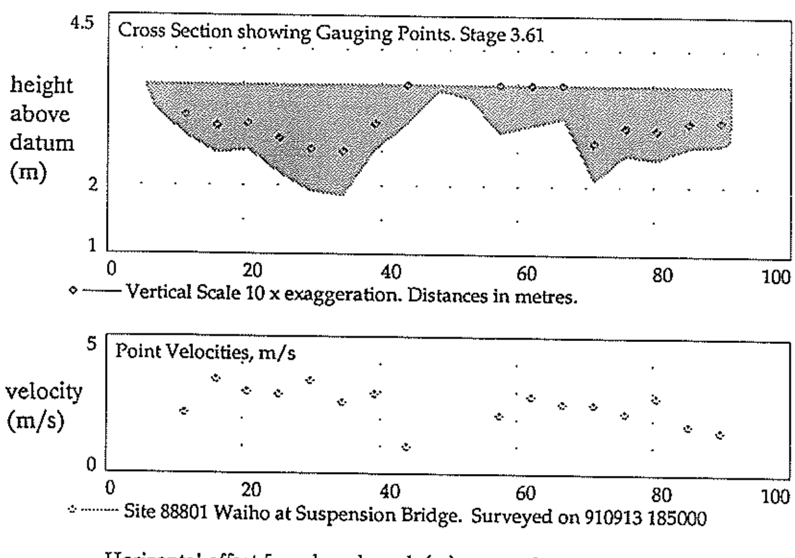

FIG. 5—Conventional gauging 13 September 1991, 1735 to 1850 hrs, 185 m³/s.

(i) surface velocities of 7 m/s have been measured with floats;
(ii) a closed road bridge was available for gauging operations;
(iii) the river has high gravel bed-load transport and ice blocks from the Franz Josef glacier which can damage conventional equipment;
(iv) the bed contours change rapidly and little is known of actual bed levels during floods;
(v) hydraulic information on the river is required for planning bridge replacement.

Test gaugings were conducted on the Waiho River during a moderate fresh on 13 September 1991. The water temperature was 5°C with rain and a 10 km/hr wind blowing downstream. Four gaugings were carried out, two using a large Ott current meter and two using the POEM. Table 1 and Figures 2 to 5 show the results of the gaugings. Figure 6 shows changes in river stage during the gaugings. Both of the stage recorders are set to the same datum.

DISCUSSION

Although it is still at the prototype stage, the POEM shows promise for use in fast rivers. It is quicker to use and easier to handle than conventional equipment and, considering the changes in cross section which occurred during the gaugings, it gave flow measurements indistinguishable on a discharge-area plot from those made with a conventional meter (Fig.7). However, a number of operational requirements were noted during the tests.

The POEM is continuously lowered to the bed and raised again, not held at fixed depths as with a conventional meter. In order to monitor the performance of this system, all depth and velocity data, and not just decile averages, were stored on a computer hard disk during some of the tests. A typical vertical profile showing all data points is given in Figure 8, it indicates lower velocity measurements while the probe is being lowered than when it is raised. This effect was more pronounced the faster the POEM was lowered (or raised), and is attributed to the small but significant velocity of the POEM itself as it is dragged a small distance downstream by the flow. In Figure 8 the maximum drag velocity is about 0.2 m/s, giving velocity readings about 0.2 m/s too low during lowering and 0.2 m/s too high on raising. The gauging procedure averages the upwards and downwards velocity profile readings so that, provided raising and lowering speeds are similar, the effect should not cause serious errors.

Although signals from the POEM are relayed to the surface at radio frequencies, contact between the underwater unit and decoder was occasionally lost. This was attributed to dirt or excess grease on the winch slip-ring or cable. Loss of contact is immediately evident to the operator and the vertical profile must be repeated.

To allow for local atmospheric pressure changes, the POEM pressure sensors are reset at zero before each vertical profile is measured. To do this, the instrument must be kept horizontal so that there is no residual internal water column affecting the pressure reading. In the field this was done with the POEM positioned on the water surface, its ports just clear of the water. Where large surface waves were present this procedure sometimes gave false readings at the velocity sensor, and the zero datum was set too high or too low. The velocity error introduced by an inaccurate zero setting decreases with the square of the velocity being measured. Fortunately, large surface waves were associated with regions of high water velocity. A second reason for resetting the sensors at the water surface

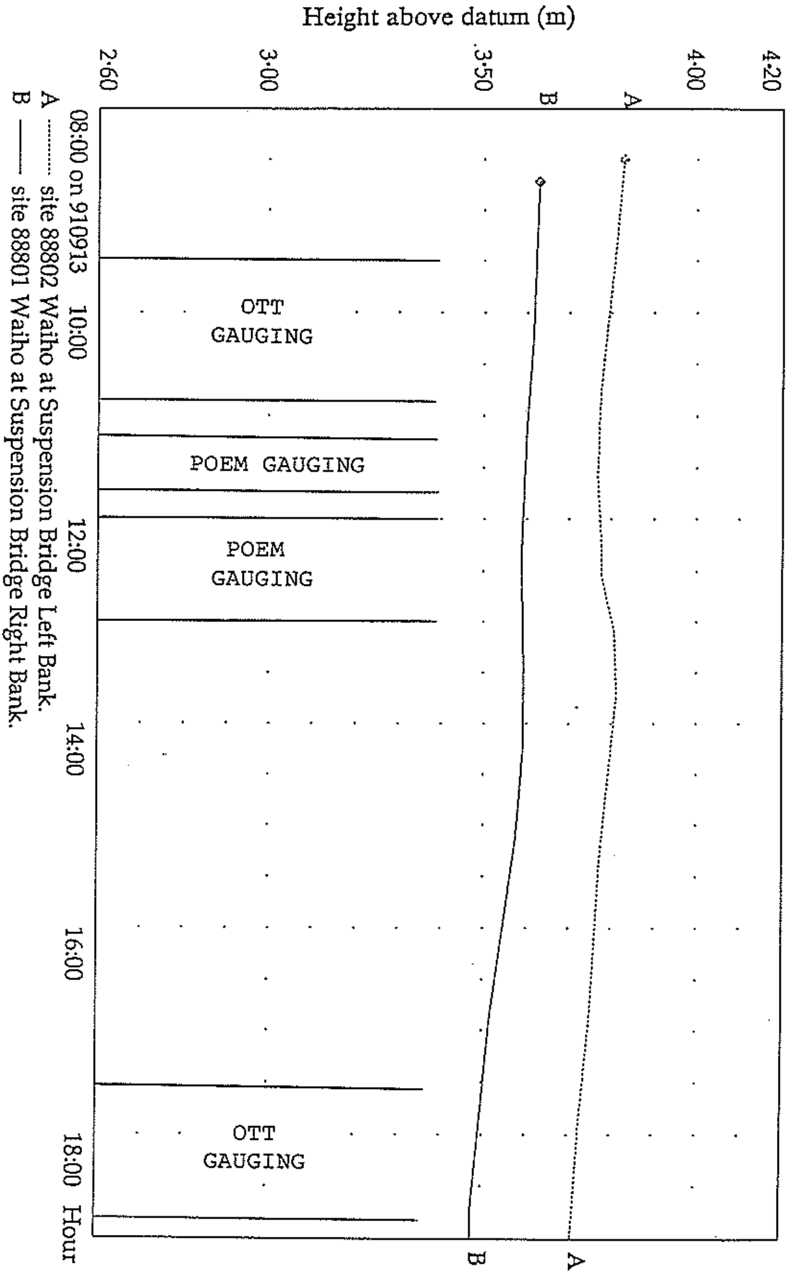

FIG. 6—River stage at left and right bank during gaugings, 13 September 1991.

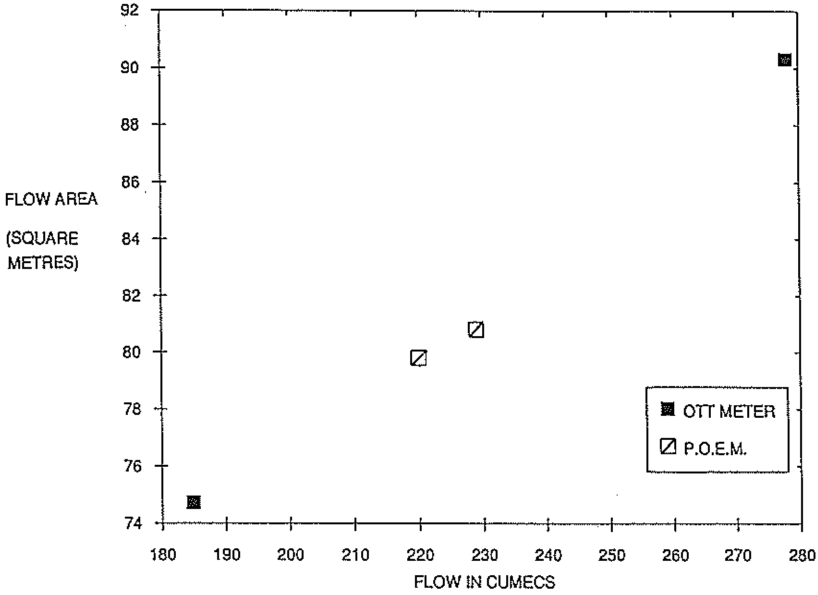

FIG. 7—Cross-sectional flow area and flow for gaugings.

is that wind velocities are lower here. Because measurements are based on the pitot tube principle, the POEM also detects wind velocities! The POEM may not give accurate readings in high winds and low water velocities unless some form of wind shield is used.

At one stage the POEM was left on the river bed for several minutes, and was raised only with difficulty after it became buried in the gravel. An inspection following the gauging showed the front of the stainless steel housing of the POEM to be pitted with microdents from rock abrasion, but no internal damage.

The cross section gauged from 1200 to 1300 hrs (Fig. 4) indicated scour in the left hand channel 0.4 m deeper than any shown by other gauging surveys. Further surveys will be needed to determine whether this effect is an error or whether the rising river stage caused this degree of scour (all other gaugings were made at falling stage, see Fig. 6).

CONCLUSIONS

The POEM gaugings took half the time of the conventional gaugings, and the unit was easier to handle than a traditional propeller meter. For the mobile-bed Waiho River, the conventional and POEM-calculated flows were indistinguishable on a flow area plot. The lower drag and the depth-measuring system of the POEM allowed gauging with no backstay and a weight less than half of that required for a conventional meter. Velocities up to 5 m/s were successfully recorded. The system is robust, but several precautions for future

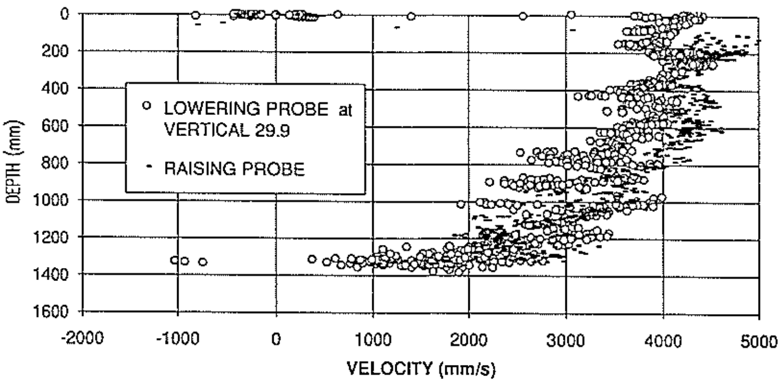

FIG. 8—Typical velocity profile measured by POEM.

use were noted: the POEM unit may be buried if left resting in mobile-bed layers; accurate resetting of the pressure sensors is essential for lower velocity measurements; the POEM should be raised at a rate similar to that at which it was lowered; occasionally it is necessary to repeat a vertical profile.

As a result of these tests, further modifications to the POEM are being investigated and more POEMs will be produced.

ACKNOWLEDGEMENTS

S. M. Thompson and W. R. Thompson assisted with the gauging exercise. M. J. Duncan and M. A. Wild helped with data processing.