भारतीय मानक

IS 12752 : 2024

Indian Standard

जलमितीय निर्धारणाएं — संरचनाओं द्वारा खुली वाहिकाओं में प्रवाह मापन — संरचनाओं के चयन के लिए दिशानिर्देश

(ISO 8368 : 2019, संशोधित)

(दूसरा पुनरीक्षण)

Hydrometric Determinations — Flow Measurement in Open Channels Using Structures — Guidelines for Selection of Structure

(ISO 8368 : 2019, MOD)

(Second Revision)

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भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS
मानक भवन, 9 बहादुर शाह ज़फर मार्ग, नई दिल्ली - 110002
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI - 110002
www.bis.gov.in www.standardsbis.in

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NATIONAL FOREWORD

This Indian Standard (Second Revision) which is modified to ISO 8368 : 2019 'Hydrometric determinations —Flow measurements in open channels using structures — Guidelines for selection of structure' issued by the International Organization for Standardization (ISO) was adopted by the Bureau of Indian Standards on the recommendation of the Hydrometry Sectional Committee and approved of the Water Resources Division Council.

This standard was first published in 1989 based on ISO 8368 : 1985. The first revision was undertaken in 2013 to align it with the then latest version of ISO 8368 : 1999. This revision has been brought to align it with the latest version of ISO 8368 : 2019.

The text of ISO standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard; and

b) Comma (,) has been used as a decimal marker, while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

In this adopted standard, reference International Standards appears for which Indian Standards also exist. The corresponding Indian Standards, which are to be substituted in their respective places, are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
ISO 772 : 2011 Hydrometric determinations — Vocabulary and symbols	IS 1191 : 2016 Hydrometry — Vocabulary and symbols (*third revision*)	Technically Equivalent
ISO 1438 : 2017 Hydrometry — Open channel flow measurement using thin-plate weirs	IS 9108 : 2020 Hydrometry — Open channel flow measurement using thin plate weirs (*second revision*)	Identical
ISO 3846 : 2008 Liquid flow measurement in open channels by weirs and flumes — Rectangular broad-crested weirs	IS 14974 : 2018 Liquid flow measurement in open channels by weirs and flumes — Rectangular broad-crested weirs (*first revision*)	Identical
ISO 3847 : 1977 Liquid flow measurement in open channels by weirs and flumes — End-depth method for estimation of flow in rectangular channels with a free overfall	IS 6330 : 2012 Liquid flow measurement in open channels by weirs and flumes — End depth method for estimation of flow in rectangular channels with a free overfall (*first revision*)	Identical
ISO 4359 : 2013 Liquid flow measurement in open channels — Rectangular, trapezoidal and U shaped flumes	IS 14869 : 2016 Flow measurement structures — rectangular, trapezoidal and U-shaped flumes (*first revision*)	Identical
ISO 4360 : 2020 Liquid flow measurement in open channels by weirs and flumes — Triangular-profile weirs	IS 14673 : 2022 Hydrometry — Open channel flow measurement using triangular profile weirs (*second revision*)	Identical

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Introduction

Flow measuring structures are used worldwide to measure liquid flow in artificial channels in water treatment facilities, research laboratories and natural watercourses. The number of weirs and structures found in the artificial environment far exceeds the number of those found in the field. Whatever the application, however, the information they provide is put to a variety of uses, including:

— hydraulic research and liquid flow control;

— local specific water availability surveys;

— day-to-day management of water resources;

— waste water disposal;

— long-term strategic water resources planning.

The flow information is also used by government-sponsored environmental protection agencies that manage the natural water resources in a country or region and enforce environmental legislation. This is intended to maintain and preserve water quantity and quality in the natural environment.

Flow measuring structures can be installed by any interested party or user. This could be an environmental protection agency or private operator, such as a commercial organization or an individual. The user is therefore faced with the choice of which form of measuring structure to install. This document gives advice on which type of structure is the most appropriate to satisfy the needs of the application, within all other relevant constraints and limitations.

The technical detail given on each type of structure is, by intention, couched in simple terms. This is so that the non-specialist user can gain an understanding of what is involved in the selection and installation of flow measuring structures, without the need for an in-depth knowledge of fluid hydraulics. Hence, the document does not cover:

— the detailed hydraulics of operation of each type of structure;

— the detailed civil engineering requirements to be met during its construction.

The user is therefore directed to the specific standards that relate to each type of structure for this level of detail. These are listed in the Bibliography and given in Tables 1 and 3 and Figure 1. In this way, the user can be ensured of the most up-to-date details on the hydraulics of operation of each type of structure.

Indian Standard

HYDROMETRIC DETERMINATIONS — FLOW MEASUREMENTS IN OPEN CHANNELS USING STRUCTURES — GUIDELINES FOR SELECTION OF STRUCTURE

(ISO 8368 : 2019, MOD)

(Second Revision)

1 Scope

This document gives guidelines for selecting a particular type of flow measuring structure for measuring liquid flow in an open channel. It describes how the individual structures function in simple non-technical terms, and sets out the factors and parameters to take into account in order to make an informed decision on which type of structure to use.

Values of the relevant parameters describing the limitations and uncertainty involved in the use of these structures are given in this document. More definitive details of a particular type of structure are given in the individual standards listed in Table 1, which cover each type of structure.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 772, *Hydrometry — Vocabulary and symbols*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 772 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

4 Symbols

Symbol	Unit	Description
a	m	height of sluice gate or radial gate opening
A	m^2	area of approach channel
B	m	width of approach channel
b	m	breadth of weir crest perpendicular to flow direction
C_{dr}		drowned flow reduction factor
D	m	diameter of u-shaped flume
g	ms^{-2}	acceleration due to gravity
H	m	total head relative to crest level
H_e	m	total effective head relative to crest level
H	m	gauged head relative to crest level (upstream head is inferred if no subscript is used)
H'	m	difference between lowest and highest crest elevations.
h	m	stage – often design capacity of structure

Symbol	Unit	Description
L	m	length of weir crest in direction of flow
m		slope term i.e. slope = 1:m
p	m	height of weir - difference between upstream mean bed level and crest level at upstream head measuring position. Sometimes denoted as p_1
Q	m^3s^{-1}	volumetric rate of flow/discharge
$S_{d/s}$	%	downstream slope for Larinier fish pass
α	Degrees (°)	angle of notch for triangular thin plate weirs
Subscripts		
1		upstream
2		downstream
e		effective
max		maximum
min		minimum
u/s		upstream

5 Types of structure

5.1 General

In general, all flow measuring structures are subject to certain requirements irrespective of their form and operation. These are given below.

a) All these structures operate on the basis that they create a unique relationship between water depth at the critical section that lies within the structure and the flow passing through it down the channel. Therefore, it is necessary to observe the depth of water in the channel at specific points to derive a value of channel flow. Depending on the type of structure, these depth observation points can be:

   1) in the approach channel;

   2) at or near the crest of the weir or the critical section of the flume;

   3) in some cases, the downstream end of the channel in which the structure is located; water depth measurements can be taken by hand using a suitable depth sounding instrument, by eye using a gauge board fixed at the specific point, or continuously using a water level recorder or pressure transducer and data logger set at the specific point.

b) The location of any structure should be such that it is free from the effects of backwater from downstream influences, such as a confluence with another watercourse. High backwater causes non-modularity or drowning of the structure with a corresponding loss of measurement accuracy. Typically, non-modularity occurs in weirs when the downstream level exceeds between 0,66 and 0,75 of the upstream level (measured relative to the crest of the weir). For some forms of weir, notably those with a triangular profile, it is possible to derive an adjustment factor to correct for the level of non-modularity by using the ratio of downstream level to a head within the separation pocket formed downstream of the crest. With the Parshall flume, a submerged calibration can be derived. However, with all forms of weir and flume, this has not been particularly successful in sediment laden streams, and, hence, for field observations, the avoidance of backwater effects is recommended.

c) Recent environmental legislation in many countries has required the installation of fish passes at weirs on fish migratory water courses.

   1) Such fish passes include Larinier super-active baffle fish passes, pool-type fish pass with V-shaped overfalls, and Dutch pool and orifice fish pass.

2) It is suggested that the recommendations in ISO 26906 be followed. See also 5.10.

d) When a flow measuring weir is located in a watercourse that carries a high silt load, the structure can be affected by siltation behind the crest, to an extent dependant on its configuration. In general, the greater the afflux created by the structure, the greater the build-up of sedimentation behind the crest. For example, a vertical thin plate weir creates a greater trap for sedimentation than a triangular profile weir. Alternatively, flumes tend to self-flush to greater degree especially at higher flow rates. This factor needs to be considered when a structure is being selected and designed. However, whatever type of structure is selected, it may be prudent to include a by-pass at the time of construction. This should have the capacity to take all the discharge in the watercourse at periods of low flow. The by-pass facilitates the clearance of any silt build-up without adverse environmental impacts during the silt removal process.

e) Some national government agencies have set clear specifications and requirements on any flow measuring structure that is to be built.

Schematic representation of flow measuring structures covered by this document are given in Table 1. Diagrams showing the construction of a particular type of flow-gauging structure are given in the appropriate International Standard listed in the Bibliography.

5.2 Thin-plate weirs

Two types of thin-plate weir are in use. These are rectangular thin-plate weirs and V-notch thin-plate weirs. For the same cross-section shape, thin plate weirs are the more sensitive because of streamline curvature over the crest.

These weirs are relatively inexpensive and easy to manufacture and install, and can be relatively small in size. They are the most accurate form of weir, particularly the V-notch weir, which is intended to measure low flows on small water courses and artificial channels. Problems with this form of weir come from the accumulation of debris behind the structure which reduces the h/P ratio, and floating debris that can block the discharge point.

5.3 Broad-crested weirs

These are, in simple terms, a weir across the channel of a specific longitudinal profile. These weirs can have a variety of cross-section shapes (e.g. round-nose, rectangular, trapezoidal, U or V-shaped), and have a range of configurations of how the sides and bottom contract to create the weir control section.

The installation of these structures invariably requires a significant level of civil engineering. They are not particularly affected by siltation or debris build-up, but the head-to-discharge relationship is not as sensitive as that for thin plate weirs.

5.4 Triangular-profile weirs

5.4.1 General

As with broad-crested weirs, the installation of these structures invariably requires a significant level of civil engineering. Triangular-profile weirs, as their name implies, have a triangular profile with typically a 1:2 profile on the upstream face and a 1:5 profile on the downstream face, giving a sharp-edged horizontal crest. As such, they have a more sensitive head-to-discharge relationship than broad-crested weirs. In situations where excess backwater impacts on the modularity of the weir, a second level measurement can be taken at a crest tapping point or at a specific point downstream of the crest, to determine a non-modularity correction factor to be applied to the discharge derived from the normal upstream level. Experience has shown, however, that a crest tapping on these weirs is prone to blockage by fine sediment, requiring regular clearing if correct functionality of the weir is to be maintained.

The deployment of these weirs is found in a range of situations from artificial channels to moderate to large natural water courses. Siltation and debris build-up behind the crest is a disadvantage but does not seriously affect the accuracy of flow measurement.

5.4.2 Streamlined triangular-profile weirs

These are a form of triangular-profile weir as discussed in 5.4.1, and, as such, the same comments apply here. The major difference is that for drowned flow operation, i.e. where excess backwater impacts on the modularity of the weir, a separate downstream measure of level should be used rather than a crest tapping required for the triangular profile weir.

5.4.3 Flat-V weirs

These are a form of triangular-profile weir with a cross-sectional V configuration. Typically, the cross-section V has a 1:10 slope on smaller channels or a 1:20 slope on a wider channel. This gives them a more sensitive head-to-discharge relationship than broad-crested weirs or simple triangular-profile weirs. However, as with other structures, the installation of these weirs invariably requires a significant degree of civil engineering. The deployment of these weirs is found in a range of situations from artificial channels to moderate to large natural water courses. Siltation and debris build-up behind the crest is a disadvantage but does not seriously affect the accuracy of flow measurement.

5.5 Trapezoidal-profile weirs

These are a form of weir which, in terms of sensitivity, have a similar head-to-discharge relationship as broad-crested weirs, and are hence are of similar accuracy. The deployment of these weirs is found in a range of situations from artificial channels to moderate to large natural water courses. Siltation and debris build-up behind the crest is a disadvantage but does not seriously affect the accuracy of flow measurement. The installation of these structures invariably requires a significant level of civil engineering.

5.6 Flumes

A measuring flume is, in simple terms, an artificial channel that has been constructed to a very specific form in terms of cross-section and bed gradient. In this way, it creates a unique relationship between water level at specific points along its section and the flow it is carrying. Flumes can have a variety of cross-sections (e.g. rectangular, trapezoidal, U-shaped) and have a variety of configurations in how the sides and bottom contract to create the flume control section (e.g. long-throated flume, short throated flume, Parshall flume, Saniiri flume).

NOTE In the USA, the construction of new Parshall flumes is no longer recommended. However, SANIIRI structures, which were developed in the USSR, are still extensively used.

A distinguishing factor with these structures is whether or not the flow in the control section exhibits streamline curvature. If the structure has streamline curvature, then the calibration is dependent on the details of the diverging transition in addition to the converging transition. Those that have a long enough throat and do not have streamline curvature (thus parallel flow in the throat) have a calibration that is independent from the downstream transition. In this case, the modular limit can be higher.

Long-throated flumes are preferred because of this independence of the downstream transition even though the downstream transition affects the modular limit. A further advantage of a critical depth flume is that debris and siltation do not tend to occur in the critical section due to the self-flushing characteristics of this type of structure.

The installation of these structures invariably requires a significant level of civil engineering.

5.7 End-depth method

End-depth methods of flow measurement involve the use of a flume where the critical water depth is taken at the downstream discharge point. However, the head-to-discharge relationship is less critical than a standard flume and hence the accuracy of flow measurement is lower. As with all flumes, one advantage is that debris and siltation build-up in the critical section does not tend to occur because there is no structure across the direction of flow. While the installation of these structures invariably requires a significant level of civil engineering, suitable existing channels can be used for discharge measurement using this method with only the minor modifications to the structure needed for measurement of end depth.

5.8 Vertical underflow gates and radial gates

These structures are usually built to control the upstream water level and/or regulate the flow released to the downstream channel. As such, they are not intended to be used as flow measurement structures, although, by virtue of the critical head-to-discharge conditions that they create, they can be used to measure discharge. This is a function of the dimensions of the opening where underflow of the gates occurs, and the upstream and downstream water level. Nevertheless, the accuracy of flow measurement by these structures is not particularly high.

The installation of these structures invariably requires a significant level of civil engineering, but silt and debris does not tend to build up behind the structures due to their self-flushing nature.

5.9 Compound gauging structures

Flow measuring structures in this category combine a number of different types of either weir or flume, but not usually in a mixed layout. The intention of the compound nature is to increase accuracy of flow measurement over an increased range of head and discharge. The overall accuracy of the compound structure is dependent on the weir or flume type used. The installation of these structures invariably requires a significant level of civil engineering and, in the case of compound weirs, siltation and debris build-up behind the crests is a disadvantage, which might or might not affect the accuracy of flow measurement.

A significant point to note is that as there is a drop-in water level across the flume or weir, there is potential for movement of substrate beneath the structure. Therefore, some form of cut-off wall in the substrate is often required to maintain stability of the structure over time. Any loss of foundation beneath the structure can cause differential settling, which can lead to collapse of all or part of the structure. This settlement can also cause the calibration of the structure to change. Some structures are more sensitive to small deviations in dimensions than others, for example, structures with sharp angles in the critical section are more prone to changes in calibration. A good example is the Parshall flume, which has a drop in the bottom after the side walls contract to their narrowest point. In all cases, good calibration requires that the structure’s dimensions are measured with the greatest accuracy.

5.10 Fish passes

There are several types of fish pass, which are described in ISO 26906, that can be used to determine discharges. Therefore, the installation of a fish pass need not necessarily jeopardize a structures ability to be used to determine discharge, and allows fish passage to work in parallel with flow measurement. Three types of fish pass that have been extensively investigated for use as flow measurement structures are described in ISO 26906, namely Larinier Super-active Baffle fish pass, and two types of fish pass which fit into the interconnected pools category: the pool-type fish pass with V-shape overfalls and the Dutch pool and orifice type. Further consideration to fish passage is given in 6.9. In addition, the Larinier superactive baffle fish pass is included as an example.

6 Factors affecting choice

6.1 General

The factors that affect the choice of which structure to use can be considered under the following headings:

— intended purpose of the structure;

— range of flow to be measured;

— accuracy to which the flow is to be measured;

— consideration of afflux and potential for submergence;

— size and nature of channel in which the structure is to be installed;

— channel slope and sediment load;

— operation and maintenance requirements;

— environmental impact;

— passage of fish;

— whole-life cost.

6.2 Intended purpose of the structure

Table 1 gives the various structures and indicates some of the purposes for which they might be applicable, together with some guidelines on their limitations. Further guidelines on their limitations are contained in Table 2.

The purpose for which the structure is required determines the range of flows and accuracy of measurement that are required. The accuracy in a single determination of discharge depends upon the estimation of the component uncertainties involved.

In theoretical terms, the following accuracy/uncertainty can be assumed:

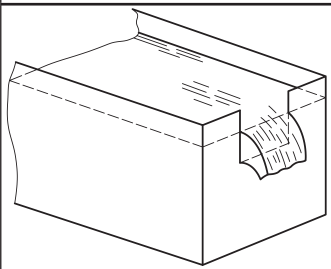
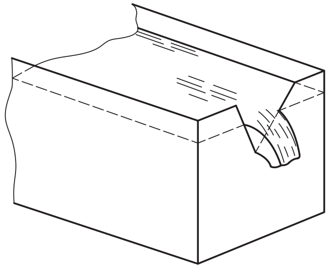
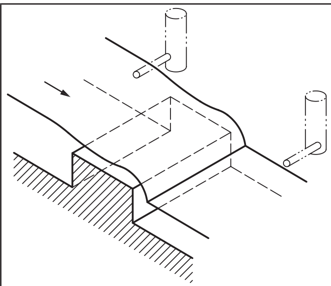
— thin-plate weirs from 1 % to 4 %;

— flumes and certain types of weirs from 2 % to 5 %;

— end-depth methods and other weirs from 4 % to 10 %.

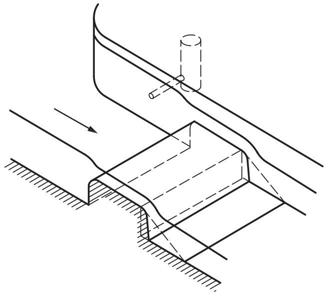
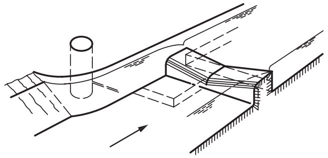
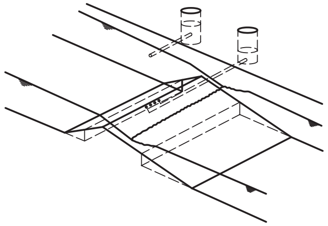
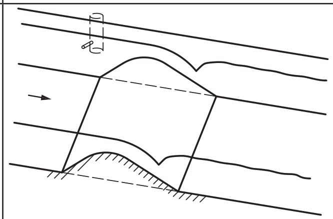
However, deviations from the design during construction and installation, and low standards of care and maintenance during use, will result in increased measurement errors. Guidance on these sources of uncertainty are given in ISO/IEC Guide 98-3 and ISO/TS 25377.

Table 1 — Applications and some limitations of structures in International Standards

Structure	Sketch of structure	ISO Standard	Approach channel length (m)	Distance from crest to head measuring section upstream (m)	Modular limit	Uncertainty[a]	Uses
Thin plate weirs Rectangular thin plate weir		ISO 1438	>10 h_{max}	> 2 h_{max}	Aerated nappe	1 to 4	Laboratory, pump tests, sediment free water, small streams and for use in hydraulics laboratories.
Thin-plate weirs — V-notch		ISO 1438	>10 h_{max}	2 to 4 h_{max}	Aerated nappe	1 to 4	Laboratory, pump tests, sediment free water, small streams and for use in hydraulics laboratories. More sensitive to low flows than rectangular thin plate weirs.
Broad-crested weirs							
a) rectangular		ISO 3846	>10 × channel width	3 to 4 h_{max}	66 %	4 to 8	Broad-crested weirs are best used in rectangular channels, but they can be used with good accuracy in non-rectangular channels if a smooth, rectangular approach channel extends upstream of the weir for a distance three to four times the maximum head. Irrigation channels with little fall available and wide range of flow.

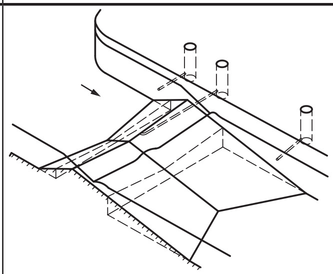
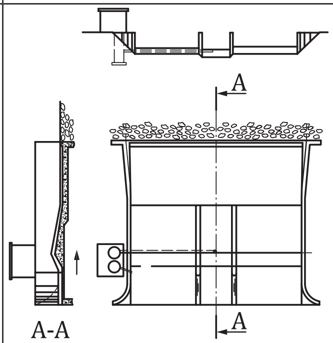
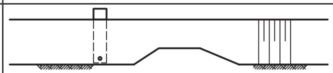
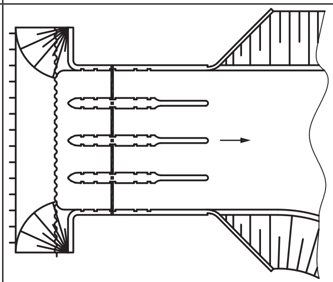
[a] At 95 % confidence level and coverage factor = 2.

Table 1 *(continued)*

Structure	**Sketch of structure**	**ISO Standard**	**Approach channel length** (m)	**Distance from crest to head measuring section upstream** (m)	**Modular limit**	**Uncertainty**[a]	**Uses**
b) round-nose horizontal		ISO 4374	>5 × channel width	3 to 4 h_{max}	80 %	4 to 8	
c) V-shaped		ISO 8333	>10 × channel width	3 to 4 h_{max}	80 %	4 to 8	
Triangular-profile weirs		ISO 4360	>5 × channel width	2 ≥ h_{max}	75 %	2 to 5	Hydrometric networks and main irrigation channels.
Streamlined trian-gular- profile weirs		ISO 9827	>5 × channel width	4 to 5 h_{max}	Varies	2 to 5	Minor irrigation channels.

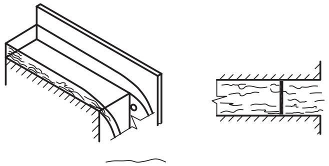
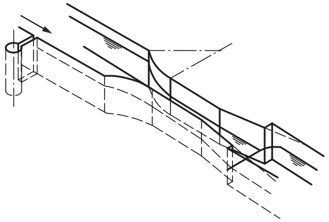
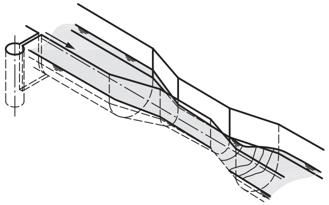
[a] At 95 % confidence level and coverage factor = 2.

Table 1 *(continued)*

Structure	Sketch of structure	ISO Standard	Approach channel length (m)	Distance from crest to head measuring section upstream (m)	Modular limit	Uncertainty[a]	Uses
Flat-V weirs		ISO 4377	>5 × channel width	> 3 h_{max} or 10H', whichever is the greater	70 %	2 to 5	Hydrometric networks for sites with a wide range of flow.
Compound gauging structures		ISO 14139	>5 × channel width	Min of 2 h_{max} of each sub structure	Varies	2 to 5	Hydrometric networks for sites with wide range of flow.
Trapezoidal broad crested weirs		ISO 4362	>10 × channel width	3 to 4 h_{max}	65 % to 85 %[d]	4 to 8	Where ease of construction is an important factor. Irrigation works and minor channels.
Vertical underflow gates and radial gates		ISO 13550	>5 × channel width	2 to 3 h_{max}		4 to 8	Locations where a near constant upstream water level is required.

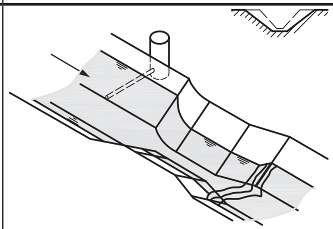
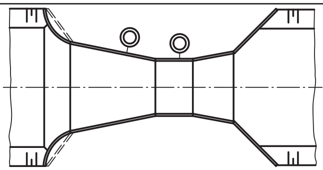
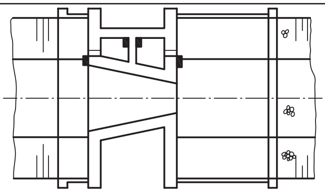
[a] At 95 % confidence level and coverage factor = 2.

Table 1 *(continued)*

Structure	Sketch of structure	ISO Standard	Approach channel length (m)	Distance from crest to head measuring section upstream (m)	Modular limit	Uncertainty[a]	Uses
End-depth method: a) rectangular b) non-rectangular		ISO 18481		At the brink		5 to 10	Where accuracy may be relaxed for simplicity and economy.
Rectangular, trapezoidal and U-shaped flumes — Rectangular flume		ISO 4359	>5 × channel width	3 to 4 h_{max}	74 %	2 to 5	Flumes can be used in channels of any shape if flow conditions in the approach channel are reasonably uniform and steady. Sediment-laden channels, flow with debris, flow with migratory fish, conduits and partially filled pipes, flow in sewers.
Rectangular, trapezoidal and U-shaped flumes — U-shaped flume		ISO 4359	>5 × channel width	3 to 4 h_{max} u/s	74 %	2 to 5	Flumes can be used in channels of any shape if flow conditions in the approach channel are reasonably uniform and steady. Sediment-laden channels, flow with debris, flow with migratory fish, conduits and partially filled pipes, flow in sewers. More sensitive to low flows than rectangular flumes.

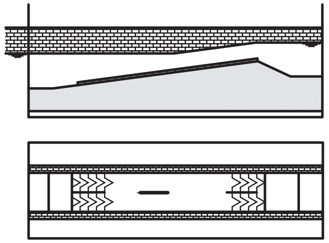
[a] At 95 % confidence level and coverage factor = 2.

Table 1 *(continued)*

Structure	Sketch of structure	ISO Standard	Approach channel length (m)	Distance from crest to head measuring section upstream (m)	Modular limit	Uncertainty[a]	Uses
Rectangular, trapezoidal and U-shaped flumes — Trapezoidal flume		ISO 4359	>5 × channel width	3 to 4 h_{max} u/s	74 %	2 to 5	Flumes can be used in channels of any shape if flow conditions in the approach channel are reasonably uniform and steady. Sediment-laden channels, flow with debris, flow with migratory fish, conduits and partially filled pipes, flow in sewers. Suited to existing trapezoidal channels to avoid a transition in the cross section
Parshall and SANIIRI flumes Parshall Flume		ISO 9826	>10 × channel width	In upstream transition as specified in standard	60 % to 80 %	4 to 8	Flumes can be used in channels of any shape if flow conditions in the approach channel are reasonably uniform and steady. Hydrometric networks and water distribution channels.
Parshall and SANIIRI flumes SANIIRI Flume		ISO 9826	>10 × channel width		60 % to 80 %	4 to 8	

[a] At 95 % confidence level and coverage factor = 2.

Table 1 *(continued)*

Structure	Sketch of structure	ISO Standard	Approach channel length (m)	Distance from crest to head measuring section upstream (m)	Modular limit	Uncertainty[a]	Uses
Larinier fish pass		ISO 26906	>5 × channel	2 x h_{max} u/s		3 - 5	Existing flow measuring structures where fish passage is a requirement. Can be used advantageously at some sites to reduce the uncertainties in low flow determinations.

[a] At 95 % confidence level and coverage factor = 2.

Table 2 — Further limitations of the flow measurement structures

Structure	International Standard	$p >$ (m)	$b >$ (m)	$h >$ (m)	$h/p <$	$h <$	L/p	h/L	Other
Thin-plate weirs — Rectangular	ISO 1438	0,1	0,15	0,03	2,5	—	—	—	
Thin-plate weirs — V-notch	ISO 1438	0,09	—	0,06	varies	—	—	—	20° < α < 100°
Broad-crested weirs									
a) rectangular	ISO 3846	0,15	0,3	0,06	1,6	—	$0,1 < L/p < 0,4$	$0,1 < h/L < 1,6$	—
b) round-nose horizontal	ISO 4374	0,15	0,3 or $> h_{max}$ or $L/5$	0,06 or > 0,01L	1,5	—	—	$h/L < 0,57$	—
c) V-shaped	ISO 8333	—	—	0,06 or > 0,05L	1,5 to 3 See ISO 8333	—	—	0,5 to0,8 See ISO 8333	H < 1,25HB
Triangular-profile weirs	ISO 4360	0,06	0,3	0,03 to 0,06	3,5	$B/2$	—	—	—
Streamlined triangular-profile weirs	ISO 9827	0,15	0,3	0,05	1,3	—	$0,2 < L/P < 2$	—	$C_{dr} > 0,9$
Flat-V weirs	ISO 4377	—	—	0,06	—	3,0	—	—	$H_1/p_1 < 2,5$
Compound gauging structures	ISO 14139	—	—	—	—	—	—	—	—
Trapezoidal broad crested weirs	ISO 4362	0,15	0,3	0,05	1,3	—	$0,2 < L/P < 2$	0,1 h/L < 1,5 – 3 Rect $0,1 < h/L < 1,2$ trap	$C_{dr} > 0,9$
Vertical underflow gates and radial gates	ISO 13550	—	—	$H_1 > 2a$ Vert gate	—	$H_1 < a/0,6$ radial	—	—	—
End-depth method a) rectangular b) non-rectangular	ISO 18481	—	0,3	$H_e > 0,04/5$	—	—	—	—	—
Rectangular flume	ISO 4359	—	0,1	0,05 or > 0,05L	$h < 3b$	—	bh/(Bh + Bp) < 0,7	h/L < 0,5 to 0,67	—
Trapezoidal flume	ISO 4359	—	0,1	0,05 or > 0,05L	h < 3b	—	—	—	—
U-shaped flume	ISO 4359	—	D = 0,1	0,05 or > 0,05L	—	—	—	—	—
Parshall flume	ISO 9826	—	—	0,03 to 0,09	—	0,8 – 1,83	—	—	—
SANIIRI flume	ISO 9826	—	—	0,09 to 0,1	—	1,1 – 1,83	—	—	—
Larinier fish pass	ISO 26906	0,15 m	b_{min} = 6 x baffle height 0,45 m to 0,9 m	0,03	3,0	0,9	---	---	$Su_{/s} = 1,2$ $S_{d/s} < 15\%$ baffle heights 75 mm to 150 mm

6.3 Range of flow to be measured

It is necessary to take account of the range of flows to be measured, i.e. the maximum and minimum flows, when deciding which type of structure to use. An indication of the potential range of some typical structures is given in Table 3.

Table 3 — Comparative discharges for various flow measurement structures for various sizes and dimensions

Structure	*p* m	*b* m	*m* (slope)	*L* m	Stage/ Static head m		Discharge m^3s^{-1}	
					min	max	min	max
Weirs								
Thin-plate, full width	0,2 1,0	1,0 1,0	—	—	0,03 0,03	0,50 2,50	0,01 0,01	0,85 9,4
Thin-plate, contracted (*b*/*B* = 0,5)	0,2 1,0	1,0 1,0	—	—	0,03 0,03	0,50 2,50	0,01 0,01	0,64 7,2
Thin-plate, V-notch (*p*/*B* = 0,5)	0.50 1,25	—	90° notch	—	0,06 0,06	0,20 1,25	0,001 0,001	0,025 2,5
Round-nose broad-crested	0,3 1,0	1,0 50,0	—	0,5 1,0	0,05 0,06	0,30 0,57	0,02 1,16	0,30 37,8
Rectangular broad-crested	0,2 1,0	1,0 50,0	—	0,5 1,0	0,06 0,10	0,48 1,50	0,02 0,81	0,63 190,0
V-shaped broad-crested (within V)	2,0 2,0	3,0 7,0	90° 150°	2,0 2,0	0,10 0,10	1,68 1,16	0,004 0,014	4,6 6,9
Trapezoidal broad crested weir	0,2 1,5	1,0 50,0	—	0,5 1,0	0,05 0,05	0,5 1,0	0,02 0,89	0,70 94,5
Triangular-profile (steel crest for min crest of 0,03) (Max stage could be higher but 1,50 m realistic)	0,2 1,0	1,0 20,0	1:2/1:5[2] 1:2/1:5[2]	—	0,03 0,03	0,51 1,50	0,01 0,20	0,90 83,40
Flat-V (1:2 upstream and 1:5 downstream slope)	0,2 1,0	4,0 80,0	1:10[3] 1:40[3]	—	0,06 0,06	0,75 3,00	0,014 0,054	5,2 760
Streamlined triangular- profile weirs	0,2 1,0	1,0 20,0	1:2/1:5[2] 1:2/1:5[2]	—	0,05 0,05	0,32 1,60	0,02 0,38	0,40 90,0
Flumes	—	—	—					
Rectangular (*b*/*B* = 0,5)	0,0	1,0	—	2,0	0,10	1,00	0,05	1,78
Trapezoidal (*L*/*B* = 1,0)	0,0	1,0	1:5[3]	4,0	0,20	2,00	0,24	47,5
U-throated (*b*/*B* = 0,5)	0,15 0,5	0,3 1,0	—	0,6 2,0	0,05 0,10	0,30 1,00	0,002 0,016	0,07 1,45
Parshall flume	0,0 0,0	0,025 15,24			0,05 0,09	0,21 1,83	0,09 ls^{-1} 0,751	5,38 ls^{-1} 92,3
SANIIRI flume	0,0 0,0	0,3 1,0			0,14 0,24	0,55 1,10	0,03 0,25	0,25 2,50

NOTE 1 Dimensions are given as examples for comparative purposes only, and in particular the maximum discharge are not to be considered as an absolute upper limit for most of the structures considered.

NOTE 2 Upstream and downstream longitudinal slopes of structure.

NOTE 3 Overflow cross-section side slope i.e. 1:m.

Table 3 *(continued)*

Structure	*p*	*b*	*m*	*L*	Stage/ Static head		Discharge	
	m	m	(slope)	m	m		m^3s^{-1}	
					min	max	min	max
Other								
Vertical underflow gate (free flowing i.e. critical depth occurs) with gate open 0,5 m	0,0 0,0	1 5			0,75 0,75	2,0 2,0	0,95 4,79	1,82 9,08
End-depth method a) rectangular b) non-rectangular – v shaped	0,0 0,0	1,0	0,5[3]		0,05 0,05	0,50 0,30	0,06 0,001	1,90 0,101
Larinier fish pass Minimum stage for fish passage = 0,18 m	0,15 0,5	0,6 6,0	— —	— —	0,03 0,03	0,90 0,90	0,005 0,051	1,22 10,40

NOTE 1 Dimensions are given as examples for comparative purposes only, and in particular the maximum discharge are not to be considered as an absolute upper limit for most of the structures considered.

NOTE 2 Upstream and downstream longitudinal slopes of structure.

NOTE 3 Overflow cross-section side slope i.e. 1:m.

6.4 Accuracy to which the flow is to be measured

In general, for the best overall accuracy over a wide range of small discharges, a thin-plate V-notch weir should be used in preference to a thin-plate rectangular notch or rectangular full-width weir. For a wide range of larger discharges, a trapezoidal flume, a flat-V weir or a triangular-profile weir should be used in preference to a broad-crested weir, free overfall or rectangular-throated flume.

6.5 Consideration of afflux and potential for submergence

When a structure is introduced to a channel, an increase in the level immediately upstream is created. This is called “afflux”. This can have a number of impacts on the upstream channel and its environment, including:

— an increase in the likelihood of flooding and a reduction in the efficiency of local drainage problems;

— limitations on the effectiveness of nearby artificial installations such as irrigation systems;

— an adverse change to the aquatic habitat upstream of the structure due to the abnormal inundation.

To combat this, a number of structures have been developed to reduce the afflux. These have high coefficients of discharge, and their accuracy is relatively unimpaired by high submergence ratios. The triangular-profile and flat-V weirs, and certain flumes, are examples of this type of structure.

However, if a structure is located at a point where downstream water levels can potentially cause submergence (or drowning) of the structure, consideration should be made as to whether the downstream level needs to be recorded to enable a drowned flow reduction factor to be calculated. This can be in the form of a second tapping point to measure level in the downstream channel or at the crest of the structure.

6.6 Size and nature of channel

The shape and size of the channel have a bearing on the practicality of selecting any particular type of structure. The material forming the bed and sides of the channel influences the acceptable head loss through the structure without introducing appreciable leakage through the bed and banks. It also determines the degree of protection necessary to alleviate scour downstream of the structure.

Most if not all structures operate better if the upstream approach channel is straight for up to 10 channel widths. This ensures that the approach flow to the structure is uniform, tranquil and aligned correctly.

6.7 Channel slope and sediment load

For flows with high suspended loads, the use of thin-plate weirs should be avoided because the crest edge might be damaged or worn by the suspended materials. In addition, the rating of weirs can be affected by deposition and scour of sediment in the approach section to the weir. In streams with bed load, the use of structures that significantly reduce the stream velocity is not recommended, as it can result in fluctuations of the bed level as the flow varies. Flumes generally perform better than weirs in streams with sediment load.

For channel gradients of less than 0,1 % and Froude numbers less than 0,25, there is no restriction on the type of structure.

For channel gradients of between 0,1 % and 0,4 % and Froude numbers between 0,25 and 0,5, flumes have an advantage over weirs with regard to the transport of sediment.

For channel gradients of greater than 0,4 % and Froude numbers greater than 0,5, standard weirs and flumes are not usually suitable, unless there is no transport of sediment.

6.8 Operation, maintenance and repair

The accuracy of any device is very dependent upon the degree of maintenance it receives. However, some devices, such as flumes, are particularly susceptible to errors of calibration due to algal growths in the throat.

Triangular and flat-V weirs are also susceptible to algal growth. Algal preventatives can be used, but this needs care to avoid environmental damage and advice should be sought from the local environment protection agency. The achievement of ultra-smooth finishes to the weir crest is in itself the most effective way to minimize algal growth and reduce the corresponding need for maintenance. Nevertheless, an important feature of weirs and flumes that are likely to suffer from excess algal growth is a by-pass channel that allows the entire flume to be by-passed at low flows. This allows the structure to be cleaned in a thorough and safe manner. Hence, the design of the structure should incorporate this feature.

When structures operate at temperatures below freezing point, account should also be taken of the effect of the accumulation of ice on the calibration. In general, weirs, and thin-plate weirs in particular, are less affected by ice than flumes. In some cases, the problem of calibration errors can be overcome by heating the air space over a structure.

The calibration of thin-plate weirs can be affected by damage to the crest and corners, and failure to clean the upstream face where algal growths may occur. These growths introduce errors into the calibration. The choice of structure, therefore, is influenced by the regularity with which maintenance can be carried out. It should be determined at an early stage in the planning of such an installation what resources will be allocated to routine but vital activity.

The accretion of larger scale debris also affects the calibration of a structure. Broad-crested weirs, triangular-profile weirs, long-throated flumes and free overfall structures normally pass floating debris more effectively than thin-plate weirs. Therefore, the use of the thin-plate V-notch weir, in particular, should be avoided unless a debris trap is installed upstream. Nevertheless, the removal of larger scale debris should be undertaken as a routine task on many watercourses. This might require the inclusion of heavy lifting equipment to remove large items such as tree branches that have been washed downstream during times of flood.

6.9 Passage of fish

The migration of fish upstream for spawning can be restricted if a structure fails to make proper provision for their passage. This is not permitted under environmental legislation in many countries. For this reason, it may be more acceptable to measure the flow by the velocity area method. Nevertheless, if a flow measuring structure is deemed to be the best solution, the factors that affect fish migration beyond a flow measuring structure should be taken into account. These principal factors are:

— the afflux created by the structure;

— its overall length;

— the depth of water below the structure;

— the depth of water through its critical section;

— the maximum flow velocity over the measuring structure.

More specifically:

a) for thin-plate or broad-crested weirs, there should be a sufficient depth of water in the downstream section from which the fish can launch themselves to clear the weir;

b) flumes obstruct fish passage to a lesser extent, but similar requirements exist, for example, there should be adequate water depth and suitable water velocity within the flume;

c) triangular profile weirs can form a serious obstruction, particularly where energy dissipation is incorporated in the stilling basin.

   An advantage of the flat-V weir over a horizontal crested triangular-profile weir is that it can be designed to minimize this obstruction by concentrating the flow in the appropriate flow range. This gives a relatively greater depth of flow over a section of the crest for a given discharge.

Larinier fish passes are prone to catching debris Where a Larinier fish pass is set in a bypass channel, consideration should be given to controlling debris ingress into the channel by means of a trash defector or floating trash boom.

Extensive development of fish passes has been undertaken since 2000 to devise acceptable fish passes on many styles of weir. The results of this work should be taken into account when a weir is being designed, or when the retro-fitting of a fish pass is required.

6.10 Whole life cost

The financial benefit of the information captured by the flow measuring structure, plus the added value gained by improved data accuracy should be set against the cost of the structure. This has a direct bearing on the relative investment costs of the different options. The capital cost of the construction plus the long-term revenue implications of maintenance should also be taken into account. For example, where a licensed abstraction is being managed, there is a legislative driver to remain compliant with the terms of the abstraction licence. Otherwise, a financial penalty might be imposed on the licensee. In this instance, the cost of non-compliance might justify the installation of a flow measuring structure. However, in the wider sense, the information from the structure can help improve the efficiency or output of a process the abstraction is supporting. This might be the irrigation of farmed crops over several years. In other words, the whole life cost of the structure should be offset against the improvement in accuracy and operational efficiency gained by its use.

7 Recommendations

7.1 Thin-plate weirs

7.1.1 General

Thin-plate weirs are dependent on the full development of the contraction below the nappe but are relatively inexpensive to construct, although the manufacture of the crest requires particular care. Aeration of the nappe is required, by vents if necessary. Also, the downstream water level should not be allowed to interfere with this aeration process, and this can limit their applicability. They are recommended where high accuracy is required. They are particularly suitable for laboratory work, use in artificial channels and other circumstances where good maintenance can be ensured and there is little risk of damage to, or deterioration of, the crest. Particular applications include the gauging of compensation flows, flow measurement in water supply pumping tests and flow measurement in many industrial situations. Thin-plate weirs of both rectangular and V-notch types are well suited for temporary installations, but if the site of the temporary weir is not ideal, such as an inadequate length of approach channel, upstream baffles might be required in the approach channel to correctly align the flow.

7.1.2 Rectangular weirs

These weirs may be full width or partially or fully contracted depending on the range of flow to be measured. The fully contracted weir has the advantage of having automatic aeration and may be installed, subject to certain conditions, in non-rectangular channels.

7.1.3 V-notch weirs

Thin-plate V-notch weirs have greater sensitivity in terms of flow measurement and are particularly suitable where the ratio of high to low flow is large and where the accuracy at low flow is important. They also have the advantage that the aeration of the nappe occurs automatically.

7.2 Broad-crested weirs

7.2.1 General

Broad-crested weirs are relatively inexpensive to construct and are robust, and thus insensitive to minor damage. They are best used in rectangular channels where regular maintenance permits clearance of any deposition upstream and of algae from the crest. These structures would normally have a fixed crest for flow measurement but if used to regulate and measure flow, as is the case for irrigation applications, a mechanically movable crest can be provided.

7.2.2 Round-nose weirs

Round-nose broad-crested weirs have a good discharge range and submergence ratio, and are appropriate for use in smaller and medium-size installations.

7.2.3 Rectangular horizontal weirs

Rectangular horizontal weirs are simple to construct and have applications in both laboratory and field conditions. There are strict limitations on geometry if accurate flow measurement is required.

7.2.4 V-shaped weirs

V-shaped broad-crested weirs are suitable for flow measurement over a large discharge range. As they remain modular up to a submergence ratio of 80 %, they are particularly suitable for watercourses with little available fall.

7.2.5 Trapezoidal-profile weirs

The trapezoidal-profile weir is of simple geometry and may be used in a both modular and drowned-flow range. Despite the simplicity of the geometry, care is needed during construction to ensure that the finished structure accurately reflects the desired design.

7.3 Triangular-profile weirs

7.3.1 General

Triangular-profile weirs are particularly appropriate for the measurement of flow in natural watercourses where minimum head losses are sought or where afflux is to be minimized, and where relatively high accuracy is required. They have a good discharge range and modular limit, they are robust, they are insensitive to minor damage and they operate even when the flow is silt-laden.

The triangular-profile weir has a constant coefficient of discharge over a wide range of level. The weir can also be used under submerged or non-modular flow conditions, although measurement accuracy is reduced in these circumstances. To measure the flow in these situations, a second head measurement is necessary to derive a changed coefficient of discharge, and this can be achieved by means of a tapping point at the crest or at a specific point downstream of the crest. A crest tapping is the more difficult to construct, and accurate pre-cast concrete sections are required if satisfactory results are to be achieved.

Despite the lower accuracy obtained in these situations, overall, a wide range of flows and water depths can be accommodated by these weirs.

7.3.2 Streamlined triangular-profile weirs

Most of the comments regarding triangular-profile weirs also apply to the streamlined structures. For drowned flow operation, a separate downstream gauge should be used rather than a crest tapping, which is required for the triangular-profile. A crest tapping is, however, more difficult to construct and accurate pre-cast sections are necessary if satisfactory results are to be achieved.

7.3.3 Flat-V weirs

Flat-V weirs are extremely sensitive and are recommended in situations where low flows are to be measured with greater accuracy than if a horizontal crest were to be used. Flat-V weirs are relatively expensive structures, particularly if erosion is liable to occur downstream, and protective works are required. If, however, high accuracy is required and instrumentation giving continuous records is installed, the additional costs are marginal compared to those of other flow gauging structures.

7.4 Flumes

7.4.1 General

Flumes are recommended where material is being transported along the channel, particularly where there is bed movement. Protective works downstream of the throat to contain the hydraulic jump are easily incorporated into the main structure. In general, flumes are calibrated theoretically or on site by current meter gauging. Therefore, the accuracy of measurement by these structures is less than that for weirs.

7.4.2 Rectangular flumes

The dimensions of rectangular flumes are easily adapted to the size of the channel. Such flumes readily fit into rectangular channels and are almost universally used in measuring the inflow to sewage treatment works. They are suitable where the afflux needs to be kept to a minimum.

7.4.3 Trapezoidal flumes

Trapezoidal flumes are used for purposes similar to those employing rectangular flumes, but are particularly recommended if it is necessary to accommodate the gauging station in a trapezoidal channel and skilled labour is available for the construction work. They are suitable where relatively high accuracy is required over a wide range of flows.

7.4.4 U-throated flumes

U-throated flumes are well suited to the measurement of flows in sewers and other conduits running partly full. However, due to their specific cross-sectional shape, construction is more complicated and thereby more expensive than a simpler rectangular flume.

7.4.5 Parshall and SANIIRI flumes

These flumes are designed to operate under both free-flow and submerged conditions, and can be used in open channels and irrigation canals when there are steady, slowly or gradually varying flows. The criteria for considering the selection of either of these flumes are given in ISO 9826:1992, Clause 4.

NOTE The Parshall flume was popular in the USA, but construction of new flumes of this type is now discouraged.

7.4.6 End-depth method

The method, utilizing existing falls, is convenient for approximate measurement where accuracy is not of paramount importance. The method demands a free fall from the end of a pipe or culvert and may be rectangular or non-rectangular in section.

7.5 Compound gauging structures

Compound structures have many of the characteristics of flat-V weirs. They can be designed to give high sensitivity at low flows by introducing one or more relatively narrow low-level sections, and high afflux at high flows can be avoided by introducing wide high-level sections. The versatility of compound weirs is further enhanced by the permitted use of different types of weirs or flumes and fish passes for the individual sections within the compound structure.

7.6 Vertical underflow gates and radial gates

Vertical underflow gates and radial gates can be operated with variable openings and hence can be used to measure a range of flows within a relatively narrow band of upstream water levels. The accuracy of this type of device is less than that of conventional overflow structures.

7.7 Larinier fish passes

Can be used where existing flow measurement structures are required to be modified for fish passage, or at new locations where fish passage is a prerequisite.

8 Parameters governing choice of structures

Tables 1 and 2 set out the broad parameters, which may be taken into account when making an informed choice of a structure. Limitations and values of coefficients are set out in the appropriate International Standard, to which reference should be made for detailed design purposes.

Table 4 provides a complete list of the set of flow measuring structures cross-referenced to the International Standard that relates to their specification. It should be used in conjunction with Figure 1 to get a broad understanding of the recommended use of each type of structure. Figure 1 also covers the steps in the decision process for the selection of flow measuring structures, taking into account the following:

— the functional requirements of the structure;

— the field of application;

— the presence of high sediment content in the water course;

— the range of flow to be measured.

In addition, a number of non-technical aspects, such as familiarity with the structure, sensitivity to alterations by unauthorized people and costs, will play a part in the choice of the structure.

Table 4 — Complete set of International Standards on structures

International Standard	Type of structure
ISO 1438	Thin-plate weirs
ISO 3846	Rectangular broad-crested weirs
ISO 4359	Rectangular, trapezoidal and U-shaped flumes
ISO 4360	Triangular-profile weirs
ISO 4362	Trapezoidal broad-crested weirs
ISO 4374	Round-nose horizontal broad-crested weirs
ISO 4377	Flat-V weirs
ISO 8333	V-shaped broad-crested weirs
ISO 9826	Parshall and SANIIRI flumes
ISO 9827	Streamlined triangular-profile weirs
ISO 13550	Vertical underflow gates.
ISO 14139	Compound gauging structures
ISO 18481	End depth methods in channels with free overfall.
ISO 26906	Hydrometry – fish passes at flow measuring structures

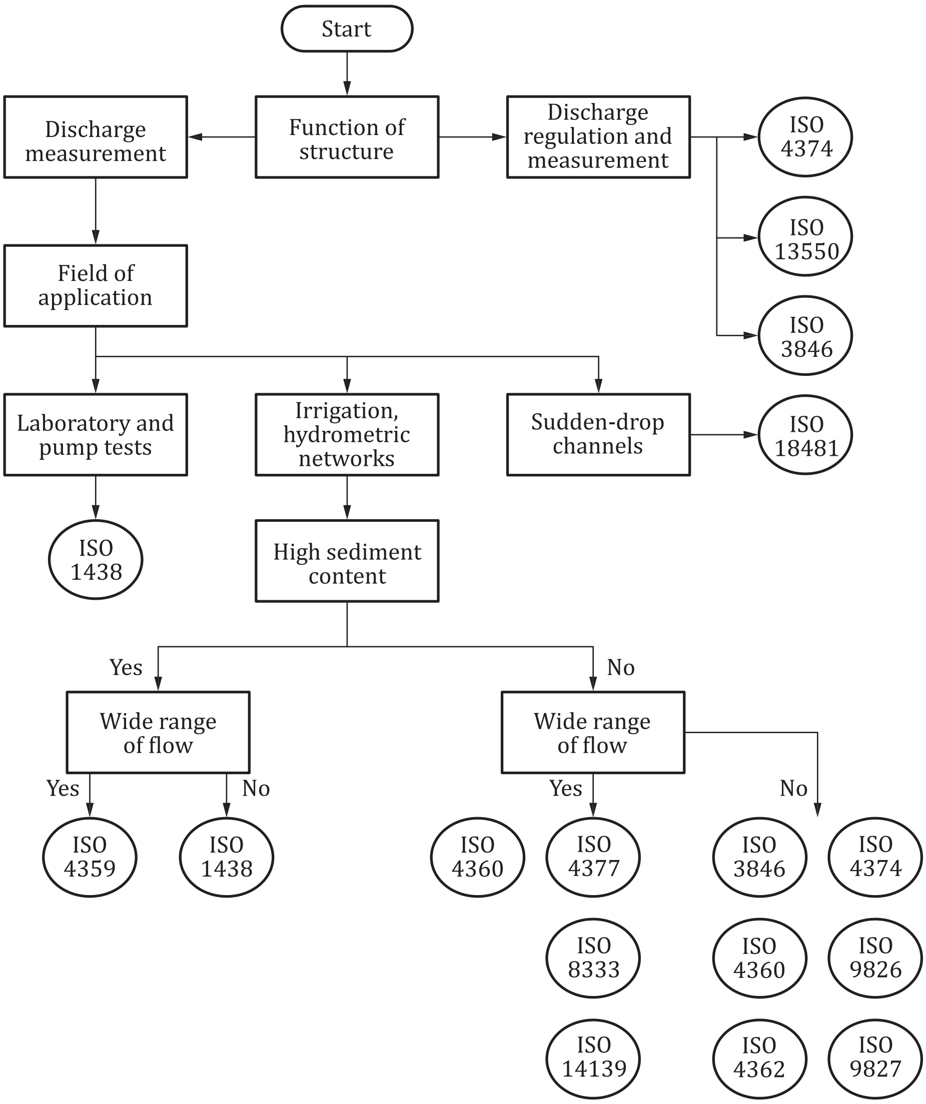


Figure 1 — Flow chart for the selection of structures

Bibliography

[1] ISO/IEC Guide 98-3, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

[2] ISO 1438, *Hydrometry — Open channel flow measurement using thin-plate weirs*

[3] ISO 3846, *Hydrometry — Open channel flow measurement using rectangular broad-crested weirs*

[4] ISO 4359, *Flow measurement structures — Rectangular, trapezoidal and U-shaped flumes*

[5] ISO 4360, *Hydrometry — Open channel flow measurement using triangular profile weirs*

[6] ISO 4362, *Hydrometric determinations — Flow measurement in open channels using structures — Trapezoidal broad-crested weirs*

[7] ISO 4374, *Liquid flow measurement in open channels — Round-nose horizontal broad-crested weirs*

[8] ISO 4377, *Hydrometric determinations — Flow measurement in open channels using structures — Flat-V weirs*

[9] ISO 8333, *Liquid flow measurement in open channels by weirs and flumes — V-shaped broad-crested weirs*

[10] ISO 9826:1992, *Measurement of liquid flow in open channels — Parshall and SANIIRI flumes*

[11] ISO 9827, *Measurement of liquid flow in open channels by weirs and flumes — Streamlined triangular profile weirs*

[12] ISO 13550, *Hydrometric determinations — Flow measurements in open channels using structures — Use of vertical underflow gates and radial gates*

[13] ISO 14139, *Hydrometric determinations — Flow measurements in open channels using structures — Compound gauging structures*

[14] ISO 18481, *Hydrometry — Liquid flow measurement using end depth method in channels with a free overfall*

[15] ISO/TS 25377, *Hydrometric uncertainty guidance (HUG)*

[16] ISO 26906, *Hydrometry — Fishpasses at flow measurement structures*

(*Continued from second cover*)

For the purpose of deciding whether a particular requirement of this standard is complied with the final value, observed or calculated expressing the result of a test or analysis shall be rounded off in accordance with IS 2 : 2022 'Rules for rounding off numerical values (*second revision*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

This Indian Standard has been developed from Doc No.: WRD 01 (21548).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110002
Telephones: 2323 0131, 2323 3375, 2323 9402 *Website*: www.bis.gov.in

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