# Current meter gauging

Current meter gauging consists of measuring the cross-sectional area in successive partial sections along with flow velocities measured by current meter at each partial section.

A measuring site is chosen conforming to specified requirements; the width, depending on its magnitude, is measured either by means of a tape, graduated cable (tagline) or by some other surveying method, and the depth is measured at a number of verticals along the width, sufficient to determine the shape and area of the cross-section.

Velocity observations are made at each vertical preferably at the same time as a measurement of depth; they are made by any one of standard methods using current meters. These measure velocity according to the principle based on the proportionality between the local flow velocity and the speed of the rotor. The mean velocity in each partial section is computed from the individual observations. The discharge is generally computed arithmetically by summing the products of the velocity and corresponding area for a series of observations in a cross-section.

Acoustic Doppler current meters (often called ADVs or acoustic Doppler velocimeters) can be used for stream gauging in the same way as a mechanical current meter, and most of the same techniques apply. The FlowTracker ADV is normally used in a wading situation. It has a logging and calculating unit connected permanently by cable. For instructions on its use, its user manual should be consulted; however the principles of site selection, velocity methods are and many of the following procedures apply equally to this instrument.

A set of field instruction sheets are presented below for the following procedures:

* Small Ott current meters - operating instructions.
* Standard current meter gauging practice.

## Site selection

The first consideration must be the purpose of the gauging and that the flow at the site represents the data required for the purpose. The presence of tributaries and flow abstractions shall be investigated fully. Note that losses to and from groundwater can sometimes occur over relatively short distances where streambeds overlie deep gravels.

In many cases the flow measurement will be combined with a water-level record at a gauging station and the flow must represent that at the station. The selection of a site for water-level recording involves further considerations as well as those for gauging (see Section 2 for details).

### Characteristics of the reach

The site selected shall, as far as possible, be on a reach with the following characteristics:

* The channel shall be straight and of uniform cross-section and slope in order to have a normal velocity distribution.
* A straight reach of five times the width is generally a minimum, although flow conditions upstream will have a strong influence on this requirement. When the length of straight channel is restricted, the gauging section should be about two-thirds of the way down the reach.
* The depth of water in the selected reach shall be sufficient to provide for the effective immersion of the current meter.
* The measuring site shall be clear and unobstructed by trees, weed and other obstacles.

In addition to the points specified above, the following shall be taken into consideration:

* Degree of accessibility.
* The bed shall not be subject to changes during the period of the measurement.
* All discharges of interest shall be contained within a defined channel or channels, having substantially stable and well-defined boundaries.
* Freedom from aquatic growth during the period of measurement.
* Remoteness from any bend or natural or artificial obstruction that may disturb the flow.
* Sites at which vortices, reverse flow or dead water zones tend to develop shall be avoided.
* Avoid measurements with converging, and more so with diverging flow over an oblique measuring section, as it is difficult to allow for the systematic errors that can arise.
* Where velocities are low, the reach should not be oriented in the direction of any prevailing strong winds.

Where the site selected is to be a permanent measuring site by virtue of the installation of gauging facilities, all the above considerations shall be extended to the full range of flows likely to be encountered.

### Modification of section or reach

Particularly with smaller flows, it may be possible to modify the reach to overcome any undesirable features. Removal of boulders, weed growth, vegetation and flood debris should be done where practical, to improve the flow pattern. Adding bed material or constructing small groynes may be useful to cut off areas of dead water or to distribute the flow more evenly.

Depending on the stream's velocity and slope, a significant period of time may be required for the flow to stabilise following such modifications.

## Measurement of width

Width measurements define the location of the required depth and velocity measurements across the selected cross-section and provide the width parameter of each partial section. Except perhaps where an angled bridge is used, the line is strung at right angles to the direction of flow. Estimation by eye is normally adequate to define this right angle.

### Equipment

A tape or tagline is normally used, stretched tight across the section. Such lines shall be suitably graduated to define each location to within ± 0.5 % of the total width, given that vertical spacing should normally provide more than 20 partial sections (for further details refer to Section 6.7.6.). They shall also have regular cumulative graduations (coded or digital) to avoid reliance on counting successive marks to check the total width.

**NOTES** Taglines are often made from small diameter (1.5 to 3 mm) wire rope with tags of anodised aluminium, colour-coded for various intervals. The lighter the cable, the less tension is required in its rigging and anchoring and handling will be both easier and safer. 1.5 to 2 mm diameter galvanised wire rope is recommended, with heavier sizes if it is also to be used to support a boat against the current.

Taglines made from some plastics are prone to stretching, thus causing unacceptable systematic errors. Only fibreglass, "Kevlar" or steel are recommended.

Where the channel is too wide for direct measurement, the distances can be determined by optical or electronic distance meters or DGPS. Stadia measurements are too inaccurate for most gauging work, but have occasionally been used as a last resort.

### Permanent markings

On bridges and cableways, markings at suitable vertical locations are generally painted on. These must be done accurately (better than ± 0.5 %) to avoid a systematic error which could affect the entire flow record.

### Fixed reference points

Where it is practical to do so, a fixed reference point should be installed so that gaugings at a site all have their distances measured in the same terms. For a bridge or a cableway, this will be implicit in the markings if a clear indication of the zero point and/or the value of a distance marking is given. Widths noted on the gauging card shall then be given in terms of the reference point.

The benefits of this practice include better detection of any errors in width measurement and may also give a record of the gauging cross-section for use in flood conditions or possibly rating change confirmation.

**NOTE:** The extra effort involved in obtaining this data may be very minimal at some sites; at others, however, frequent changes in the gauging location may sometimes render it irrelevant.

### Resolution

Width measurements shall be resolved to at least 0.5% of the total width, and depth and velocity readings shall be taken at points within this tolerance of the marked location.

### Accuracy

Random errors will occur with the positioning of the current meter about the marked location. This will be affected by a number of factors including the care taken in positioning, the swing of a suspended weight, and the roughness of the bed material. They will also occur with small inaccuracies in the width markings, but larger errors here will tend to be systematic ones and must be avoided.

Systematic errors will occur with incorrectly calibrated distance markings, such as on cableways or bridges. Taglines that have stretched will also provide systematically under-estimated discharges at several sites. As systematic errors tend to be undetectable as compared with random errors (which show up, for instance, as scatter on a rating curve), particular care must be exercised to ensure that they do not occur.

## Measurement of depth

Depth measurements both define the cross-sectional area and provide the basis for the current meter velocity measurements. Where the conditions dictate, or where higher accuracy is desired, additional depth-only verticals are measured.

### Equipment

Measurements are made with a graduated "wading rod" or a weighted sounding-line and reel with a revolution counter. Occasionally echo-sounders or pressure transducers may be used where appropriate.

### Interval

Depth measurements shall be made at intervals close enough to define the cross-sectional profile. In general, the intervals shall not be greater than 1/20th of the width (ISO 748-2000). This requirement is in addition to that of observing more than 20 to 25 verticals under all except the most adverse conditions (e.g. with rapidly changing stage).

### Soundings

Depth-only measurements are made where velocity measurements are not practical or efficient (e.g. in slow water near banks) but are necessary to properly define the cross-section. In addition, soundings intermediate to each vertical will often enhance accuracy with little additional work.

### Resolution

When using wading rods, depths shall be read to the nearest 3 mm where depths are mostly less than 500 mm, and to at least the nearest 5 mm above this.

When using sounding weights and gauging reel, depths shall be read to the nearest 10 mm.

### Accuracy

Random errors will occur with the non-uniform nature of the bed, due both to undulations and local roughness. Taking a sufficient number of verticals is essential to minimise these. In addition, each sounding shall be made using a technique that takes an average reading in the local area.

When wading in shallow clear water this may be done by eye. In all other cases, at least two measurements shall be taken and the mean value adopted. However if these readings should differ by more than 5%, two more readings shall be taken; if these are within 5% their mean value shall be adopted; if not, the mean value of all four readings shall be adopted, and this factor noted to show that the accuracy of this measurement is reduced.

Systematic errors could occur with incorrectly calibrated sounding equipment. The performance and consistency of reel counters should be observed and checked if suspect.

They may also occur with incorrect techniques, such as incorrect zeroing of the bottom of the Columbus weight, or allowing the weight of the equipment to come off the cable-car or the bow of a boat before observing the reading.

## The current meter:

### Description

Current meters measure the velocity of flowing water. There are mechanical, electromagnetic and acoustic meters commonly used for stream gauging. (There are also acoustic profilers that are used in a different way – these are covered in a separate section.)

The two main mechanical types are the cup-type with vertical axis rotors (Price AA and Pygmy) and the screw- or propeller-type with a horizontal axis (Ott, Oss and Seba). Essentially these current meters consists of:

* The rotating element; a screw or turbine type wheel which is turned by the water flowing past the stationary meter.
* An electrical device which signals the revolutions; usually a wiping contact or a magnetic reed switch.
* A frame which holds the rotating element and enables the instrument to be mounted on a wading rod or above a sounding weight. It also normally has a tailfin to keep the instrument facing directly into the flowing water.

Acoustic Doppler current meters (often called ADVs or acoustic Doppler velocimeters) can be used for stream gauging in the same way as a mechanical current meter, and most of the same techniques apply. The FlowTracker ADV is normally used in a wading situation. It has a logging and calculating unit connected permanently by cable. For instructions on its use, its user manual should be consulted; however the principles of site selection, velocity methods are and many of the following procedures apply equally to this instrument. Appendix G contains field procedure and a quick start user guide for this instrument.

### Calibration

Current meters are "rated" so that the velocity of the water can be measured by counting the number of revolutions the screw or bucket-wheel makes in a measured time period. This is carried out a special rating facility where the meters are towed through still water to simulate their use in flowing water.

The calibration is normally supplied as a slope and constant for the straight-line graph which represents the relationship between revolutions per second and velocity. The slope of the graph denotes the proportionality between the two, while the constant defines the effective starting velocity of the meter. The velocity is calculated by multiplying the revolutions per second by the slope, and adding this product to the constant.

In some cases meter calibrations may more accurately be described by a series of two or three straight lines with defined limits, or possibly another mathematical relationship.

Meters shall be re-calibrated after suffering any damage or whenever their performance is suspect. As a guideline, Re-calibration should also be carried out after approximately 300 hours of use or at 5-yearly intervals, whichever is the shorter.

### Checking calibration and condition

The condition of a meter shall be checked in the following way:

(a) Visually check the meter, before and after each gauging, for worn or damaged bearings, proper shaft alignment and straightness, and deformation of the bucket wheel or propeller. A small dent in a bucket or damage to the leading edge of a propeller may seriously affect the meter's rating. ADV’s should suffer no damage to their transducer faces, nor to their arms.

(b) Check the rotors by hand for the correct amounts of play; bucket wheels should lift off the pivots by a small amount, and propellers should have very little play on their shafts.

1. For mechanical meters, carry out a spin test to check whether the meter is in good condition and within calibration:

* Place the meter in the correct operating attitude in an environment protected from air currents
* Spin the rotor fast with a quick flick by hand, or in the case of small Ott meters, by blowing.
* With a stopwatch measure the time taken for the rotor to come to rest. As it nears its stopping point, observe its motion carefully to see whether the stop is abrupt or gradual. If the stop is abrupt, the cause shall be found and corrected before use.
* Compare the spin test with the minimum allowable for that type of meter, as stated on the meter's instruction card and also given in Table 6.1.

The spin test results for both before and after the gauging shall be recorded in the appropriate location on the gauging card.

**Table 6.1:** **Guidelines for current meter use.**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Meter type** | **Minimum spin test (seconds)** | **Minimum depth for clearance from bed (m)** | | **Recommended velocity range (m/s)** | |
| **0.6 method** | **0.2.0.8 method** | **minimum** | **maximum** |
| Price AA - wiping contact - reed switch | 160 160 | 0.38 0.38 | 0.75 0.75 | 0.076 0.050 | 3.6 3.6 |
| Pygmy | 60 | 0.15 | 0.30 | 0.076 | 0.9 |
| Small Ott - prop 1 - prop 3 | 25 8 | 0.38 0.38 | 0.75 0.75 | 0.06 0.15 | 0.3 2.0 |
| Large Ott - brass prop - plastic prop | 35 10 | 0.95 0.95 | 1.9 1.9 | 0.06 0.06 | 6. 6.0 |
| Amsler | 25 | 0.95 | 1.9 | 0.5 | 6.0+ |
| Seba (large) mini P1 mini P3 | 10 25 8 | 0.95 0.38 0.38 | 1.9 0.75 0.75 | 0.06 0.06 0.15 | 6.0 0.3 2.0 |

### Non-conformance to spin test

If, prior to a gauging, a meter does not meet the minimum spin test it should not be used. When a meter does not meet its spin test at the end of a gauging, the following shall be carried out:

* Enter a remark to this effect on the gauging card, and treat the gauging as suspect data.
* Carry out a further gauging, if feasible.
* Investigate the cause of the low spin test and rectify by cleaning, replacing pivots, etc., or sending for repair if necessary.
* If considered cost-effective (i.e. if the affected gauging is particularly valuable), send the meter to for rating before repair, and calculate the gauging using this rating. Depending on the cause of the low spin test, it may be appropriate to use a mean of the two ratings, or a combination if it was noted at which vertical damage occurred.

## Choice of current meter

The limiting factors for the use of various types of current meters are:

* The suspension method; the smaller meters are generally without fittings to allow them to be used with suspension equipment, due to the larger meters being almost invariably better suited to this.
* The low velocities encountered; the minimum velocity for reliable measurements is generally 0.15 m/s (ISO 748-1979 (E)), but some meters can be calibrated satisfactorily below this, as shown in Table 6.1. Low velocities in this range should be avoided as much as possible, as any small deviation in meter performance (such as, for example, by weed becoming caught) will cause a large percentage error in the velocity.
* The high velocities encountered; the smaller meters such as the small Ott reach limits to their rotor speed above certain velocities and their use above these are not recommended (see Table 6.2).
* The depth of the water; the shallowness is of concern as: "the horizontal axis of the current meter shall not be situated at a distance less than 1.5 times the rotor height from the water surface, nor shall it be at a distance less than 3 times the rotor height from the bottom of the channel. Furthermore, no part of the meter shall break the surface of the water." (ISO 748-2000(E)). As a consequence, minimum recommended depths for the use of individual meters are given in Table 6.1. In practice, the use in depths shallower than those recommended will be necessary at times; and where the stream-bed is relatively smooth and at the sides of the channel this will be of less significance, but in other conditions it may reduce accuracy. The revision of the Standard (ISO 748-2000 E)), relaxes the earlier recommendation to say that “no rotating-element current meter shall be selected …where the mean depth is less than 4 times the diameter of the impeller … No part of the meter shall break the surface of the water.”

**NOTE:** Ott meters have the so-called "component runner" which resolves oblique flow into the velocity in the direction of the meter's axis. It therefore gives the best performance in turbulent flow, where the direction of flow will be constantly and rapidly varying.

* The degree of oscillation of the meter due to its suspension. Suspension from boats, for example, can cause an oscillation of the meter relative to the location of the vertical as the boat oscillates around this point. Bucket-wheel meters record horizontal velocity whatever its direction, and while movement of the boat in the upstream and downstream directions will tend to cancel out, lateral movement will be additive.
* With a meter with a component runner (propeller) these movements will tend to be resolved with only the longitudinal movement recorded. Therefore wherever practical, large Ott meters shall be used for all boat gaugings.

## Velocity measurement

Current meters measure water velocity at a point, but in a stream the velocity varies at every point in the channel, in time as well as in space. Thus in a flow measurement, the mean velocity is measured at a number of points (verticals) across the channel, throughout the depth and over a sufficiently long time.

### Vertical velocity

Velocity typically varies throughout a vertical in a manner which is depicted in Figure 6.1. However conditions such as weed growth on the bed, a non-uniform cross-section, turbulence and other factors may alter this pattern markedly.

The most accurate method of determining the mean velocity in a vertical is by use of the velocity distribution method, where velocity observations are made at a number of points in each vertical between the surface and the bed. The spacing of the points shall be chosen so that the difference in velocity between adjacent points is not more than 20% with respect to the higher value of the two. The velocity observations are plotted in graphical form and the mean velocity determined with the aid of a planimeter, digitiser or equivalent method. For further details see ISO 748-1979 (E) (in ISO, 1983).

Where possible, the first gaugings at a station should always be carried out using the velocity distribution method, and calculated using various combinations of reduced-point methods to determine which is the most accurate method.

This method is usually not suitable for routine discharge measurements because the gain in precision is offset by the time taken (which can normally be used to advantage elsewhere). Instead, one of a number of reduced-point methods is normally used.

These are:

***The one-point method***

With this method velocity observations are made at each vertical by setting the current meter at 0.6 of the depth below the surface (or, in the case of wading measurements, at 0.4 of the depth from the bed). The value observed is taken as the mean velocity in the vertical.

This method is the least accurate, and it is preferable to use two or more points in the vertical (see below). However it is often necessary to use this method owing to depth limitations (see "Choice of current meters" in Section 6.5.2 above and Figure 6.1).

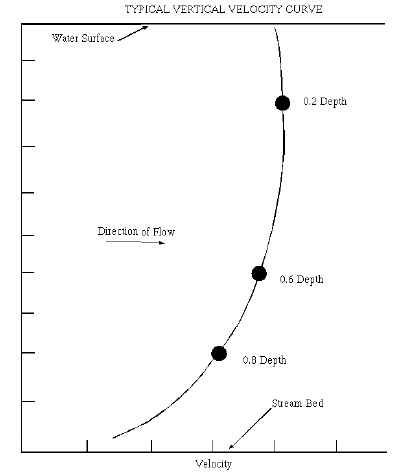
***The two-point method***

* With this method, velocities are measured at 0.2 and 0.8 of the depth below the surface, and the average of these two values is taken as the mean velocity in the vertical.
* This method is widely used and shall be regarded as the minimum standard method (where the depth allows its use; see above).

***The three-point method***

* The one- and two-point methods can be combined, and this three-point method is better again than either of these two on their own.
* The average of the three values may be taken as the mean velocity in the vertical. Alternatively, the 0.6 measurement may be weighted by first averaging the 0.2 and 0.8 measurements and then averaging the result with the 0.6 value.





**Figure 6.1: A typical vertical velocity curve**

***The four-point method***

* With this method the velocities are measured at points located at 0.1, 0.4, 0.6, 0.9, of the depth below the surface. This is not a standard method according to ISO 748-1979 (E), and is thus not recommended unless it is proven to give good results at a particular site by comparison with the velocity distribution (or multi-point) method.
* Because of the extra time required to take the measurements this method should not be used if the river stage is changing rapidly.

***Five-point method***

* With this method measurements are made at 0.2, 0.6 and 0.8 of the depth, and at as near as possible to the surface and the bottom (note the limitations on these related to meter rotor height; see Table 4.2). The mean velocity may be determined from a graphical plot of the velocity profile with a planimeter, or from the equation:

v = 0.1(vsurface + 3 v0.2 + 3 v0.6 + 2 v0.8 + vbed)

* This method is recommended in ISO 748-1979 (E) for use when the channel is free from ice and aquatic growth.

***Six-point method***

* Like the above, this method is recommended in ISO 748-1979 (E), but for use in more difficult conditions, for instance where there is aquatic growth or a covering of ice.
* Velocity observations are made at 0.2, 0.4, 0.6 and 0.8 of the depth, and as near as possible to the surface and the bed, according to the limitations associated with rotor height as described above.
* The mean velocity may be determined from a graphical plot of the velocity profile with a planimeter, or from the equation:

v = 0.1(v surface + 2 v 0.2 + 2 v0.4 + 2 v0.6 + 2 v0.8 + v bed)

***Surface one-point method***

* In flood or other conditions where the above methods are not feasible, velocity shall be measured at one point just below the surface. The depth of submergence of the current meter shall be uniform over all of the verticals and shall take account of the limitations related to meter rotor height; and care shall be taken to ensure that the observations are not affected by random surface or pressure waves or wind. In practice, a depth of 0.5 m or 1.0 m can be used.
* This "surface" velocity may be converted to the mean velocity in the vertical by multiplying it by a correction coefficient which will be specific to the section and to the discharge. The coefficient shall be computed for particular stages by correlating the "surface" velocity with the velocity at 0.6 or 0.2 and 0.8 depth.

Where it is not possible to check the coefficient directly, it may be noted for guidance that, in general, the coefficient varies between 0.84 and 0.90 depending upon the shape of the velocity profile. The higher values between 0.88 and 0.90 are usually obtained when the bed is smooth, but values outside this range may occur under other conditions. In practice the coefficient should be computed from additional measurements of "surface" velocity at any verticals where it is possible to take one- or two-point measurements at the same or lower stages.

### Horizontal velocity

The variations in velocity across the cross-section are taken into account by carrying out measurements at an adequate number of verticals.

An "adequate number" is:

* For uniform channels, intervals between verticals shall not be greater than 1/15 of the width and no partial section shall contain more than 10% of the total discharge.
* For irregular profiles, intervals shall not be greater than 1/20 of the width, and unequal distance spacings will normally be required.

## General procedure:

This section outlines the general procedure for a conventional current meter gauging, but presumes that the reader already has a working knowledge of the technique. This understanding should be obtained by practical "in-stream" instruction.

The main points are:

### Gauging card

A standard gauging card shall be filled out whether or not data are recorded on electronic media in the field. Record data on the location, party, meter details, details on the method, wind speed, turbidity, etc. Refer to Figure 6.2 for an example of the minimum acceptable details.

**NOTES:**

(a) The wind speed required is normally that which is estimated to be at the water surface and which may have an effect on the flow in the stream. In the case of lake sites, wind can have a significant influence on the lake level (“through wind tilt") and a more general estimate of speed and direction should be given, and extended into the Remarks area if necessary.

(b) Whether the water is turbid or not ("discoloured" on some cards) can be defined as whether the bed material can be seen at 0.3 m depth.

### Spin test

As an assurance of correct meter condition and performance, a spin test shall be done on the (mechanical) meter both before and after the gauging. Any gauging without satisfactory spin tests (see Table 6.2) shall be deemed to be unacceptable and shall not be used.

### Water temperature

Water temperature shall be measured to an accuracy of ± 1.0oC with a thermometer, and recorded on the gauging card.

### Site selection

The site of the gauging cross-section shall be selected in accordance with Section 6.1 above.

### Width measurement

The width measurements shall, where practical, be referenced to a fixed reference point so that all gaugings (or as many as practical) at the site have their distances in the same terms, in order to reduce errors and facilitate checking.

The width shall normally be measured by direct measurement, from a tagline, tape or permanent markings (see Section 6.2 above).

### Vertical spacings

The number and spacing of the verticals in the cross-section are decisive factors for the accuracy with which the total discharge can be determined (ISO/TR 7178-1983 (E)). In order that accuracies are within the required ± 8%, at least 20 and preferably more than 25 verticals shall be measured. When more than 30 verticals are measured, accuracy is improved very little.

Verticals shall be spaced so that both the cross-sectional profile and the variation in the horizontal velocities are defined accurately. For regular profiles, the minimum requirements (in addition to the 20 vertical minimum) are:

* "That intervals shall not be greater than 1/15 of the width and no partial section shall contain more than 10% of the total discharge."
* When the channel is sufficiently uniform it may be possible to allocate equal distance spacing between the verticals without conflicting with the above requirement.
* With irregular profiles, intervals shall not be greater than 1/20 of the width, and unequal distance spacing will normally be required. However, it is often possible to use mostly equal distance spacing by simply measuring a few extra verticals.

### Water's edge

For the sake of standardisation, start the measurement from the left bank (determined when facing downstream) and proceed to the right bank. If desired, distance values can decrease, but this is not convenient in the case of "permanent" marking or the distance reference point.

On the gauging card identify the water's edge at the left bank by the abbreviation W.E.L.B. (and W.E.R.B. for the right bank) and note the depth. If there is no flow, proceed to the last point of zero flow, which is the effective water's edge, measure the depth here and note it as "E.W.E." For calculating discharge the cross-section begins here, and ends at a corresponding point on the opposite bank if the same situation occurs there. However the area between the bank(s) and the effective water's edge(s) shall be defined adequately with depth measurements, as the total area of the cross-section is used in the area and mean velocity calculations.

### Assessments

Whilst measuring the velocity of the first vertical, the mean velocity of the first partial section (from W.E.L.B. or the E.W.E. to the first vertical) is estimated as a percentage of the (mean) velocity at that first vertical. Record it as a percentage value in the same line as the W.E.L.B or E.W.E. The same procedure in reverse is required at the opposite bank when it is reached.

**NOTES:**

(a) It is possible, but unusual and undesirable, to have a situation where an assessment is as high as 100% or more. It could occur, for instance, beside a smooth bridge abutment when the previous vertical had its flow reduced by obstructions in the channel immediately upstream.

(b) A more common situation is where the velocity decreases at a uniform rate from the vertical to the water's edge. This would have an assessment of 50%.

(c) In practice, assessments are usually in the range of 40% to 80%.

### Depth measurement

As a general rule, at least two measurements shall be taken and the mean value adopted. However if these readings should differ by more than 5%, two more readings shall be taken; if these are within 5% their mean value shall be adopted; if not, the mean value of all four readings shall be adopted, and this factor noted to show that the accuracy of this measurement is reduced.

**NOTE:** When carrying out a wading gauging in good conditions this can be done quickly by moving the rod to several locations in the close vicinity; with other types of suspension it will require two or more soundings.

Depth measurements shall be recorded to the nearest 1cm, and to the nearest 1 mm where depths are mostly below 300 mm.

### Velocity method

The various methods are described above.

Either the two- or three-point methods shall be used wherever possible. Only where depths are too shallow for these methods shall the one-point method be used.

For each position of the current meter, the actual setting in terms of the method being used at the time and as called out by the person booking (if applicable) shall be recorded as a means of assuring accuracy and permitting full checking on procedures at a later date.

### Velocity measurement

The current meter shall be held in the desired position so that it is not affected by any disturbances of flow from the personnel, boat, sounding weight, etc.

After the current meter has been placed at the selected point in the vertical, it shall be permitted to become adjusted to the flow before the readings are started.

The velocity at each selected point shall be observed by exposing the current meter for a minimum of 40 seconds.

The current meter shall be removed from the water at intervals for examination, at least once per vertical. This will normally be done when moving from one vertical to another or, when wading, while setting the meter height.

### Booking the data

Further points to note are:

* Note who is booking and who is gauging, by underlining the name of the booker. This can be used to sort on individuals' gauging accuracy, for QA and training purposes.
* Ensure that face cards are complete in all details.
* Book values to the appropriate significant figures.
* The person booking shall calculate the depth settings, note them on the card, and call out the values to the gauger as a check.
* The booker shall orally repeat the data values while recording them, to provide a check.

### Oblique flow (angle of current)

If oblique flow is unavoidable, the angle of the direction of flow to the perpendicular to the cross-section shall be measured and the velocities corrected.

This measurement shall be made using the protractor printed on the gauging cards, which is graduated in the cosines of the angles; see Figure 6.2. This value can then be applied directly to the mean velocity in the vertical.

The angle of the surface flow should not be assumed to be the same as that in the vertical. Instead, the angle of the meter assembly when submerged, preferably at 0.6 depth if water clarity permits, should be observed.

**NOTE:** When measuring velocity that is at a (measured) angle, the current meter must point directly into the flow. If, for instance, the meter is held on a wading rod perpendicular to the tape when it is meant to be measuring the velocity coming at the stated incident angle, the velocity will tend to be under-estimated.



**Figure 6.2:** **Measurement of the angle cosine using a gauging card**

### Stage

Discharge measurements are often taken to provide data for a stage/discharge relationship. To be of value, the stage at the time of measurement must also be recorded with commensurate accuracy. Sufficient stage readings shall be obtained to define the fluctuations adequately, and the time of the vertical shall be noted on the gauging card every 10-15 minutes.

Where the stage height during the period of the gauging fluctuates less than 0.05m, a simple arithmetic mean shall be calculated. Otherwise use the formulae in section 4.7

When the gauging site is a significant distance (say more than 1 km) from the recorder and stage readings are changing significantly, stage readings for the gauging may require correction for the time of travel between the gauging site and the recorder. This can be estimated by dividing the distance between the gauging site and the recorder by the mean velocity for the gauging.

### Gauging techniques for changing stage

When the stage is changing rapidly, as in a flood, the time spent obtaining an accurate gauging can be negated by an inaccurate stage value due to irregular fluctuations. In this circumstance it is usually more effective to reduce the number of verticals, use the 0.6 method and count revolutions for only 20 seconds. The resulting abbreviated gauging can thus be completed in a relatively short time and the stage height is more likely to have a comparable accuracy. However, the continuous gauging technique is usually a better choice; see later in this section..

## Wading gaugings

Wading measurements offer the possibility of selecting the best available cross-section, as well as greater resolution and precision in depth and width measurement and the ability to closely monitor the meter's performance. Where they can be done in safety, the wading method shall be the preferred choice.

### Safety considerations

Whilst wading, personnel can be exposed to significant danger, and all shall be familiar with the NIWA safety instructions relating to this work.."

### Location

Established gauging stations usually have a standard location where gaugings are carried out, and which will have a reference point to tie together the distance measurements. Notwithstanding this requirement, the reach will be subject to change and the best cross-section should be selected each time.

### Setting up

While taking the tagline across, examine the section for its velocity distribution, depths and obstructions. Consider whether any rocks or debris need to be removed (be certain, particularly in small streams, that these are not part of the recorder station's control).

Rig the tagline at a right angle to the direction of the current flow. If there is oblique flow or the reach diverges, viewing from each bank may assist in estimating the best mean line. At verticals where there is oblique flow, estimate the angle with the aid of the protractor on the gauging card.

### Modification of channel

Where necessary, modify the channel by removing boulders, debris and vegetation growth from the measuring section and the area immediately above it. Vegetation on the stream bed should be removed for a distance of about three times the depth from the area upstream and downstream from the section. Small dykes may be constructed to cut off sections of shallow flows or dead water near the river bank. Allow sufficient time for conditions to stabilise before proceeding with the measurement. These modifications must not be done on any reach where the water-level recorder stage/discharge relationship could be affected.

### Meter setting

With wading rods, the meter setting is measured upwards from the stream bed rather than downwards from the water surface. Thus to calculate the meter setting for the 0.6 method, the depth is multiplied by 0.4; the centre-line of the meter is then set at this height from the bed on the rod. Similarly, for a 0.8 setting, the depth is multiplied by 0.2, and for the 0.2 setting, by 0.8.

### Standing position

The person gauging shall stand at least 0.5 m to the side and 0.5 m downstream of the meter, to avoid influencing the velocity measurement.

### The use of wading rods

The wading rod shall be held in a vertical position to keep the current meter axis horizontal, and the current meter shall be kept oriented directly into the flow.

Sound depths carefully, without allowing the rod base to sink into soft bed material, and in rough streambeds, selecting a location that will provide an average between the tops of the boulders and the depths between.

### Vertical spacing in small channels

Vertical spacings at less than the current meter rotor diameter will degrade accuracy. Thus smaller meters or an ADV shall be used in place of larger meters where vertical spacings need to be less than 0.15 m.

## Slackline cableway gaugings

With slackline or unmanned cableways, the traveller operates as an “unmanned cable car” and all operations are carried out from the bank. One winch is used to position the traveller along the cross-section and a second gauging reel is used to sound and place the meter at the correct depths for velocity measurements.

### Assembly of equipment

Assemble the current meter and sounding weight on the hanger bar. The minimum depth required to enable the meter to be accurately positioned will depend on the weight/hanger bar/meter combination. For combinations where the distance from the bottom of the weight to the centre-line of the meter is 0.20 m, the minimum required depth for the 0.6 depth method is 0.55 m, and the minimum for the 0.2 and 0.8 method is 1.15 m. For combinations where the distance is 0.30 m, the minimum depths are 0.80 and 1.60 respectively.

With the equipment assembled and mounted on the cableway, connect the electronic counter to the sounding reel plug, and spin the current meter bucket wheel to make certain that proper contact is being made between the brush and slip ring on the sounding reel and in the current meter contact chamber. Record the size of the weight and the distance from the centre-line of the meter to the bottom of the weight.

### Distance measurement

The initial point for cableway measurements is usually located at or near the left bank tower or anchor. Width measurements painted on the cable can be difficult to see; instead tie a tape or tagline to a (standard) point on the traveller and read the distance from a (standard) point on the cableway structure.

### Begin gauging

Proceed with the gauging as described in the previous section on wading gauging. Unlike wading gaugings, meter setting depths are calculated downwards from the water surface. 0.6 measurements are calculated by multiplying the depth by 0.6, 0.2 measurements by 0.2, etc.

The meter and weight are positioned at the first vertical and lowered until the bottom of the weight just touches the water. The depth counter is set to read zero. The assembly is then lowered until the weight just touches the bottom. In some cases the exact point is difficult to feel, but watch the slackline cable rise as the weight goes off it. The depth indicated by the counter is read to give the sounded depth which is recorded (air- and wet-line corrections being made if necessary). The depth reading should be taken when the weight first touches the stream bed. If the velocities are high, scour may cause the weight to slowly sink into the bed.

An alternative procedure is to zero the counter when the centre-line of the meter is at the water surface. The sounded depth is then the counter reading when the weight touches the bed plus the distance from the centre of the meter to the bottom of the weight. For the sake of having a convention (to minimise errors) this method is not recommended unless it is used to eliminate vertical angles.

## Bridge gaugings

The general procedure is the same as for gauging from a slackline cableway.

### Disadvantages

Bridges with piers are seldom ideal situations from which to make discharge measurements but, for reasons of economy, are often used. Variations in velocities, angular flow, scour and deposition caused by piers may affect the accuracy of the measurement. The two main hazards (see safety instructions) are from road traffic and the tipping of gauging cranes due to snagging floating debris.

### Upstream or downstream side

Provided the meter assembly is not swept downstream under the bridge to become snagged on debris, the meter cable hangs free of the bridge structure, and scour holes are not encountered, the upstream side of a bridge may be preferred for metering. If any of these difficulties are encountered, the downstream side may be used, but accuracy may be reduced by the turbulence generated by piers, and there will be more difficulty in avoiding floating debris. Each situation must be considered on its merits.

### Width measurement

One of the abutments is normally chosen as the initial point for bridge measurements. As in the case of cableways, this should be on the left bank of the stream, and the initial point shall be clearly identified and used as a reference point for all gaugings. Where it is permissible to paint marks on the bridge it should be done in a neat and orderly fashion.

### Equipment

Select and assemble the equipment required for the measurement. In most cases a bridge crane and a reel can be used with weights of 34 kilograms or less.

## Boat gaugings

Boats are normally used only when cableways and bridges are unavailable. Powered boats often provide the only practical means of obtaining measurements in difficult conditions.

### Positioning

Positioning methods must provide both a means of measuring the distance across the cross-section and of keeping the boat's position static for velocity observations. The most commonly used method is to rig a tagline prior to each measurement.

Other methods include a combination of an electronic distance meter (EDM) and flags set out on the bank, or DGPS (differential GPS.

### Tagline rigging

Tagline rigging requires skill, co-ordination and caution by those involved. Not only are there potential hazards to the gauging team during this operation, but taglines are a dangerous obstacle for other boats; strict safety precautions must be observed, including marking the tagline with bright fluorescent markers at intervals to make it clearly visible to craft on the river.

Normally a temporary tagline is rigged for the duration of the gauging. Cables ranging in diameter from 1.5 mm to 3 mm are used; lighter cables (1.5 to 2 mm) are recommended, as they will require less tension and make the operation easier and safer.

The operation is carried out with a reel mounted on the bank. The tagline shall not be attached to the boat; if problems occur it should be quickly let go. Attachment to the boat can be very hazardous if the tagline snags or the reel jams; serious accidents have occurred in the past with this.

When the tagline is run across, all of the line or as much as possible will need to be kept out of the water. This not only reduces the amount of downstream drag on the cable but eliminates the possibility of snagging the cable on the stream bottom. The best way to achieve this is to use as light a cable as possible and to position the reel high on the bank. This height may not always be possible; a guide pulley attached to a tree or suspended from a tripod (fashioned from tree branches) may provide this.

The anchorage on the far bank is installed prior to running the tagline across. This can be an iron bar driven into the bank, a rock bolt or a cable fixed to a tree. A carabiner, hook or some suitable fitting can be fastened to this anchorage to make the fastening of the tagline quicker and easier.

The next step is to "run" the line across the river. Three people are normally required for this operation. One person on the bank controls the tagline reel and the rate at which the cable is paid out, another operates the boat and the third person holds the tagline end aboard the boat and connects it to the anchorage when the far bank is reached.

The line should preferably be hand-held during the crossing by way of a short piece of rope tied to the end. (This short rope should have no metal clips or rings which may cause the line to snag between rocks, etc.). Where the strain is likely to be too great to be held by hand, the gauging should be abandoned as being to dangerous. Tying on is not permitted for safety reasons .

Where adequate preparations have been made, the rigging of a tagline is not necessarily a chancy dash, but rather becomes a systematic operation.

### Positioning the boat at a tagline

In lower velocity rivers a boat may be attached to the tagline or a second line rigged for the purpose. In higher velocities a powered boat is usually nosed up to the tagline and held in position under power by a skilled operator. Apart from the gauging cranes specially manufactured to fit the various boats used, the sounding and metering equipment and the techniques are the same as those used for bridge and cableway measurements.

## Gauging calculation:

### Calculation on-site

Gaugings shall be calculated on-site to check the result and the quality of the gauging before leaving. Should any partial section contain more than 10% of the flow, extra verticals shall immediately be added in to remedy this. The calculated discharge shall be compared with the station's flow rating immediately following the measurement, and prior to departing from the site.

The purpose of this is to identify potential gauging errors, equipment problems or rating changes in "real time". If the gauging deviates by more than +/- 8% a second measurement shall be made using a different **instrument** or **method**.

### Checking calculations and filing

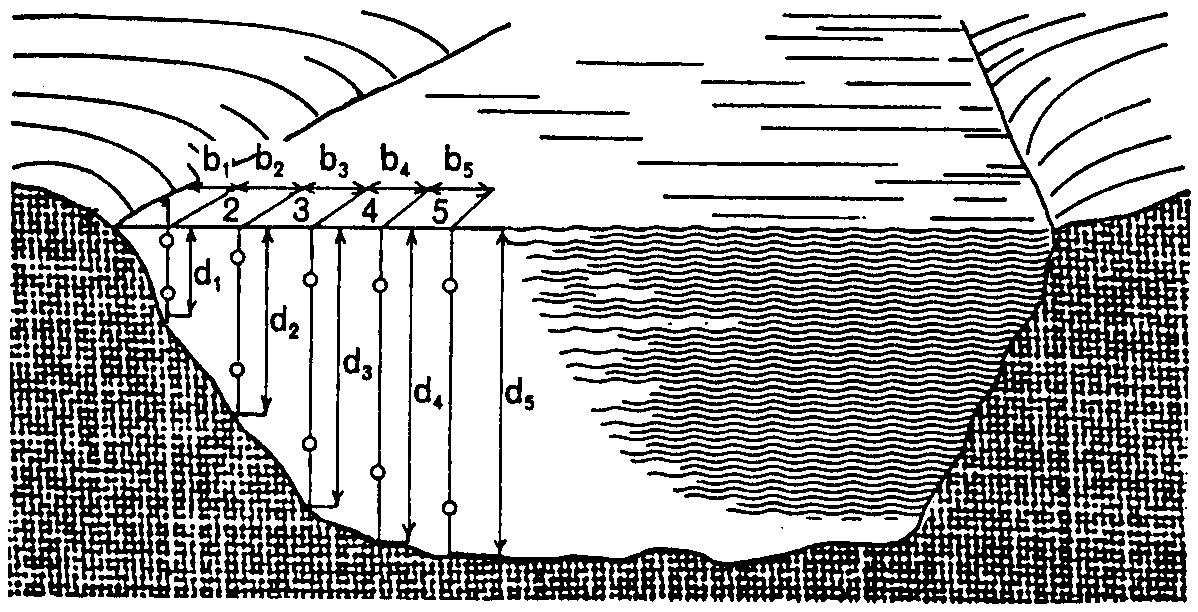
Gaugings shall be calculated by an approved calculation program and checked by a different person. Appropriate evidence of the method and the values input (a printout) and the initials of the people shall be on or attached to the gauging card. Normally the input will be to TDGauge which will file an “image” of the card in its database.

### Calculation

There are two recognised methods for calculating gaugings, the differences being in the way the depths and velocities are averaged. The two methods are termed the mean-section and the mid-section methods, and there is normally little difference between them. It is more common (outside the USA) to use the mean-section method, as it is better suited for measurements where verticals are unequally spaced.

Discharge is calculated as follows:

* The cross-section is regarded as being made up of a number of segments, each bounded by two adjacent verticals (Figure 6.3). The number of sections required is that which is required to accurately determine the section area and mean velocity (see Section 6.7.6).



**Calculation of current meter gaugings**

* If v1 and v2 are the mean velocities at the first and second verticals respectively, if d1 and d2 are the depths measured at verticals 1 and 2 respectively, and (b2-b1) is the horizontal distance between the verticals, the discharge in a partial section is:

q1 = (b2 -b1) x (d1 + d2)/2 x (v1 + v2)/2

where

q1 = discharge through partial section 1

b1 = distance from initial point to vertical 1

b2 = distance from initial point to vertical 2

d1 = depth of water at vertical 1

d2 = depth of water at vertical 2

v1 = mean velocity in vertical 1

v2 = mean velocity in vertical 2

The total discharge is obtained by adding the discharges for all segments.

### Assessments

The velocities in the partial sections adjoining the water's edges shall be estimated as percentages of the mean velocities in the adjacent verticals. This is an approximate technique, but if the area of these end partial sections is kept to a minimum then the overall effect on the accuracy of the gauging will be minimal.

### Computation of mean gauge height

Discharge measurements are often taken to provide data for a stage/discharge relationship. To be of value, the stage at the time of measurement must also be recorded with commensurate accuracy. Sufficient stage readings shall be obtained to define the fluctuations adequately, and the time of the vertical shall be noted on the gauging card every 10 - 15 minutes, and more frequently when the stage is changing rapidly.

The mean stage height for the period of the gauging shall be calculated according to the formulae below:

(a) If the fluctuations are less than 0.05 m, an arithmetic mean shall be used.

(b) If the fluctuation is more than this amount, ISO 748-2000 recommends using:

h = (q1 h1 + q2 h2 + q3 h3 + ... + qn hn)Q

in which:

h = mean stage height;

Q = total measured discharge [= (q1 + q2 + q3 + ... + qn)];

q1, q2, q3 .. qn = discharge measured during time interval 1, 2, 3, ... n;

h1, h2, h3 .. hn = average gauge height during time interval 1, 2, 3, .. n.

(c) However Rantz (1982) demonstrates that this tends to overestimate stage height, and suggests that where the changes in discharge with stage height is linear in the range of stage that occurred during the measurement, a time-weighted mean gauge height is better.

This is calculated from:

h = (t1 h1 + t2 h2 + t3 h3 + ... + tn hn)/T

where :

h = mean gauge height;

T = total time for measurement

t1, t2, t3 ... tn = duration of time intervals between breaks in the slope of the gauge height *vs* time graph;

h1, h2, h3 ... hn = average gauge height during time intervals 1, 2, 3, ... m.

Where the change in discharge with stage height is curvilinear, neither method is reliable, and Rantz and others (1982; p 173) recommend that the mean of the two estimates should be used. They also provide examples of the calculations.

## Gauging in difficult conditions

During flood events current meter gaugings can be difficult and dangerous, but vital information may be measured without exposing the hydrologist to unnecessary risk with the aid of the following techniques.

### Rapidly changing stage

When very rapid changes in stage occur during a measurement, the weighted mean gauge height, calculated as above, may not accurately define the gauge height applicable to the discharge measured. Two techniques may be used to reduce this error:

***(a) Abbreviated gauging procedure***

To reduce the range of stage during the measurement, the normal procedure can be abbreviated to allow measurements to be made more rapidly. However, these shortcuts in the measurement procedure will reduce the accuracy of the measured discharge, and they must be chosen carefully to produce a minimal combined error in measured discharge and computed mean gauge height.

The normal abbreviated procedure is:

* Use the 0.6-depth method. The 0.2-depth method or the subsurface method may be used if severe difficulties are experienced with the meter at this depth.
* Reduce the velocity-observation time to about 20 to 30 seconds.
* Reduce the number of sections taken to about 15 to 18.

By incorporating all three of the above practices a measurement can be made in 15 to 20 minutes.

If the subsurface or 0.2 method of observing velocities is used, correlations with observations of mean velocity will be required (done as soon as possible afterward and at as close a stage as possible) to establish relationships to convert these measurements to mean velocity.

***(b) Continuous gauging***

This technique is the preferred method to use when the stage is changing rapidly. It involves carrying out a number of abbreviated gaugings as above, noting the time of each vertical. Calculations are done by relating variations in depth and velocity to time and calculating discharge values for particular times. Rantz et al (1982) pp 175-177 describe applying the technique to flash floods.

The steps are:

* Use 8 - 15 verticals, according to the uniformity of the cross-section and the rapidity of the change in stage.
* Make one-point velocity measurements, at 20 to 30 seconds duration.
* Note the time of each vertical (the beginning of the velocity count).
* Obtain a stage reading on every third vertical, preferably a staff gauge reading as there may be lag in the recorder well due to the changing stage.
* Begin calculations by plotting, separately for each vertical, the depth of water against time over the period of the complete gauging. If conditions were such that soundings were not made, use data from cross-sections taken before and after the flood.
* Calculate the velocity for each vertical, and plot the values against time separately for each vertical.
* Select a stage for which to calculate a flow, and for its corresponding time, read off the graphs the depths and velocities to synthesise a gauging.
* Repeat the above step a number of times to compile a number of gaugings at selected stage heights over the stage range of the continuous gauging.

Calculate these gaugings according to normal practice, using the selected stages to plot them on the rating curve.

### 

### Discharge Calculation Methods

There are two common arithmetic methods for calculating discharge from velocity and depth verticals, the differences being in the way the depths and velocities are averaged.

These methods are:

Mean-Section Method, and

This method shall be the calculation method for this Standard

Mid-Section Method

This method is used in the USA. For more information, see ISO748:2007 section 8.3.2.

Two further arithmetic calculation methods are available for a unique flow condition or measurement type, these are:

Independent Vertical Method

This method is used for calculating rapidly changing discharge. For more infrmation, see ISO748:2007 section 8.4

Float Measurements

This is a calculation method used when velocity information is only available from time of travel of surface floats. For more information, see ISO748:2007 section 8.6.

Note: Either of these methods shall only be used in rapidly changing flow or flood conditions.

### Mean-Section Method

Discharge shall be calculated as follows:

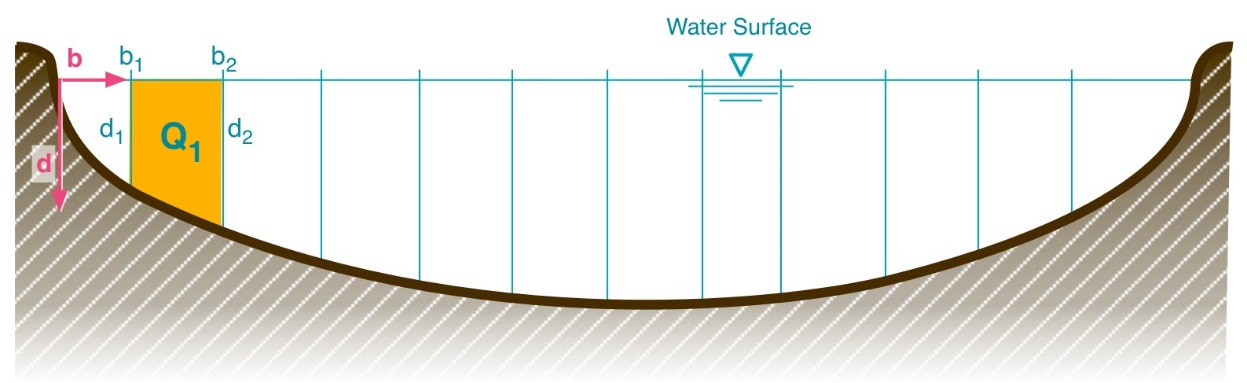
Determine cross-sectional segments

Calculate the discharge of each segment

Calculate total discharge

#### Determine Cross-Sectional Segments

The cross-section is regarded as being made up of a number of segments, each bounded by two adjacent verticals (Figure 3)



Cross-Sectional Segments

Illustrator: Chris Heath

#### Calculate Segment Discharge

If v1 and v2 are the mean velocities at the first and second verticals respectively, if d1 and d2 are the depths measured at verticals 1 and 2 respectively, and (b2-b1) is the horizontal distance between the verticals, the discharge in a segment is:

q1 = (b2 -b1) x (d1 + d2)/2 x (v1 + v2)/2

where:

q1 = discharge through segment 1

b1 = distance from initial point to vertical 1

b2 = distance from initial point to vertical 2

d1 = depth of water at vertical 1

d2 = depth of water at vertical 2

v1 = mean velocity in vertical 1

v2 = mean velocity in vertical 2

Note: The additional discharge in the segments between the effective waters edge and the first vertical, and between the last vertical and the other effective waters edge can be estimated as a proportion of the velocity at the adjoining velocity vertical.

#### Calculate Total Discharge

The total discharge is obtained by summing the discharges for all segments.

**Current meter – operating instructions**

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| **Price-type AA current meter - instructions** | |
| **(reed switch version)** | |
| This is a bucket-wheel type meter with a vertical shaft. A reed switch gives a pulse signal each revolution.  These meters are produced by a number of American manufacturers (including Gurley) to a USGS design. The reed switches have been added by NIWA. | **Recommended velocity range:** 0.08 to 3.6 m/s.  **Minimum spin test: 160 seconds**  (minimum spin test after servicing at IS: 240 secs). |
| **Preparations for use**  Retract the bucket-wheel raising nut (the “brake”) fully. Note that this has a left-hand thread. (If the nut has been over-tightened, unscrew the contact chamber locating screw, and lift the contact chamber slightly).  **When packing away:**  1 Screw down the bucket-wheel raising nut, but ***do not over-tighten***. Excessive force on this can spread the meter frame.  Note that the purpose of this nut is to lift the bucket-wheel off the pivot.  2 Carefully shake water off the meter, holding the bucket-wheel as well as the frame.  3 Note that the tailfin fits into the box with the counterweight to the top.  4 As soon as practical, clean the meter as detailed here. Carry out a spin test and record the results overleaf. | **Cleaning**  1 Remove the pivot and contact chamber.  2 Wash all components in white spirits or hot water and detergent. With hot water, let the meter get as hot as possible to aid drying.  3 Pay particular attention to the bearing surfaces in the bucket-wheel hub and the contact chamber to clean off oil and accumulated grit.  4 Do not attempt to remove the vertical shaft or alter the contact wires.  5 Gently shake off any excess liquid and dry with a soft lint-free cloth.  6 Sparingly oil both bearings and reassemble the meter.  7 Spin test the meter whilst held still in a horizontal position, protected from air currents. Check that the stop is not abrupt.  **Items Accompanying**  2 spare pivots tailfin  oil bottle oil dipstick |

**SPIN TEST RECORD**

**Record spin tests after cleaning in readiness for next gauging and to provide a record of meter performance.**

**Note the number of the pivot used/changed**

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| **Date (ddmmyy)** | **Spin test** | **Date**  **(ddmmyy)** | **Spin test** | **Date (ddmmyy)** | **Spin test** | **Date (ddmmyy)** | **Spin test** | **Date (ddmmyy)** | **Spin test** |
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| **Pygmy current meter - instructions** | |
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| This is a bucket-wheel type meter with a vertical shaft. A wire contact gives a pulse signal each revolution.  These meters are produced by a number of American manufacturers to a USGS design. | **Recommended velocity range:** 0.08 to 0.9 m/s.  **Minimum spin test: 60 seconds**  (minimum spin test after servicing at IS: 240 secs). |
| **Preparations for use**  1 Replace the brass travelling pivot with one of the two service pivots (the one noted as current on the reverse of this card).  2 Sparingly oil the pivot point before installation.  3 Spin test the meter or, if freshly cleaned and tested, note the spin test recorded for that pivot.  **When packing away**  1 Replace the pivot with the brass travelling pivot.  2 Carefully shake water off the meter, holding the bucket-wheel as well as the frame.  3 As soon as practical, clean the meter as detailed here. Carry out a spin test and record the results overleaf. | **Cleaning**  1 Remove the pivot and contact chamber cap. Gently ease the bucket-wheel assembly out of the frame. Do not force, but turn it to a different position to find a position where it will come out easily.  2 Wash all components in white spirits or hot water and detergent. With hot water, let the meter get as hot as possible to aid drying.  3 Pay particular attention to the bearing surfaces in the bucket-wheel hub and the contact chamber to clean off oil and accumulated grit.  4 Do not attempt to remove the vertical shaft or alter the contact wires.  5 Gently shake off any excess liquid and dry with a soft lint-free cloth.  6 Sparingly oil both bearings and the cap threads (seal the contact chamber) and reassemble. Check the contact closure.  7 Spin test the meter whilst held still in a horizontal position, protected from air currents. Check that the stop is not abrupt.  **Items Accompanying**  2 pivots travelling pivot  oil bottle oil dipstick |

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| **Small Ott current meter - instructions** | |
| **(Ott C1 and C2 meters)** | |
| This is a screw-type meter with a horizontal shaft. A reed switch (C2) or a wiping contact (C1) give a pulse signal each revolution.  Props of different pitch can be readily interchanged; EDSC normally provides two, with No. 1 being for the lowest velocities and No. 3 for the higher ones.. | **Recommended velocity range:**  Prop 1: 0.06 to 0.3 m/s  Prop 3: 0.14 to 2.0 m/s  **Minimum spin test:**  Prop 1: 25 seconds  Prop 3: 8 seconds  (minimum spin test after servicing at IS: Prop 1 = 30, Prop 3 = 10). |
| **Preparations for use**  1 As these meters are very delicate, please handle and use with care.  2 When coupling the electrical wire to the meter only gently tighten the knurled nut (on C2s the reed switch can be crushed; with C1s only gently tighten the screw in the contact as the insulation can split).  3 Check that the shaft is not bent by spinning it before fitting the prop. (Some props are drilled off-centre, which gives the impression of a bent shaft).  4 Fit the desired prop by holding the meter away from your body and pushing it on gently and squarely. Note that the main shaft can easily be bent.  5 Spin test by blowing the prop.  **When packing away**  1 Remove the prop gently and squarely as noted above.  2 As soon as practical, clean the meter as detailed here. Carry out a spin test and record the results overleaf. | **Cleaning**  1 Unscrew the front plug on the meter body and remove complete with shaft and bearings.  2 Wash the body and the shaft as complete units, preferably in white spirits or hot water and detergent, rising in clean hot water before drying.  3 Do not poke anything into the body on C1 meters as contacts may be damaged. Do not take the bearings off their shaft.  4 Pour in enough oil so that when the shaft is refitted a small amount is forced past the sealing plug.  5 Spin test the meter while held still in a horizontal position and protected from air currents. Check that the stop is not abrupt.  **Items Accompanying**  2 prop electrical cable  oil bottle wading rod adaptor  dismantling tool |

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| **Large Ott and Seba current meters - instructions** | |
| **(Ott C31 Universal, Seba F1)** | |
| This is a screw-type meter with a horizontal shaft. A reed switch gives a pulse signal each revolution which, for fast counts, must be counted using a scaler or electronic counter.  Props of different pitch can be readily interchanged; Instrument Systems normally provides two, with No. 1 being for the lowest velocities and No. 3 for the higher ones.. | **Recommended velocity range:**  (Prop 2) 0.1 to 6.0 m/s  **Minimum spin test:**  Metal prop: 30 seconds  Plastic prop: 10 seconds (but must spin smoothly to a stop)  (minimum spin test after servicing at IS: 50s & 15s |
| **Preparations for use**  1 Check that the meter is clean and filled with oil. Do this by unscrewing the propeller with the grooved “transition piece” while holding the meter with the prop downwards. Fill the prop cavity with oil to slightly more than half-full, and reassemble. A little oil should overflow out of the gap between shaft and sleeve as you screw them together.  2 Spin test the meter or, if you know it is freshly cleaned and tested, use the spin test recorded overleaf.  **When packing away**   * + 1. Carefully shake water off the meter, holding the prop as well as the body.     2. As soon as practical, clean the meter as detailed here. Carry out a spin test and record the results overleaf.   **Items Accompanying**  electrics cables counter  oil bottle 2 screwdrivers  tailfin screw hanger bar  spare locating pin for hanger bar | **Cleaning**   1. Loosen the large screw on the side of the meter and remove, complete, the prop, bearings and shaft from the body 2. Unscrew the tapered transition piece from the prop and extract the contact sleeve and shaft. (Note: with Seba meters, remove the fragile reed switch from the centre of the shaft and put it aside in a safe location 3. It should not be necessary to remove the bearings from the shaft unless they are very dirty (feel griity when rotated). If removed, take careful note of the order and reassemble them exactly the same. 4. Clean all parts, preferably in white spirits or hot water and detergent, rising in clean hot water before drying. Gently shake off any excess liquid and dry with a soft lint-free cloth. 5. Reassemble and fill prop with enough oil (just over half-full) so that a little overflows when tightened 6. Spin test the meter while held still in a horizontal position and protected from air currents. Check that the stop is not abrupt. |

**Standard current meter gauging practice**

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| Our standards state that gaugings shall conform to the appropriate ISO standards. These are extensive, but the following points are some of the essentials for high quality gaugings, and they also summarise the main practices to which gaugings shall conform. | |
| **Selection of site**  Where available, select a straight reach with a minimum of turbulence, irregularities and weed, etc.; with sufficient depth for the meter and velocity method and sufficient velocity for the meter to register accurately. Improve the section by removing boulders or debris if practical.  **Vertical spacing**  The number of verticals shall be chosen so that the discharge in each segment will be no more than 5% of the total, insofar as possible, and that in no cases should they exceed 10%. This will be checked by the quality control features of the calculation software and be taken into account in the uncertainty calculation.  **Width measurement**  Should be to an overall accuracy of ± 1%; therefore resolution needs to be to ± 0.5%, and taglines, etc. accurate to ± 0.5%.  Where practical, all measurements shall be in terms of a permanent or semi-permanent reference point to facilitate checking and assist with cross-section data for flood gauging.  **Spin tests and other tests**  Must be done (and recorded) both before and after, to confirm that the meter conforms to its calibration. Note the minimum spin tests listed in Table 1.  Also check meters before, during and after gauging for damage, deformation of the rotor, correct operation of the contacts, etc. | **Depth measurement**  Shall be to the highest resolution practicable:  under 500 mm to nearest 5 mm  other wading to 10 mm  all other situations to 10 mm  At least two measurements shall be made and the mean value adopted. (when wading, this can be done by determining the most representative spot and positioning the rod there. Following setting the meter, check that the rod depth is the same.) However if they deviate by >5%, take two more and mean all four.  **Velocity method**  Use the 2 or 3-point method by preference. Use the 0.6 method only if too shallow or there is documented evidence that it is accurate at that site and flow.  Measure the velocity over at least 40 seconds where the velocity is regular, and 50 seconds where it is pulsating.  **Choice of current meter**  Use the meter best suited to the conditions, with reference to Table 1. Where there is a conflict between minimum depths and velocity ranges, it may be best to favour the latter. However, try to avoid having the interval between verticals less than the rotor width. In turbulent flow and from boats, propeller meters are preferable.  **Check the meter for weed, etc.**  Remove the meter from the water between each vertical to examine it for damage and debris, etc. Make a closer and more frequent check when weed is present.  **Stand downstream** and to the side when wading, at least 0.5 m each way. |

**TABLE 1.** Guidelines for current meter use.

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|  | **Minimum spin** | **Minimum depth for correct clearance from bed [ISO748:2007] (m)** | **Recommended velocity range (m/s)** | |
| **Meter type** | **test (seconds)** |  | **minimum** | **maximum** |
| **Price AA** - wiping contact  - reed switch | 160  160 | 0.20  0.20 | 0.076  0.050 | 3.6  3.6 |
| **Pygmy** | 60 | 0.09 | 0.076 | 0.9 |
| **Small Ott** - prop 1  - prop 3 | 25  8 | 0.20  0.20 | 0.016  0.15 | 0.3  2.0 |
| **Large Ott** - brass prop  - plastic prop | 35  10 | 0.50  0.50 | 0.06  0.06 | 6.0  6.0 |
| **Amsler** | 25 | 0.50 | 0.5 | 6.0+ |
| **Seba** (large)  mini P1  mini P3 | 10  25  8 | 0.50  0.20  0.20 | 0.06  0.06  0.15 | 6.0  0.3  2.0 |

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| **Waters’ edges**  Give considered assessments. Remember that uniform deceleration from the last velocity reading to the WE or Effective WE suggests an assessment of 50%.  **Booking**  Complete the card in all respects.  Note who does which job; underline the booker’s name.  Calculate and record meter settings and call them out to the gauger. Repeat back data values as a check.  Question unusual values. Confirm them correct with a tick following checking.  **Stage**  An accurate mean stage height is as important as an accurate Q as far as ratings go. Take sufficient readings before, during and after. If the stage changes by more than 50 mm, calculate the weighted mean gauge height using one of the methods in the Field Manual.  **Oblique flow**  Measure the cosine of any horizontal angles preferably using the angle of the submerged meter rather than the water surface. **If using a meter that is set up to measure the normal component of the velocity directly (e.g., the FlowTracker ADV) then the meter needs to be held normal to the cross-section and the angle need not be measured nor the correction applied.**  **Calculation**  All gaugings shall be calculated and filed using GAUGE, and checked either by an independent method or a different person. If possible calculate before leaving the site in order to check the rating and whether a further gauging is needed to confirm. | **Water temperature**  Measure to a resolution of 0.53°C with a thermometer which has been checked against a calibrated one, and record on the card.  **FLOOD GAUGINGS**  **Rapidly-changing stage**  Reduce the uncertainty due to changing flow by shortening each gauging and/or using the continuous gauging technique.  Reduce the number of verticals to about 15 and the times of observation to about 20 seconds.  Preferably use the 0.6 method; if not possible, use the 0.2 or subsurface method in which case correlations with mean velocity will be necessary as soon as possible afterwards and at as high a stage as possible.  **Vertical angles**  Use a calculator program (the Psion program by L Reddish) or air-line and wet-line tables to work out the vertical depths and meter settings. A short-cut method may also be used. Whatever the method, record the air-lines, angles and meter settings on the card.  Or use a backstay if available.  **Stage measurements**  Record the time of each vertical.  Take as many staff gauge and EPB readings as possible, as well as sufficient recorder readings to define the variations in stage.  Calculate Mean Gauge Height according to the most appropriate formula in the Field Manual. |

**CONTINUOUS GAUGING TECHNIQUE**

* Use 8-15 verticals, according to the uniformity of the cross-section and the rapidity of the changes in stage.
* Make 0.6 depth velocity measurements, at 20 to 30 sec duration.
* Note the time of each vertical (the beginning of the velocity count).
* Obtain a stage reading on about every third vertical if there is a person available, otherwise each 15 minutes. Preferably take a staff gauge reading also to check the possibility of the intake becoming blocked.
* When the gauging is complete, begin another straight away, using the same vertical locations.
* Begin the calculations by plotting, separately for each vertical location, the depths of water against the corresponding stages. Continue for the complete gauging. If conditions prevented soundings being made, use data from cross-sections taken before and after the flood.
* Calculate the velocity for each vertical, and plot the values against stage separately for each vertical. (If the plots indicate different velocities on the rising and falling stages (a “loop” rating), plot velocities and depths against time.
* Select a stage for which to calculate a flow, and and from the above plots the depth and velocity at each vertical to synthesise a gauging.
* Repeat the above step a number of times to compile several gaugings (about as many as were completed in the field) at selected stage heights over the stage range of the continuous gauging.
* Calculate the discharge of each synthesised gauging according to normal practice, and plot on the rating at the selected stages.