

Australian Standard[®]

**Measurement of water flow in open
channels**

**Method 4.3: Measurement using flow
gauging structures—Round-nose
horizontal broad-crested weirs**



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Method 4.3: Measurement using flow gauging structures—Round-nose horizontal broad-crested weirs

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PREFACE

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This Standard is one of a series which deals with methods of measurement of water flow in open channels. The series when complete will consist of the following parts:

- Part 1: *Vocabulary and symbols*
- Part 2.1: *General—Guidelines for the selection of methods of measurement*
- Part 2.2: *General—Establishment and operation of a gauging station*
- Part 2.3: *General—Determination of the stage-discharge relation*
- Part 2.4: *General—Estimation of uncertainty of a flow-rate measurement*
- Part 2.5: *General—Guidelines for the selection of flow gauging structures*
- Part 3: *Velocity-area methods*
- Method 3.1: *Measurement by current-meters and floats*
- Method 3.2: *Measurement by moving-boat method*
- Method 3.3: *Measurement by slope-area method*
- Method 3.4: *Collection and processing of data for determination of errors in measurement*
- Method 3.5: *Investigation of total error*
- Method 3.6: *Measurement of flow in tidal channels*
- Method 3.7: *Measurement by ultrasonic (acoustic) method*
- Method 3.8: *Electromagnetic method using a full-channel-width coil*
- Part 4: *Measurement using flow gauging structures*
- Method 4.1: *Thin-plate weirs*
- Method 4.2: *Rectangular broad-crested weirs*
- Method 4.3: *Round-nose horizontal broad-crested weirs (this Standard)*
- Method 4.4: *V-shaped broad-crested weirs*
- Method 4.5: *Triangular profile weirs*
- Method 4.6: *Flat-V weirs*
- Method 4.7: *Rectangular, trapezoidal and U-shaped flumes*
- Method 4.8: *Trapezoidal profile weirs*
- Method 4.9: *Parshall and Saniiri flumes*
- Method 4.10: *End-depth method for estimation of flow in rectangular channels with a free overfall*
- Method 4.11: *End-depth method for estimation of flow in non-rectangular channels with a free overfall (approximate method)*
- Part 5: *Dilution methods*
- Method 5.1: *Constant-rate injection method for the measurement of steady flow*
- Method 5.2: *Integration method for the measurement of steady flow*
- Part 6.1: *Measuring devices, instruments and equipment—Rotating element current-meters*
- Part 6.2: *Measuring devices, instruments and equipment—Direct depth sounding and suspension equipment*
- Part 6.3: *Measuring devices, instruments and equipment—Calibration of rotating element current-meters in straight open tanks*
- Part 6.4: *Measuring devices, instruments and equipment—Echo sounders for water depth measurements*
- Part 6.5: *Measuring devices, instruments and equipment—Water level measuring devices*
- Part 6.6: *Measuring devices, instruments and equipment—Cableway system for stream gauging*
- Part 6.7: *Measuring devices, instruments and equipment—Ultrasonic (acoustic) velocity meters*
- Part 6.8: *Measuring devices, instruments and equipment—Position fixing equipment for hydrometric boats*

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- (iii) Substitute a full point (.) for a comma (,) as a decimal marker.
- (iv) The references to other publications should be replaced by references to Australian Standards as follows:

<i>Reference to International Standard</i>		<i>Australian Standard</i>	
ISO		AS	
		3778	Measurement of water flow in open channels
772	Liquid flow measurement in open channels—Vocabulary and symbols	3778.1	Part 1: Vocabulary and symbols
5168	Measurement of fluid flow—Estimation of uncertainty of a flow-rate measurement	3778.2.4	Part 2.4: General—Estimation of uncertainty of a flow-rate measurement

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Measurement of water flow in open channels

Part 4: Measurement using flow gauging structures

Method 4.3: Round-nose horizontal broad-crested weirs

1 Scope

1.1 This International Standard deals with the measurement of flow in rivers and artificial channels under steady flow conditions using round-nose horizontal broad-crested weirs (see figures 1 and 2).

1.2 The flow conditions considered are limited to steady flows which are uniquely dependent on the upstream head. Drowned flows, which depend on downstream as well as upstream levels, are not covered by this International Standard.

1.3 The round-nose horizontal broad-crested weir has a good discharge range and modular limit and is appropriate for use in small- and medium-sized installations. It is particularly robust and insensitive to minor damage.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 772: 1988, *Liquid flow measurement in open channels — Vocabulary and symbols*.

ISO 5168: 1978, *Measurement of fluid flow — Estimation of uncertainty of a flow-rate measurement*.

3 Definitions and symbols

For the purposes of this International Standard, the definitions given in ISO 772 apply. A full list of symbols with the corresponding units of measurement is given in annex A.

4 Installation

4.1 Selection of site

4.1.1 The weir shall be located in a straight section of channel, avoiding local obstructions, roughness or unevenness of the bed.

4.1.2 A preliminary study shall be made of the physical and hydraulic features of the proposed site, to check that it conforms (or can be made to conform) to the requirements necessary for measurement of discharge by the weir. Particular attention should be paid to the following features in selecting the site:

- a) the adequacy of the length of channel of regular cross-section available (see 4.2.2.2);
- b) the uniformity of the existing velocity distribution (see annex B);
- c) the avoidance of a steep channel (but see 4.2.2.6);
- d) the effects of any increased upstream water level due to the measuring structure;
- e) the conditions downstream (including influences such as tides, confluences with other streams, sluice gates, mill dams and other controlling features which might cause drowning);
- f) the impermeability of the ground on which the structure is to be founded and the necessity for piling, grouting or other means of controlling seepage;
- g) the necessity for flood banks, to confine the maximum discharge to the channel;
- h) the stability of the banks, and the necessity for trimming and/or revetment in natural channels;
- i) the uniformity of the cross-section of the approach channel;
- j) the prevailing wind, which can have a considerable effect on the flow in a river, or over a weir or flume, especially when the river, weir or flume is wide and the head is small and when the prevailing wind is in a transverse direction;
- k) aquatic weed growth;
- l) sediment transportation.

4.1.3 If the site does not possess the characteristics necessary for satisfactory measurements, or if an inspection of the stream shows that the velocity distribution in the approach channel deviates appreciably from the examples described in annex B, the site shall not be used unless suitable improvements are practicable. Alternatively, the performance of the installation may be checked by independent flow measurements.

4.2 Installation conditions

4.2.1 General requirements

4.2.1.1 The complete measuring installation consists of an approach channel, a weir structure and a downstream channel. The condition of each of these three components affects the overall accuracy of the measurements. Installation requirements include features such as the surface finish of the weir, the cross-sectional shape of the channel, the channel roughness and the influence of control devices upstream or downstream of the gauging structure.

4.2.1.2 The distribution and direction of velocity may have an important influence on the performance of a weir (see 4.2.2 and annex B).

4.2.1.3 Once a weir has been installed, any changes in the systems which affect the basis of the design will alter the discharge characteristics.

4.2.2 Approach channel

4.2.2.1 If the flow in the approach channel is disturbed by irregularities in the boundary, for example by large boulders or rock outcrops, or by a bend, sluice gate or other feature which causes asymmetry of discharge across the channel, the accuracy of gauging may be significantly affected. The flow in the approach channel shall have a symmetrical velocity distribution (see annex B) and this can most readily be achieved by providing a long straight approach channel of uniform cross-section.

4.2.2.2 A length of straight approach channel equal to five times the water-surface width at maximum flow will usually suffice, provided that flow does not enter the approach channel with high velocity via a sharp bend or angled sluice gate. However, a greater length of uniform approach channel is desirable if it can readily be provided.

4.2.2.3 The length of uniform approach channel suggested in 4.2.2.2 refers to the distance upstream of the head measuring position. However, in a natural channel it would be uneconomic to line the bed and banks with concrete for this distance, and it would be necessary to provide a contraction in plan if the width between the vertical walls of the lined approach to the weir is less than the width of the natural channel. The unlined channel upstream of the contraction shall nevertheless comply with the requirements of 4.2.2.1 and 4.2.2.2.

4.2.2.4 Vertical side walls to effect a contraction in plan shall be symmetrically disposed with respect to the centreline of the channel and shall preferably be curved with a radius R of not less than $2H_{\max}$. The downstream tangent point shall be at least $H_{\max}$ upstream of the head measurement section. The height of the side walls shall be chosen such that the design maximum discharge can be contained.

4.2.2.5 In a channel where the flow is free from floating and suspended debris, good approach conditions can also

be provided by suitably placed baffles formed of vertical laths, but no baffle shall be nearer to the point at which the head is measured than a distance of $10H_{\max}$.

4.2.2.6 Under certain conditions, a hydraulic jump may occur upstream of the measuring structure, for example if the approach channel is steep. Provided that the hydraulic jump is at a distance upstream of not less than about $30H_{\max}$, flow measurement will be feasible, subject to confirmation that an even velocity distribution exists at the gauging station.

4.2.2.7 Conditions in the approach channel can be verified by visual inspection or measurement for which several methods are available such as current-meters, floats, velocity rods, and concentrations of dye, the last being useful to check conditions at the bottom of the channel. A complete and quantitative assessment of velocity distribution may be made by means of a current-meter. The velocity distribution should then be assessed by reference to annex B.

4.3 Weir structure

4.3.1 The structure shall be rigid and watertight and capable of withstanding flood flow conditions without damage from outflanking or from downstream erosion. The weir crest shall be at right angles to the direction of flow and the geometry shall conform to the dimensions given in the relevant clauses.

4.3.2 The surfaces of the weir and of the vertical abutments flanking the weir shall be smooth; they may be constructed in concrete with a smooth cement finish, or surfaced with a smooth non-corrodible material. In laboratory installations, the finish shall be equivalent to that of rolled sheet metal or planed, sanded and painted timber. The surface finish is of particular importance on the horizontal crest, but the requirements may be relaxed beyond a distance along the profile $1/2H_{\max}$ upstream and downstream of the crest profile.

4.3.3 In order to minimize errors in the discharge measurements, the following tolerances should be aimed at during construction:

- on the crest width, 0.2 % of this width with a maximum of 0,01 m;
- on the horizontal surfaces, slopes of 0,1 % (1 mm/m).

The structure shall be measured on completion of construction and at regular intervals thereafter and if it varies from the design dimensions by more than the permissible tolerances, the discharge shall be re-computed.

4.4 Movable measuring structure

4.4.1 For water management purposes, it is in many cases necessary to measure flows and also to control water levels or flow at the same location. A combined measuring and regulating structure provides the most economic means for this purpose. The movable round-nose horizontal broad-crested weir may be constructed with one single vertical slot in which the supporting plate of the weir crest can be raised or lowered

according to the desired crest level. A vertical guide wall, founded on the bed of the channel and parallel to the supporting plate, acts as a watertight barrier for the movable weir.

4.4.2 If regular sediment flushing is expected to be necessary, the weir may be constructed with two slots. The movable weir is placed in the downstream slot while a bottom gate is placed in the upstream slot. During flow measurement, the bottom gate is lowered onto the bed. To flush sediment that has settled upstream of the weir, the bottom gate is opened by connecting it to the movable weir and raising the weir and gate together.

4.4.3 The most commonly used type of movable weir is that with two vertical slots. This telescopic weir consists of two sliding blades and a movable weir which are mounted on a steel guide frame in the following manner:

- a) The bottom gate is blocked in place under operational conditions and acts as a bottom limiter for the movable weir.
- b) The upper slide is connected to the bottom gate by means of two steel strips placed in the frame grooves and acts as a top limiter for the movable weir.
- c) The movable weir is connected by two steel strips to a horizontal lifting beam. The weir crest is horizontal in both directions. The upstream nose of the weir is rounded off in such a way that flow separation does not occur.

Figure 2 shows the round-nose horizontal broad-crested weir as a measuring and regulating structure.

4.5 Downstream conditions

Conditions downstream of the structure are important in that they control the tail-water level. This level is one of the factors which determines whether modular or drowned flow conditions will occur at the weir. It is essential, therefore, to calculate or observe tail-water levels over the full discharge range and to make decisions regarding the type of weir and its required geometry in the light of this evidence.

5 Maintenance — General requirements

Maintenance of the measuring structure and the approach channel is important to secure accurate and continuous measurements. It is essential that the approach channel be kept clean and free from silt and vegetation as far as practicable for the minimum distance specified in 4.2.2.2. The float well and the entry from the approach channel shall also be kept clean and free from deposits.

The weir structure shall be kept clean and free from clinging debris and care shall be taken in the process of cleaning to avoid damage to the weir crest.

6 Measurement of head

6.1 General requirements

6.1.1 Where spot measurements are required, the head upstream of the weir crest can be measured using a vertical or inclined gauge, a hook gauge, point gauge, wire weight gauge or tape gauge. Where a continuous record is required, a recording gauge shall be used. The location of the head measurement section is dealt with in 7.2.

6.1.2 With decreasing size of the weir and the head, small errors in construction and in the zero setting and reading of the head measuring devices become of greater relative importance.

6.2 Gauge well

6.2.1 It is usual to measure the head in a separate gauge well to reduce the effects of water-surface irregularities. When this is done, it is also desirable to measure the head in the approach channel as a check.

6.2.2 The gauge well shall be vertical and of sufficient height and/or depth to cover the full range of water levels, and shall have a minimum height of 0,3 m above the maximum water level estimated. At the recommended position for the measurement of head, the well shall be connected to the approach channel by means of a pipe or slot.

6.2.3 Both the well and the connecting pipe or slot shall be watertight, and where the well is provided for the accommodation of the float of a level recorder, it shall be of adequate size and depth to give clearance around the float at all stages. The float shall not be nearer than 0,075 m to the wall of the well.

6.2.4 The pipe or slot shall have its invert not less than 0,06 m below the lowest level to be gauged, and it shall terminate flush with the boundary of the approach channel and at right angles thereto. The approach channel boundary shall be plain and smooth (equivalent to carefully finished concrete) within a distance of 10 times the diameter of the pipe or width of slot from the centreline of the connection. The pipe may be oblique to the wall only if it is fitted with a removable cap or plate, set flush with the wall, through which a number of holes are drilled. The edges of those holes shall not be rounded or burred.

6.2.5 Adequate additional depth shall be provided in the well to avoid the danger of the float grounding on the bottom or on any accumulation of silt or debris. The gauge well arrangement may include an intermediate chamber of similar size and proportions between it and the approach channel, to enable silt and other debris to settle out where they may be readily seen and removed.

6.2.6 The diameter of the connecting pipe or width of slot shall be sufficient to permit the water level in the well to follow the rise and fall of head without appreciable delay, but it should be as small as possible, consistent with ease of maintenance, to damp out oscillations due to short-period waves.

6.2.7 No firm rule can be laid down for determining the size of the connecting pipe or slot, because this is dependent on the circumstances of the particular installation, for example whether the site is exposed and thus subject to waves, and whether a large diameter well is required to house the floats of recorders. It is preferable to make the connection too large, rather than too small, because a restriction can easily be added later if short-period waves are not adequately damped out. A pipe 100 mm in diameter is usually suitable for flow measurement in the field. A diameter of 3 mm may be appropriate for precision head measurement with steady flows in the laboratory.

6.3 Zero setting

6.3.1 Initial accurate setting of the zero of the head measuring device with respect to the crest level of the weir, and regular checking of this setting thereafter, are essential if overall accuracy is to be attained.

6.3.2 An accurate means of checking the zero shall be provided. The instrument zero shall be obtained by direct reference to the weir crest, and a record shall be made of the settings carried out in the approach channel and in the gauge well. A zero check based on the water level (when the flow either ceases or just begins) is liable to serious errors due to surface tension effects and shall not be used.

6.3.3 In the case of a movable weir both the upstream water level and the crest level vary. The elevation of the crestline can be read from a fixed gauge. A typical method for measuring the elevation of the crestline is by the installation of this gauge, fixed at the abutment and parallel to the lifting beam on which a horizontal strip indicates the elevation of the crest.

The weir is brought to a certain level. The reading of the fixed gauge on the abutment is recorded, and the zero setting described in 6.3.2 can be carried out.

A direct reading can be obtained by constructing the stilling well close to the lifting beam. The gauge is connected to the lifting beam so that it moves in the stilling well, while its zero coincides with the elevation of the vertexline. This method can also be applied for continuous recording.

7 Round-nose horizontal broad-crested weirs

7.1 Definition

7.1.1 The standard weir comprises a truly level and horizontal crest, between abutments. The upstream edge shall be rounded in such a manner that flow separation does not occur, and downstream of the horizontal crest there shall be either:

- a) a rounded edge,

- b) a downward slope, or
- c) a vertical face.

The weir shall be set at right angles to the direction of flow in the approach channel.

7.1.2 The dimensions of the weir and its abutments shall comply with the requirements indicated in figure 1. The radius, r , of the upstream crest shall not be less than $0,2H_{\max}$. The length of the horizontal portion of the weir crest shall not be less than $1,75H_{\max}$ nor should the sum of the crest length and nose radius be less than $2,25H_{\max}$.

7.1.3 In the case of a movable weir, the weir body may be made of steel or aluminium metal plate. If the weir has a fixed crest then it may be made of metal plate or of well-finished concrete.

If the structure has to be used to regulate and to measure flows, which is often the case for weirs used for irrigation purposes, then the construction will take the form of a vertical sliding overflow structure, movable by hand or mechanically.

7.2 Location of head measurement section

7.2.1 The head on the weir shall be measured at a point far enough upstream of the crest to be clear of the effects of draw-down, but close enough to the weir to ensure that the energy loss between the section of measurement and the upstream edge of the weir crest can be considered to be negligible. It is recommended that the head measurement section be located a distance of between three and four times $H_{\max}$ upstream of the weir block.

7.2.2 The crest height, if movable, shall be measured simultaneously with the upstream water level (see 6.3.3).

The head, h , (see figure 1) shall be determined within an absolute accuracy of a few millimetres (see 9.2). Regular inspection and maintenance of the whole structure is therefore indispensable.

7.3 Provision for modular flow

Flow is modular when it is independent of variations in tail-water level. For this to occur, assuming subcritical conditions in the tail-water channel, the tail-water total head level must not rise beyond a certain percentage of H . If the downstream face of the weir is vertical, this percentage is dependent on H/p_d : it is 63 % for low values of H/p_d , rising to 75 % at $H/p_d = 0,5$ and 80 % at $H/p_d \geq 1$. These values also apply to a movable weir structure. If the weir block has a downstream slope flatter than 1 in 5, the modular limit may be taken as 5 % higher throughout. In the above, p_d is the height of the crest above the downstream bed level.