The Determination of River Discharge

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It is now generally recognised that a knowledge of the natural resources of a country is of national import, in that it is the ruling factor in inducing the development of large industrial and other classes of undertakings, all tending to the prosperity of the country.

Looming large amongst such natural resources is the river system, which in some countries, indeed, forms the most important asset. Our own Commonwealth, although not so richly endowed in this direction as certain other countries, still possesses wonderful resources in its river system, and a short description of the methods generally adopted in the determination of river discharges may not be out of place.

Deduction of Flow from Rainfall

Owing to the fact that rainfall records are more often available than stream-flow records, it is often necessary, in the preliminary stages of a scheme for the utilisation of a river, to rely upon assumptions of the flow deduced from rainfall data.

Many efforts have been made to co-relate these two sets of values, and much useful work has been done in this direction, the best known relationships being those put forward by Vermeule, in the following form:—

$$F = R - E$$
$$E = 15.5 + 0.16R$$

Where F = annual run-off in inches; R = annual rainfall in inches; E = annual losses in inches.

This formula was evolved for the streams of the eastern part of the United States, but this form of equation has received fairly general recognition, and appears to be much more accurate than the method of adopting a mean percentage run-off, provided that care is taken to determine the correct values of the constants in the equation for the particular stream concerned.

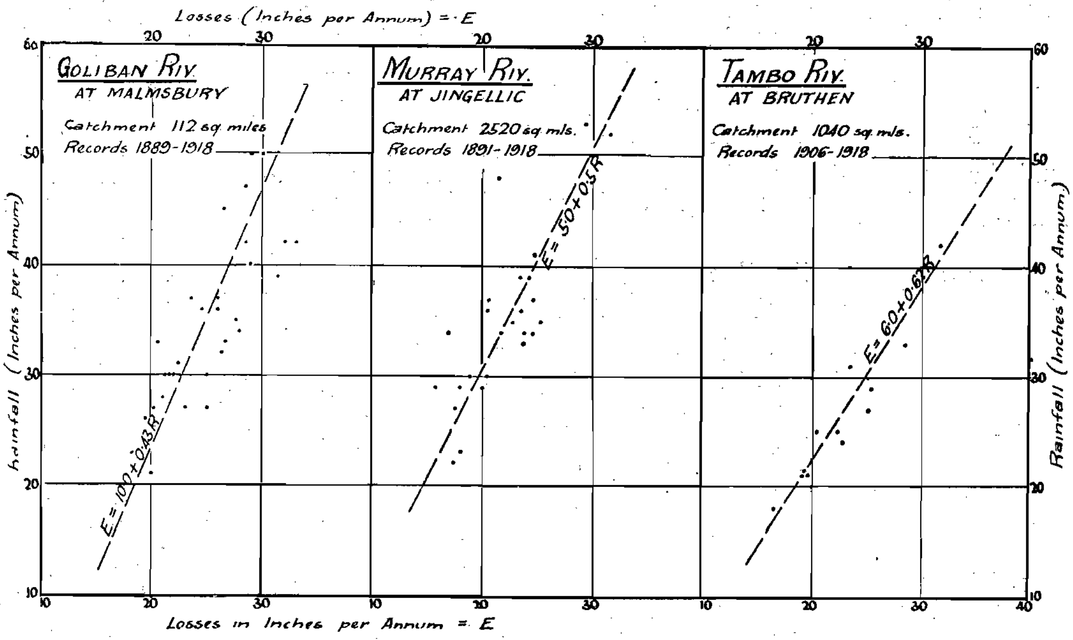

Fig. 1. Annual Run-off, showing the Application of Vermule's Formula to some Victorian Streams

The accompanying diagram, Fig. 1, which is plotted from the published records of the Victorian state rivers and water supply commission, illustrates the application of this type of formula to some of our Victorian streams, but shows clearly the great differences which occur in the formulæ for different streams. This diagram also shows the large errors which would arise through the adoption of a fixed percentage for any one stream regardless of variations in the annual rainfall. Vermeule also arrived at a basis for the computation of monthly run-off, but an attempt to treat any Victorian streams similarly resulted only in a maze of inconsistent figures.

The difficulties of this method are to determine the values of the constant and percentage loss, and also to determine the different values of these for different seasons, within a reasonable

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margin of error. The difficulty of assuming correct values for the rainfall where such stations are sparsely scattered over a large area is also very real. Necessity arose a short time ago for the author to determine the flow from rainfall records under almost the most favorable conditions possible. The catchment area was known and rainfall stations reasonably close, whilst catchment, rainfall and stream flow were also known at a gauging station about 10 miles downstream on the same river.

A careful investigation was made and the annual values for Vermeule's formula determined with reasonable agreement. All efforts, however, to determine the seasonal variations proved hopeless and certain assumptions had to be made. The deduced run-offs for the smaller catchment have since been checked by stream-flow measurements and have proved the annual flow assumed to be approximately correct, but the assumed seasonal variations of flow were quite incorrect. It is impossible to stress too greatly the fact that all assumptions of run-off based on rainfall data should be used with great caution and checked by actual stream-flow measurements as soon as practicable.

River Gauging Routine

The established routine of obtaining continuous records of river flow involves the assumption that whilst the river bed remains unaltered, any particular height of the water surface at the gauging site will always correspond to the same discharge in the river. It is, of course, necessary that the river bed should remain unaltered not only at the gauging station itself, but also for a sufficient distance upstream and downstream from this site to maintain practically the same hydraulic conditions.

This assumption is practically universal, but is only approximately correct as for any particular gauge height; the flow is usually slightly greater when the river stage is rising than when it is falling, but these differences are usually very slight and are therefore ignored.

The general routine of establishing and maintaining a gauging station is as follows:—(1) Select site for gauging station. (2) Establish and securely fix gauge staff. (3) Arrange for readings of staff to be taken as often as required, usually daily. (4) Take measurements of stream discharge at different water levels on gauge. (5) Establish a rating table from (4) by which discharge corresponding to each reading is obtainable.

It will be noted that the above routine requires the co-operation of a local resident who is willing to assist in this work for a nominal remuneration. When continuous measurements of stream discharge are required at places remote from civilisation, this is obviously impossible. Moreover, even when suitable arrangements can be made for daily readings, it is impossible to obtain records of any rapid variations of flow, such as high floods, which may occur between the regular times of readings. In a "flashy" stream these variations may be of considerable magnitude and in some cases might entirely upset the value of the records. In these cases it is advisable to install an automatic recorder which will give a continuous record of the variations of the water surface. These instruments are discussed in more detail later.

Selection of Gauging Sites.—As gaugings are usually required at some particular locality on a stream for the purpose of furnishing data for some special scheme the location of the site is fixed within certain limits. The exact location, however, is of the greatest importance and considerable care combined with judgment and experience is necessary in order to obtain satisfactory results, and in no case should be selection of a site be made in a hurried manner.

It might be pointed out that the records of a gauging station, once established, are frequently required for the design of works, in the future, which may be of considerably greater magnitude than those in mind when such gaugings were initiated and therefore all gaugings should be as accurate as is reasonably possible.

It is desirable, although not necessary, that the position for discharge measurements may be at the gauging station, but cases will often arise where the best points for these two requirements do not coincide, and no accuracy is sacrificed, provided discharge measurements are taken within a short distance upstream or downstream of the gauge staff, and special care is taken to notice that no water enters or leaves the river between the two points.

In selecting the site it is desirable to have a knowledge of the river at widely varying stages of flow, as frequently a site which is excellent for low stages may be totally unsuitable for flood flows, and vice versa.

The following points are among those which should be noted:—(1) General course of the stream adjoining the site should preferably be reasonably straight. (2) Bed of stream should, where possible, be of a solid permanent nature, not likely to be altered by floods, etc.; this applies particularly to the "control" point in the bed downstream of the gauge, which point really controls the water level at the gauge. (3) Control, below gauge, should preferably be well defined, and not subject to alteration by scour, log-jambs, etc. (4) Banks should be solid and not subject to serious erosion and should preferably not be covered with timber below flood level. (5) Water surface at site should be smooth and not subject to turbulence. (6) Control should be such as to give as great a variation in gauge height as possible for variations in flow, i.e., a very wide control will induce very small variations in gauge height with perhaps quite considerable variations in flow when the river is low. (7) All structures, tributary streams, etc., downstream from the gauge should be noted and care taken that the gauge height will not be affected by backing-up, etc., from these causes. (8) Except for automatic gauges the gauge must be within reasonable distance of the gauge reader's residence.

It is obviously not always possible to obtain all these conditions, and experienced judgment is then necessary in making the best of the existing local conditions. In this regard the case might be mentioned where a rock control was greatly improved in accuracy by the blasting of a cut through the rock for low flows.

To illustrate the several references which appear above the "control" point, this control may be likened to a weir in the stream, the effect of which is to back up the water and control its level on the upstream side of such weir. If any portion of the weir be removed by flood waters or any other cause the conditions of water level upstream are immediately altered; an exactly similar effect takes place when any alteration occurs in a natural control point. Hence one appreciates the importance of ensuring that the control is of a permanent nature not liable to change.

The analogy of a weir also serves to illustrate the question of accuracy and range of water level. It is obvious that for a certain difference in flow the resulting variations in water level will be less for a long weir than for a short one. This means that small variations of flow are measured more accurately by means of water levels in the case of the short weir, or control, and, hence, the desirability of obtaining a control of such shape that the width of the stream is not too great at times of low flow. The fact that a station eminently suitable at high flows may be valueless at times of low flow is worth repeating.

A word of warning regarding the placing of gauges on bridge piers, etc., may not be out of place: this is often an excellent arrangement and is always convenient, but care should be taken that the river does not carry much floating timber, etc., otherwise the accuracy of the gauge will be seriously impaired. The piers and abutments themselves often cause considerable backing up and turbulence during flood flows.

Installation of Gauge.—In the case of stations where the readings are not taken automatically, the usual type of gauge staff consists of a light steel plate enamelled all over, having a white surface whereon are marked and numbered, in black, feet and tenths of a foot. These steel plates are provided with screw-holes and are securely fastened to a rigid support. Wood staves, where used, should be carved as well as painted, but in any case require more maintenance and are not so easily read.

In some streams it is found impossible to properly secure the staff in a vertical position, owing to the interference to stream flow involved at flood times and the consequent risk of damage by floating logs, etc. These conditions may render it advisable to secure the staff on a batter slope closely approaching the natural slope of the river bank, in which case a special staff is necessary with graduations of such length as to read direct the vertical variations in the height of water level.

In other cases again it may be found that the best location of the staff varies considerably with the stage of the river; for instance, at the selected location the water may be comparatively free from turbulence up to a gauge height of six or seven feet, but due to local conditions of the banks, etc., may develop a most undesirable condition of turbulence above that height. In the somewhat unusual cases where this cannot be avoided discontinuous staves may be used, one location being used up to, say, 5 ft. and a separate stave in a different position for readings above 5 ft. This demands careful setting of the two staves so that the readings at the common water level may accurately correspond, which does not necessarily mean that the common points on the two staves are at the same reduced level.

In any case the zero mark of the staff or staves should be connected by dumpy levels to a permanent bench mark as soon as possible after the gauging station is established. This precaution is a very necessary one to enable the re-establishment of checking of the staff in the event of its being damaged by flood, and its neglect might necessitate the abandonment of valuable discharge measurements.

Measurement of Discharge.—There are several methods of measuring the discharge of a stream, each method with its own special scope. The usual methods, in their order of importance, are as follows:—(1) Current meter, (2) weir gaugings, (3) chemical gaugings.

In addition to these methods, which are for accurate work, approximate measurements may be taken by the use of floats, etc.

1. Current Meter.—A current meter for measuring the velocity of flowing water consists essentially of two main parts: (a) A wheel so arranged that when suspended in flowing water it is caused to revolve at a rate varying with the velocity of flow; (b) a device for recording or indicating the number of revolutions in a given time. The relationship between the velocity of flow and the revolutions of the wheel is determined by rating each meter at the maker's works.

The distinguishing characteristics of a good current meter are: (a) Simplicity of construction with no delicate parts to get out of order; (b) a small area of resistance to the velocity of the water; (c) a simple and effective device for indicating the number of revolutions of the wheel, and (d) easy adaptability to use under varying conditions.

These conditions are well met by a meter of the Price pattern, which is the type of meter generally used in this country. The general appearance of the meter is shown in Fig. 2, which illustrates meters of this type. The working part consists of a horizontal wheel carrying six conical cups which revolves on a pivot-point bearing, and engages an indicating mechanism at its upper bearing. The recording mechanism usually consists of a telephone indicating device operated by a small dry cell, which registers a loud click for each revolution, or every five or ten revolutions, as desired. In small streams the meters may be suspended by a rod, but for larger streams a cable is necessary, in which case a weight is required under the meter, as shown, and a tail vane to balance the meter and keep it in the direction of the flow.

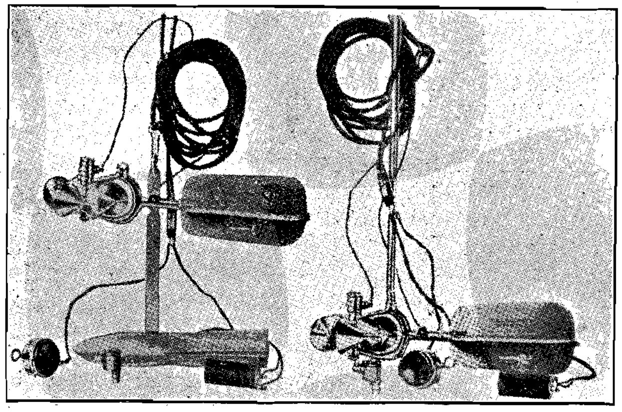

Fig. 2. Price-pattern Current Meter

In using the meter, observation is made of the number of seconds required to make a selected number of revolutions—the number being selected so that the time is not less than about 30 seconds. The accuracy of these meters decreases very rapidly as zero velocity is approached and they should preferably not be used for velocities of less than 1 ft. a second and never for velocities below 0.5 ft. a second.

As this type of meter consists of a horizontal wheel it should be noted that the velocity of the water in any horizontal direction will be recorded by the meter, and it is therefore important that the flow at the site selected for measurement should be free from eddies and cross currents, otherwise these will be recorded as if they were velocities in the direction of the general stream flow and will thus give an erroneous result.

Tables giving the relationship between the revolutions of the wheel with the meter cups and the velocity of the water are supplied by the makers with each meter. These are usually the average of the determinations of a large number of meters of the same pattern. In America, where most of these meters are manufactured, special arrangements are provided for rating meters, consisting of a steel track which is laid either over or parallel to a large continuous trough of water. A special truck upon which are mounted the meter and recording gear is propelled along this track, and the meter thus rated by being moved through the still water at a uniform speed, noting the time, the number of revolutions, and the distance—these factors often being recorded electrically. The r.p.m. and the velocity (ft./sec.) are then calculated from these data. Many runs are made with varying speeds and the results, when plotted with r.p.m. and velocity (ft./sec.) as co-ordinates, locate the points, which define the meter rating curve from which the rating table is prepared. It will be noted that the effect of moving the meter through still water is the same as if the meter were stationary and the water moving at the same rate.

Provided meters are treated with care they do not readily lose their adjustment, but experience has shown that there is a general tendency for the number of revolutions to become somewhat less as the pivot point becomes worn. A number of meters recently checked after about three years' service in intermittent use showed about five per cent reduction. It is therefore necessary that the rating of meters in ordinary service should be checked at least once in six months, and more frequently for any special work.

In Australia there is not sufficient demand for the establishment of an elaborate station for rating meters, and, for checking meters, it is therefore necessary to adopt methods which may appear somewhat crude, but which give results of a very satisfactory degree of accuracy. The method adopted requires a basin of still water such as a reservoir or lake, preferably sheltered from wind action.

A steel wire, accurately painted in 10-ft. sections is stretched across the water at a height of 2-3 ft. above the surface, and the meter is fixed to a frame extending over the prow of a small light rowing boat. The boat is then pulled across the lake by the assistant hauling on the cable, and the distances, number of revolutions, and times are noted by the observer. Many runs are made at varying speeds and the results plotted as previously mentioned. Distances are noted by the observer releasing markers, which are free to slide along the cable, at the start and the completion of the count of the revolutions, the times being simultaneously noted by means of a stop-watch. This is an operation requiring practice to obtain a satisfactory result, but is very accurate in the hands of an experienced operator. The time of run required should not be less than 30 sec. and the length available should not be less than about 200 ft., to allow a certain distance for stopping and starting. Ratings should never be attempted on a windy day.

Procedure in Making a Discharge Measurement.—The site selected for taking discharge measurements should possess the following characteristics:—(a) Should be located as close as possible to the site of gauge staff; (b) bed of stream should be uniform and the stream free as far as possible, from eddies, cross currents, etc.; (c) velocity should, if possible, be greater than 1 ft. per sec. and current meter should not be used in any case where velocity is less than 0.5 ft. per sec.

The discharge of a stream is determined by subdividing the cross section of the stream by vertical lines into panels, soundings being taken at each panel line, such subdivisions being taken sufficiently close together to ensure that the cross-sectional area of the stream is accurately determined. The mean velocity of flow is then measured for each partial area. Each such velocity is multiplied by its respective partial area and the summation of the products made to give the total discharge. Gauge readings are taken at both the beginning and completion of a set of observations. Soundings may be taken either with a graduated rod or with weight and line, the former being suitable for smaller streams.

In making a velocity measurement, the meter is held at the point in the stream at which the velocity is desired. The wheel is allowed to revolve for a few seconds, in order that it may adjust itself to the current, the time for a given number of revolutions is then noted accurately by means of a stop-watch, and the velocity obtained from the rating table for the meter. The time of measured run should not be less than 30 sec., and is usually taken at a regular number of revolutions for ease of reduction.

The method described renders necessary the determination of the mean horizontal velocity in the vertical through each panel point, and the various methods are in use for this determination, among which four may be mentioned, the first only, being entirely satisfactory, the remaining three involving assumptions which are only roughly approximate.

These latter methods, however, take less time and are therefore useful for measurements in times of flood, or at times when the stage of the river is rapidly changing, and when it is very desirable that the measurements should be completed as rapidly as possible to avoid any considerable variation in the gauge reading during the operation. The methods are: (a) the vertical velocity curve method, (b) the two-tenth and eight-tenth method, (c) the six-tenth method, and (d) the sub-surface method.

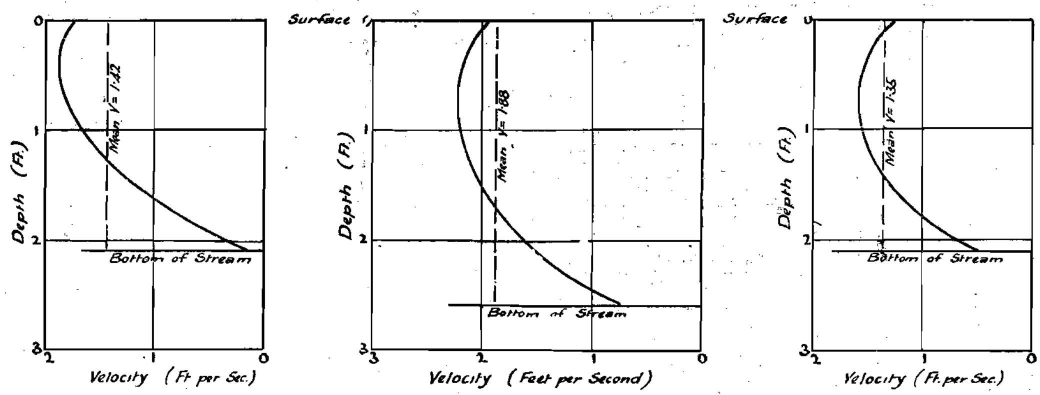

Fig. 3. Typical Vertical Velocity Curves

Mean velocities calculated by the different methods are set out hereunder for purposes of comparison: (a), Vertical velocity curve method; (b) 2/10—8/10 method; (c), 6/10 method; (d), sub-surface method.

(a) 1.42	(a) 1.88	(a) 1.35
(b) 1.4	(b) 1.8	(b) 1.3
(c) 1.5	(c) 2.0	(c) 1.45
(d) 1.48	(d) 1.7	(d) 1.1

(a) In the velocity curve method, measurements of velocity are taken at intervals in each vertical, usually just below the surface, and at each fifth to tenth of the depth of the stream and as near the bottom as possible. The number of measurements taken in each vertical velocity curve at each vertical depends upon the depth of the stream, the idea being to obtain sufficient measurements to plot a vertical velocity curve at each vertical section, from which the mean velocity in each vertical may be obtained graphically.

Typical vertical velocity curves taken from actual discharge measurements are shown in Fig. 3. Studies of vertical velocity curves taken on many streams under various conditions show a general parabolic form with the axis parallel with the surface and usually situated between the surface and one-third of the depth. From the maximum the velocity decreases gradually upward to the surface and downward to the bottom, where it changes more rapidly on account of the friction of the bed.

The vertical velocity curve is the only accurate method and is interesting and useful in furnishing a guide for use in the other less exact methods.

(b) In the two-tenth and eight-tenth method, measurements of velocity at two points in the vertical located at 2/10 and 8/10 of the depth. The mean velocity is then assumed as the mean of these two velocities. This assumption is based on the theory, stated above, that the velocity curve is a parabola.

(c) The six-tenth method involves the determination of the velocity in each section at a depth of 0.6 of the total depth of the stream at that section. This velocity is then assumed to be the mean velocity in that vertical. This method is based upon a similar assumption to that in (b).

(d) In the sub-surface method the velocity immediately below the surface only, is measured in each section. This velocity is then reduced by an assumed amount to determine the mean velocity. The coefficient for this reduction varies considerably with the size and velocity of the stream and the nature of its bed, and it is usually assumed that the mean velocity is approximately 0.85 of the velocity at the surface.

An analysis of a large number of recent observations on streams with rocky although fairly even beds and with depths from 1 ft. to 2 ft. shows that the relationship between mean velocity and surface velocity varies between 0.50 and 1.00, so that the accuracy of this method must always be open to serious question. It will therefore be seen that the vertical velocity curve method is the only accurate method, and in this respect it is interesting to compare the results obtained by this method in some actual measurements as shown in Fig. 3 in order to note the extent of the error involved in adopting the less exact methods.

All measurements of mean velocity were taken and calculated by the vertical velocity curve method, but for purposes of comparison the results which would have been obtained by the other methods are also set out. It should be noted that the errors involved in the less accurate methods are frequently much greater than in the cases shown.

There is, however, an important point which must not be overlooked in this regard. Particularly in the case of large rivers the time involved in the completion of a discharge measurement by the vertical velocity-curve method is very much more than by the other methods, and, at times of rapid fluctuation in the water surface, such as flood time, there may be a considerable variation in the gauge readings between the commencement and completion of the discharge measurement. It is usual in such cases to adopt the mean of the two gauge measurements, but any variation involves a source of error which may be of considerable magnitude. In such cases it is, therefore, often preferable to adopt one of the theoretically less exact methods which involve less time and often actually give a more accurate result under these circumstances.

It is, of course, impossible to give much idea of the time required for a discharge measurement as this depends entirely upon the size of stream and the accuracy desired, and may vary between, say, 15 to 20 minutes for a very small stream to several hours for a very large one.

The method of taking the current-meter measurements also depends upon the size of the stream: small streams are usually measured by wading, the meter being attached to light steel rods graduated to show the depth of the meter vanes below the surface, whilst larger streams require the use of a boat, or preferably, if the gauging station is a permanent one, the installation of a fixed cableway upon which a travelling cage is supported. The meter is then held by means of a flexible cable connection, a substantial lead weight being attached under the meter to maintain its stability. For streams of moderate size the cableway is by far the most satisfactory method, being convenient for use under all conditions of flow, its advantage being especially apparent at times when the flow of the river is so rapid as to render the handling of a boat inconvenient as well as hazardous. Measurements across the stream are usually obtained by stretching a steel tape or cable from bank to bank at a convenient elevation above the water.

2. Weir Gaugings.—This method is only suitable for small streams owing to the excessive cost involved in the construction of a weir on a large stream and the difficulty of preventing leakage under or around such a structure without expensive cut-off works. Furthermore, it is difficult to eliminate the velocity of approach in many instances and the structure unless of a very permanent nature is subject to damage by floods.

Unless built accurately to some standard, which has been previously calibrated by some positive method, a weir cannot be regarded, under field conditions, as essentially accurate, and, on any stream of sufficient size and velocity to enable the current meter to be efficiently used, the weir has the disadvantage of additional cost without any corresponding advantages on the score of increased accuracy.

The discussion of the various weir formulæ is outside the scope of the present article. It should be understood, however, that this criticism of the weir as an aid to river discharge measurements does not apply to the cases where a permanent weir is erected solely for the purpose of acting as a "control" point in circumstances where it is quite impossible to obtain a natural control. Such conditions are frequently met with in mountain torrent streams where, for a distance of miles, the water in the stream may be in a state of turmoil and the measurement of both water levels and velocities a matter of impossibility. Under these conditions and in the case of an important scheme, the cost of a low weir may be amply justified and its construction will afford both a permanent control for water level records and a site for current meter measurements.

3. Chemical Gaugings.—This method may be used to advantage under certain conditions where the methods previously mentioned are impracticable. For example, the writer was recently confronted with the problem of obtaining a few isolated discharge measurements upon a mountain torrent stream for purposes of comparison with a gauging station some few miles downstream in the flatter section of the stream. A measuring weir had been installed at this location some four years previously but had been destroyed about two years afterwards during a flood, and its reconstruction was quite out of the question as only a few measurements were desired. In this case the chemical method proved easy of application, and the results were such as would appear to show a high degree of accuracy.

In this method a chemical is added to the stream at a regular known rate and, after thorough mixing, samples of the river water are taken and the chemical contents determined. The amount of chemical in the samples may be very accurately determined and the rate of flow calculated therefrom, for example, if w (lb.) = weight of chemical added each second; Q = discharge of stream (cusecs); m (lb.) = amount of water after mixing containing 1 lb. of chemical.

$$\text{Then } \frac{w}{62.5Q} = \frac{1}{m} \text{ or } Q = \frac{mw}{62.5}$$

It is obvious that for this method the stream flow conditions must be such as to ensure a thorough mixing of the chemical with the whole volume of flowing water; thus, this method is particularly applicable to swift flowing turbulent mountain streams which are difficult to gauge by any other method. It is also important that the rate of the addition of chemical should be constant throughout the gauging.

The chemical usually used is common salt which is best added in the form of a strong solution. This solution can be delivered to the stream through a small orifice over which a constant head is maintained and for isolated measurements this equipment may usually be readily improvised at small cost.

A sufficient length of stream should be allowed between the point of dosage and the point of sampling to allow of thorough mixing and samples should be taken from different points in the cross section of the stream. The chemical contents of the natural water of the stream should also be determined and allowance made therefor in calculating the discharge.

Float Measurements.—These are useful at times, particularly to obtain flood discharges where the use of the current meter is difficult; but this method can, at best, only be regarded as approximate.

Floats may be either surface floats, or may be rods weighted so as to float vertically in the stream and submerged to the desired depth. They are timed over a measured section of the stream at varying points in the cross section and from the velocities thus measured the mean velocity is determined as previously described. For this method it is essential to obtain a straight length of stream with a comparatively uniform cross section throughout the measured length.

Rating Curve.—Having decided upon the most suitable method for obtaining discharge measurements, the process of obtaining a good rating curve for the gauging station is commenced. This may take a few years, as it is necessary to obtain measurements at as many stages of flow as possible and also as many check measurements at each stage as possible.

It is preferable to plot the results upon logarithmic ruled paper, as the shape of the curve then usually approaches a straight line with the result that extraordinary discharges outside the range of actual measurements are more readily extrapolated than otherwise. Even after sufficient points on the curve have been obtained, it is necessary to continue to take fresh discharge measurements to ensure that no changes are taking place in the control or the stream bed which might alter the rating. From the rating curve, when completed, the discharges corresponding to each gauge reading are read off and recorded as may be desired.

Automatic Recording Gauges

As previously mentioned the installation of an automatic gauge is desirable when any one or more of the following conditions prevail:—1, Where particularly accurate or continuous records are required; 2, where the stream is subject to sudden changes of discharge during the 24 hours; 3, where reliable and accurate records are desired of flood stage; 4, where the station is situated in an uninhabited region where gauge readers are not available or cannot be trusted.

Naturally there are different types of automatic recorders developed to meet the varying requirements set out above. However, speaking generally, the following are the essential features, viz.:—1, Float rising and falling with the surface of the water and transmitting such variations to the recording gear; 2, reliable clock controlling the action of the time record.

These instruments are of two main classes: (a) Where the station is installed in a readily accessible location and the automatic gauge is desirable for accuracy of records rather than to obviate frequent visits a graphic type of recorder is eminently suitable. These recorders are manufactured by several firms and differ considerably in detail. Usually they are designed to operate without attention for periods up to about two weeks, although special instruments of this kind may be designed to operate for one month, and some of these are now giving satisfactory service in Victoria. The energy required to operate the clock may be supplied either by a spring or a weight, and in the case of the longer period instruments is usually the latter.

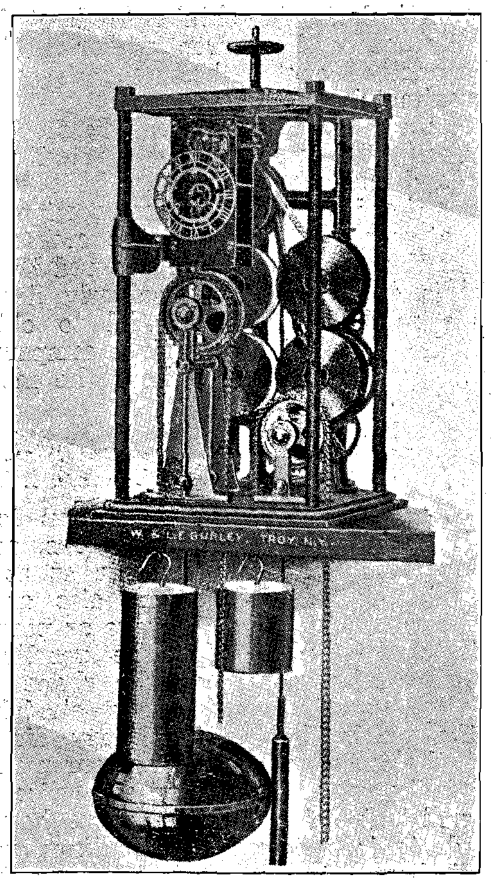

Fig. 4. Side View of Gurley Printing Water Stage Register, showing Paper Reels, Type Wheels, and Cushioned Hammers

(b) Where the station is installed in extremely mountainous and inaccessible parts, the cost of frequent visits to change the records would be prohibitive and to meet these conditions a "printing" type of gauge has been developed which will operate unattended for periods of six to seven months, and records the stage by printing the height and time on a paper ribbon at every quarter of an hour. The clock in this case is driven by a weight which requires a drop of about 20 ft. for the six months' period. Fig. 4 shows the type of construction for an instrument of this kind, the cover being removed. The instrument shown is manufactured by Messrs. W. and L. E. Gurley, Troy, New York, U.S.A.

These instruments have proved very reliable in service, and it is worthy of note that two of these are installed on the Bogong High Plains at an elevation of about 5,500 ft. above sea level where they are usually snow covered for about six months of the year. These operated satisfactorily throughout last winter. They all require the construction of a vertical shaft directly under the instrument, connected near the bottom by a tunnel or pipe culvert to the river. This shaft then acts as a float chamber and also accommodates the driving weights, if these are used. A reasonably substantial shelter shed over the instrument is also necessary.

BRISBANE SEWAGE OUTFALL

Following a considerable agitation in the local press, the mayor of Brisbane called on the medical officer of health and the chief engineer to make an inspection with reference to the allegation that the treatment of sewage by the Metropolitan water and Sewerage Board at Pinkenba outfall constituted a possible menace to health, provided a breeding place for flies and was productive of offensive odors. The board expressed considerable pleasure at the report which was forwarded by the mayor, which was supplemented by a favorable report as to the condition of the affluent from their own chemist. The report from the city health officer was as follows:—"(a) There is no offensive solid or liquid material being deposited upon land from the sewer or the sewer pumps; the material taken from the screens is negligible in quantity, and is not a source of nuisance or danger to health; (b) the presence of sulphuretted hydrogen is inevitable, and the radius of its distribution is such as to preclude any nuisance or injury to residents; (c) the sewage is being discharged without treatment, but it would be impossible to state without more extensive investigation that this feature is open to objection. The question would involve legal as well as scientific inquiries, but the visible results observed did not suggest any cause for alarm on this ground, for the time being at all events."