INTERNATIONAL STANDARD

ISO 8368

Third edition
2019-11

Hydrometric determinations — Flow measurements in open channels using structures — Guidelines for selection of structure

Déterminations hydrométriques — Mesure de débit dans les canaux découverts au moyen de structures — Lignes directrices pour le choix des structures

Reference number
ISO 8368:2019(E)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Page

Foreword ... **v**
Introduction ... **vi**
1 Scope ... **1**
2 Normative references ... **1**
3 Terms and definitions ... **1**
4 Symbols ... **1**
5 Types of structure ... **2**
5.1 General ... 2
5.2 Thin-plate weirs ... 3
5.3 Broad-crested weirs ... 3
5.4 Triangular-profile weirs ... 3
5.4.1 General ... 3
5.4.2 Streamlined triangular-profile weirs ... 4
5.4.3 Flat-V weirs ... 4
5.5 Trapezoidal-profile weirs ... 4
5.6 Flumes ... 4
5.7 End-depth method ... 4
5.8 Vertical underflow gates and radial gates ... 5
5.9 Compound gauging structures ... 5
5.10 Fish passes ... 5
6 Factors affecting choice ... **5**
6.1 General ... 5
6.2 Intended purpose of the structure ... 6
6.3 Range of flow to be measured ... 14
6.4 Accuracy to which the flow is to be measured ... 15
6.5 Consideration of afflux and potential for submergence ... 15
6.6 Size and nature of channel ... 15
6.7 Channel slope and sediment load ... 16
6.8 Operation, maintenance and repair ... 16
6.9 Passage of fish ... 17
6.10 Whole life cost ... 17
7 Recommendations ... **18**
7.1 Thin-plate weirs ... 18
7.1.1 General ... 18
7.1.2 Rectangular weirs ... 18
7.1.3 V-notch weirs ... 18
7.2 Broad-crested weirs ... 18
7.2.1 General ... 18
7.2.2 Round-nose weirs ... 18
7.2.3 Rectangular horizontal weirs ... 18
7.2.4 V-shaped weirs ... 18
7.2.5 Trapezoidal-profile weirs ... 19
7.3 Triangular-profile weirs ... 19
7.3.1 General ... 19
7.3.2 Streamlined triangular-profile weirs ... 19
7.3.3 Flat-V weirs ... 19
7.4 Flumes ... 19
7.4.1 General ... 19
7.4.2 Rectangular flumes ... 19
7.4.3 Trapezoidal flumes ... 20
7.4.4 U-throated flumes ... 20
7.4.5 Parshall and SANIIRI flumes ... 20

7.4.6 End-depth method ... 20
7.5 Compound gauging structures ... 20
7.6 Vertical underflow gates and radial gates ... 20
7.7 Larinier fish passes ... 20
8 Parameters governing choice of structures ... 20
Bibliography ... 23

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 113, *Hydrometry*, Subcommittee SC 2, *Flow measurement structures*.

This third edition cancels and replaces the second edition (ISO 8368:1999), which has been technically revised.

The main changes from the previous edition are:

— the list of types of structure included in the text has been reviewed and the details of any structure that is no longer recommended for use have been removed;

— the technical details of all structures included in the text have been reviewed and updated where necessary;

— greater detail has been given to the considerations needed when evaluating the whole life cost of a structure;

— greater detail has also been given to the considerations needed when evaluating the impact of a structure on the environment, and the natural processes occurring in the channel.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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.

Hydrometric determinations — Flow measurements in open channels using structures — Guidelines for selection of structure

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.