NOTES ON RIVER DISCHARGE OBSERVATIONS.

(A Paper read before the Sydney University Engineering Society)

JULY 23RD, 1899.

BY WM. POOLE, JUNR., ASSOC. M. INST. C.E.

A. Morrison.

NOTES ON RIVER DISCHARGE OBSERVATIONS.

By Wm. Poole, Junr., A.M.I.C.E.

In the present short paper the author disclaims any general description or critical notice of the various methods employed in observing the discharge of streams of various sizes, but will confine himself to such as have come within his own experience.

One of the great questions affecting the economic well-being of the vast plains on the western side of the Great Dividing Range is Water Conservation and Irrigation. In this back country there is a large number of rivers, the principal of which are the Macintyre, Gwydir, Namoi, Castlereagh, Macquarie, and Bogan, uniting to form the Darling, which, after a long and isolated course, joins the Murray River. Further south there is the Lachlan, which joins the Murrumbidgee, and this in turn unites with the Murray. All these streams are at the disposal of the engineer, for irrigation or other schemes of utilisation. It is, then, necessary to know what is the least quantity of flowing water in these rivers which is available for such purposes. All of them, except the two last-mentioned, cease flowing in dry seasons like the present; and of the latter, the flow in the Murrumbidgee is at times very small, and in the Murray only moderate. Irrigation works of great extent being thus out of the question without special means of storage,—it is of great importance to know what amount of water during the twelve months is likely to be at our disposal for this purpose or for distribution through the many arm-branches and effluent channels which form a portion of our waterway system. For this purpose river gauges have been erected at a number of places and gaugings of the flow taken at various heights. These river-discharge observations have been carried on more or less systematically during the last fifteen years. The method generally employed is that of rod floats. This system was brought into use in this colony by Mr. G. H. McKinney, M.I.C.E., who has been in charge of the Water Conservation Branch since its inauguration. In this system a uniform reach is selected as near the gauge as possible. The stream at the selected sight should be straight, the banks at a uniform width apart, the bed should have a uniform cross-section, the deep part not shifting from side to side, and lastly, the bed must be free from submerged timber and other obstructions which interfere with the uniform flow of the stream and hinders the passage of the vertical rod floats. This last-named condition is often exceedingly difficult to obtain, which fact induced the author, as hereafter explained, to considerably modify the manner in which floats were used. The uniform section and moderate velocity in the large canals of India render them admirably adapted for the ordinary method which is in general use. The system was largely adopted by Major Allan Cunningham, R.E., in his famous Rorkee Hydraulic Experiments.

Method of Gauging.—The usual method of procedure is briefly as follows: A base line, parallel to the current, is laid out on one bank of the river, and is generally 200ft. long; but in many cases, on the smaller rivers, *e.g.*, the Lachlan, the length has to be reduced to 100ft. on account of the want of uniformity, or obstructions in the river bed. Three sectional, or observation, lines, are set off across the river at right angles, one from either end, and one from the centre of the base line. Substantial posts are set out on both banks at each cross-section, and from them lines of fencing-wire are stretched across the river, about 3 ft. above the water. Distances are measured off along these wires, from the base line, small pegs being driven in on land, and tags of rag fastened across the river, to mark the position of every 10ft., special distinguishing tags being placed at every 50ft. The reduced levels of these positions on land and of the water level at the time of observation are ascertained by levelling, and the depths of water by sounding. While the foregoing operations are proceeding, long wooden floats are prepared of pine, 1in. square, in section, and of different lengths to suit the various depths. Major Cunningham has shown "that the rod velocity is always somewhat less than the mean "velocity past its own immersed length, and that, finally, to measure "mean velocity past a vertical of depth H, the rod should be immersed "only about 0·94. As practical necessity also obviously involves the "use of a rod immersed decidedly less than the full depth, this result "is of great importance, as it removes one of the chief objections "hitherto urged to the use of the rods, namely, that in consequence of "not reaching into the slack water near the bed, they move quicker "than the mean velocity.'* It is necessary to weight the rods so that they will maintain a vertical position; a suitable quantity of scrap iron is therefore attached to the lower end of the rod, or in lieu thereof, bags filled with sand, these latter being known as "pudding bags." It is necessary to weight very long rods, *e.g.* 25 to 35ft., at several places along their length, a single heavy weight at the lower end, causing them, while sinking, to bend too sharply and break in two. The floats are set free far enough up stream to allow them to assume a normal velocity before reaching the upper wire. The time at which a float passes each wire is noted by the engineer who remains on the river bank, and the distance from the base line is read by a reliable assistant who follows behind in a boat.

Difficulties.—The lower end of the float is frequently fouled by submerged snags, the head is carried down stream and drawn below the surface of the water, the float in many instances being lost. Suitable scantlings for floats can rarely be obtained in country towns;

---

*Recent Hydraulic Experiments. Proc. Inst. Civil Engineers. Vol. LXXI., page 21.

long strips have to be laboriously sawn by hand from boards, thus occasioning much preliminary waste of time. To guard against an undue loss of floats, several yards of strong twine may be attached, one end to the head of the float, the other to a cork. Sunken floats can then in most cases be hauled to the surface and recovered. Float observations are taken at frequent intervals, generally at about every 10ft. across the stream. If two floats diverge very much in their courses, they are repeated, an intermediate observation being also taken. The foregoing may be considered as the normal method of procedure. It frequently happened that on the smaller rivers normal conditions could not be obtained; the difficulties were got over by the author in the following manner:—

(*a*) The bed of the best available site contained a few submerged snags which obstructed the passage of floats of proper lengths. Floats cut sufficiently short to clear the obstructions would be of various proportions of length to depth of water, and would give results of which would be of little value, except after special calculations; it was therefore desirable to use a uniform method, and the simplest was by means of surface floats, *e.g.* a rod float cut up into 3in. lengths. Special observations were carried out by the author to ascertain the ratio of velocity between rod and surface floats; the average was found to be 9 : 10. Mr. C. E. Bloomfield independently established the same ratio. Whenever it was necessary to use such surface floats, proportional allowance was made in the subsequent calculations to reduce the results to normal conditions.

(*b*) The available boats were often very cumbersome and dangerous. Surface floats were accordingly used. The ordinary steel fencing-wire at the cross-sections was found very difficult to manage, being very liable to get foul of a snag. The author therefore adopted galvanized binding-wire, which was found so light and convenient that it was almost always used instead of the more cumbersome fencing-wire. The same wires were taken about as part of the travelling impedimenta, the three wires, each 400ft. long, only weighing a few pounds. The wires were securely tagged and drawn across the river, being so light that they could generally be held clear of the water. When the gauge site was convenient to a bridge—it generally was—the wires were stretched out along the deck of the bridge, swung over the side, held clear of the water, carried to position and fixed.

(*c*) At some places no boat could be obtained. If there was a bridge the light wires were placed in position in the manner before mentioned. The central wire was placed just up stream from the bridge, so that the depth of the water could be taken from the bridge above, the distance between the wires reduced to 50ft. Surface floats were thrown well up stream, beyond the upper wire, and position of passage observed from the bridge. This method should not be used except in such extreme cases. In several cases the current was so sluggish that the width of the bridge was taken as the base for the observation of float velocities, the vertical sides of the squared girders forming a sharp line of interception.

Surface floats can only be used on calm days.

Office Work.—The reduction of the observations is simple. In estimating the discharge, the velocity of each filament is the average from the upper to the lower wire, and the sectional area used is that of the central cross-section. Velocities are usually calculated in feet per second, and the discharge in cubic feet per second. A diagram is plotted shewing the path of each float, and shews at a glance if the current has been fairly uniform in direction. The velocity of each float from the upper to the lower wire is calculated, also that from upper to middle and middle to lower wire, the two latter being used as checks on the uniformity of flow during the period of observation.

The middle cross section is plotted, showing depths of water, etc.; a curve of velocities is plotted upwards, the water level being taken as the base. For convenience in calculation, the section is generally divided into five or more parts, the sub-divisions being at points where the sectional depths or velocities shew a marked change in uniformity, *e.g.*, from the water's edge to the toe of the bank; over this distance the depth and velocity rapidly increase; the central section is that over which both depth and velocity are fairly uniform The average velocity of each division is culculated and multiplied into the sectional water area of the same division, giving the discharge past this section; the total of these sectional amounts being the discharge of the river at the time of observation

The discharge for a given river height is not always a constant quantity, being greater with a rising and less with a falling river than that obtained under normal conditions (*i.e.* when the gauge height has remained almost constant for several days). This variation is readily understood when it is considered that the surface slope of the stream is steeper with a rising river and flatter with a falling river.

In cases where the slope of the stream was also known it was found by calculation that the co-efficient of roughness in Ganguillet and Kutter's Formula was often as high as ·040 to ·050. The accuracy of these determinations of roughness was at first doubted, but was substantiated by the results obtained on different rivers. It must not be overlooked that the rivers in question are very tortuous in their courses, the current frequently changes from side to side, the depth varies greatly within short distances, and the bed of the streams are much obstructed by submerged timber *debris.* Ganguillet and Kutter, in their work, "Flow of Water in Rivers and other Channels," quote several examples where this co-efficient is as great, or even greater, than those just mentioned. The results adduced by the author cannot therefore be considered abnormal when the foregoing considerations are taken into account.

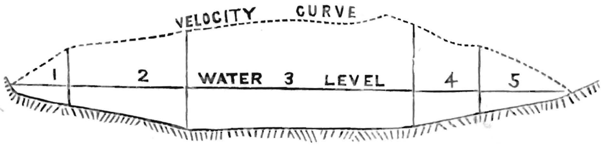
APPENDIX.

BARWON RIVER AT MUNGINDI.

Date of Observation, October 1st, 1894.—Gauge Height, 7ft. 0¼in.

Surface Floats used.

Mean velocity, 1·12ft. per sec.—Discharge, 635·6 cub. ft. per sec.



Velocity of Floats, feet per sec.	0·00	—	—	—	0·88	—	1·13	—	1·29	1·43	—	1·43	—	1·49	—	1·54	1·43	1·11	—	0·97	—	—	0·00
Distance from Base Line.	29	30	35	40	42	50	56	60	61	67	70	73	80	85	90	94	100	105	110	112	120	125	126
Depth of Water in feet.	0·0	1·7	2·3	2·8	3·2	4·7	—	7·0	7·2	—	8·3	—	7·2	—	6·6	—	6·2	—	4·2	4·4	1·8	0·1	0·0

Section.	Distance.	Velocity Area.	Velocity, feet per sec.	Sectional Area, in square feet.	Discharge, cub. ft. per sec.
1	29·42	5·7	0·44	29·6	13·0
2	42·61	20·1	1·06	97·2	103·0
3	61·100	56·7	1·45	350·0	507·5
4	100·112	13·6	1·13	60·6	68·5
5	112·126	6·7	0·48	29·6	14·2
					706·2
		Less 10% for Surface Floats			70·6
		Total Discharge, feet per sec.			635·6