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Hydrometric determinations — Flow measurements in open channels using structures — Compound gauging structures

Déterminations hydrométriques — Mesure de débit des liquides dans les canaux découverts au moyen de structures — Structures de jaugeage hybrides

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 14139 was prepared by Technical Committee ISO/TC 113, *Hydrometric determinations*, Subcommittee SC 2, *Notches, weirs and flumes*.

Annexes A to C form a normative part of this International Standard.

Hydrometric determinations — Flow measurements in open channels using structures — Compound gauging structures

1 Scope

This International Standard specifies the methods of measurement of flow in rivers and artificial channels, using any combination of standard weirs and/or flumes in a compound structure. For guidance on the selection of weirs and/or flumes, refer to ISO 8368. All structures can be operated in the modular flow range, but only a limited number of structures can be used in the drowned (non-modular) flow range (see clause 4). Compound weirs improve the quality of discharge measurements at low stages.

The characteristics of velocity distribution are described annex A.

Structures standardized for operation in the drowned (non-modular) flow range and the method of computation of flow are described in annex B.

Methods and examples of flow measurement calculations are given in annex C.

Compound flow-measuring structures without divide piers need in situ or model calibrations and are not covered by this International Standard.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 772:1996, *Hydrometric determinations — Vocabulary and symbols.*

ISO 1438-1:1980, *Water flow measurement in open channels using weirs and Venturi flumes — Part 1: Thin-plate weirs.*

ISO 3846:1989, *Liquid flow measurement in open channels by weirs and flumes — Rectangular broad-crested weirs.*

ISO 4359:1983, *Liquid flow measurement in open channels — Rectangular, trapezoidal and U-shaped flumes.*

ISO 4360:1984, *Liquid flow measurement in open channels by weirs and flumes — Triangular profile weirs.*

ISO 4362:1999, *Hydrometric determinations — Flow measurement in open channels using structures — Trapezoidal broad-crested weirs.*

ISO 4374:1990, *Liquid flow measurement in open channels — Round-nose horizontal broad-crested weirs.*

ISO 4377:1990, *Liquid flow measurement in open channels — Flat-V weirs.*

ISO/TR 5168:1998, *Measurement of fluid flow — Evaluation of uncertainties.*

ISO 8333:1985, *Liquid flow measurement in open channels by weirs and flumes — V-shaped broad-crested weirs.*

ISO 8368:1999, *Hydrometric determinations — Flow measurements in open channels using structures — Guidelines for selection of structure.*

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

ISO 9827:1994, *Measurement of liquid flow in open channels by weirs and flumes — Streamlined triangular profile weirs.*

3 Terms, definitions and symbols

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

Symbol		Units of measurement
A	area of cross-section of flow	m^2
b	crest width	m
B	width of approach channel	m
C_D	coefficient of discharge	non-dimensional
C_{dr}	drowned-flow reduction factor	non-dimensional
C_v	coefficient of approach velocity	non-dimensional
e	uncertainty in absolute magnitude	non-dimensional
g	acceleration due to gravity	m/s^2
h	gauged head	m
H	total head	m
h_p	crest-tapping pressure head	m
h_v	velocity approach head	m
L	length of flume throat or weir crest in direction of flow	m
n	number of measurements in a set	non-dimensional
p	height of flume invert or weir crest above mean bed level	m
Q	total discharge	m^3/s
Q_1, Q_2, Q_3	individual section discharges (in general Q_n)	m^3/s
Q_{mod}	total modular discharge	m^3/s
q	discharge per unit width	m^3/s
s_y	standard deviation of a set of measurements of quantity y	m
$s_{\bar{y}}$	estimated standard deviation of the mean of several readings of quantity y	m
$\bar{v}$	mean velocity at cross-section	m/s
$\bar{v}_a$	mean velocity in approach channel	m/s
X_Q	percentage uncertainty in total discharge	non-dimensional

$X_{Q,1}$, $X_{Q,2}$, $X_{Q,3}$ [1)]	percentage uncertainty in individual section discharges	non-dimensional
X_{tu}	percentage uncertainty in estimating upstream water levels or upstream total head levels	non-dimensional
X_{td}	percentage uncertainty in estimating downstream water levels or downstream total head levels	non-dimensional
X_y	percentage uncertainty in quantity y	non-dimensional
α	Coriolis energy coefficient	non-dimensional
Δ	difference in weir-crest levels	m
δ	boundary layer displacement thickness	m

Suffixes

1	denotes upstream value
2	denotes downstream value

Superscripts

G	refers to gauging section
T	refers to crest-tapping section
S	refers to any other section

4 Characteristics of compound gauging structures

A compound gauging structure as covered by this International Standard comprises two or more individual structures, operated in parallel and separated by divide piers.

The individual structures, which can be used in a compound gauging weir, are specified in ISO 1438-1, ISO 3846, ISO 4359, ISO 4360, ISO 4362, ISO 4374, ISO 4377, ISO 8333, ISO 9826 and ISO 9827. The structures described in ISO 4360, ISO 4362, ISO 4377, ISO 8333, ISO 9826 and ISO 9827 may be used in the drowned flow range (see annex B.1).

In the modular flow range, discharges depend solely on upstream water levels, and a single measurement of upstream head is required. In the drowned flow range, discharges depend on both upstream and downstream water levels, and two independent head measurements are required. These are:

a) the upstream head; and either

b) the head measured in the crest-tapping for a triangular profile weir (two dimensional or flat-V forms);

c) the head measured within the throat of a Parshall flume; or

d) the head measured in the tailwater for the other structures.

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1) In cases where the subscript of a symbol also contains a subscript, it is house style to write the second subscript on the same line, after a comma.

Thus X_{Q_1} is written $X_{Q,1}$.

The flow conditions considered are limited to steady or slowly changing flows. The essentially parallel flow through the compound structure is ensured by the use of divide piers. The flow is separated by the divide piers into each individual weir or flume. The discharge can be determined through each individual section by a single upstream head measurement, at one section only, in the case of modular flow or by two independent head measurements, at one section only, as required for drowned flow conditions. The summation of the discharges through each of the sections provides the measurement of total flow within the channel.

5 Installation

5.1 Selection of site

A preliminary survey shall be made of the physical and hydraulic features of the proposed site to check that it conforms (or may be made to conform) to the requirements necessary for measurement using the weir.

Particular attention shall be paid to the following features in selecting the site of the weir:

a) the availability of an adequate length of channel of regular cross-section;

b) the existing velocity distribution;

c) the avoidance of channels having gradients greater than 0,4 %;

d) the effects of any increased upstream water level due to the flow-measuring structure;

e) the conditions downstream, including such influences as tides, confluence with other streams, sluice-gates, mill dams and other controlling features that 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 sealing in river installations;

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 clearance of rocks or boulders from the bed of the approach channel;

j) the effects of wind.

NOTE 1 Wind can have a considerable effect on the flow in a river or over a weir, especially if these latter are wide and the head is small and the prevailing wind is in a transverse direction.

If the site does not possess the characteristics required for satisfactory measurements, it shall be rejected unless suitable improvements are practicable.

If a survey of a stream shows that the existing velocity distribution is regular, then it should be assumed that the velocity distribution will remain satisfactory after the weir has been built.

If the existing velocity distribution is irregular and no other site for a gauge is feasible, due consideration shall be given to checking the distribution after the weir has been installed and to improving it, if necessary.

NOTE 2 Several methods are available for obtaining more precise indications of irregular velocity distribution: velocity rods, floats or concentrations of dye can be used in small channels, the latter being useful in checking conditions at the bottom of the channel. A complete and quantitative assessment of velocity distribution may be made by means of a current meter.

NOTE 3 After installation, the velocity profiles will always be improved by the increased depth of water approaching the compound weir.

5.2 Installation conditions

5.2.1 General

The complete measuring installation consists of an approach channel, a flow-measuring structure and a downstream channel. The parameters of each of these three components affect the overall accuracy of the measurements.

Installation requirements include such features as weir finish, the cross-sectional shape of the channel, channel roughness and the influence of control devices upstream or downstream of the gauging structure.

The distribution and direction of velocity have an important influence on the performance of a weir, these factors being determined by the features mentioned in this subclause.

5.2.2 Approach channel

For all installations, the flow in the approach channel shall be smooth, free from disturbance and shall have a velocity distribution as normal as possible over the cross-sectional area (see annex A); this can usually be verified by inspection or measurement. In the case of natural streams or rivers, this flow can only be attained by having a long, straight approach channel free from projections into the flow. Unless otherwise specified in the appropriate clauses of this International Standard, the approach channel shall comply with the general requirements outlined in this subclause.

The altered flow conditions due to the construction of the weir may have the effect of building up shoals of debris upstream of the structure, which in time may affect the flow conditions. The likely consequential changes in the water level should be taken into account in the design of gauging stations.

In an artificial channel, the cross-section shall be uniform and the channel shall be straight for a length equal to at least five times its width, and more if attainable.

In a natural stream or river, the cross-section shall be reasonably uniform and the channel shall be straight for such a length as to ensure regular velocity distribution.

If the entry to the approach channel is through a bend or if the flow is discharged into the channel through a conduit of smaller cross-section or at an angle, then a longer length of straight approach channel is required to achieve a regular velocity distribution.

Baffles shall not be installed closer to the points of measurement than five times the maximum head to be measured.

Under certain conditions, a standing wave may occur upstream of the gauging device, for example if the approach channel is steep. Provided this wave is at a distance of no less than 30 times the maximum head upstream, flow measurement is feasible, subject to confirmation that a regular velocity distribution exists at the gauging station.

If a standing wave occurs within this distance, the approach conditions and/or gauging device shall be modified.

Means of ensuring that the baffles are at all times free of debris both on and below the water surface should be provided.

5.2.3 Flow-measuring structure

The structure shall be rigid, watertight and capable of withstanding flow conditions without distortion or fracture. It shall be at right angles to the direction of flow and shall have the dimensions specified in the relevant International Standard(s) for the type of flow-measuring structure(s) chosen.

For the purposes of this International Standard, a compound flow-measuring structure consists of a series of individual weirs or flumes, which are disposed across the width of an open channel. The individual sections of the compound structure shall be separated by divide piers such that each section can be treated as a simple weir or flume, thus minimizing three-dimensional flow conditions. The computation of discharge for individual sections can therefore be based on established discharge equations (see the references in annex B).

The divide piers that separate individual sections of the compound structure shall be at least 0,3 m thick to avoid sharp curvatures at their upstream noses (cutwaters), which can be semi-circular or semi-elliptical.

To minimize cross flows at the cutwaters of the divide piers and subsequent flow separation, the difference in levels between adjacent crests (weirs) or inverts (flumes) shall not exceed 0,5 m.

NOTE 1 Flow conditions at and near the cutwaters of the divide piers will be improved if the upstream bed levels bear a similar relationship to crest or invert levels at each individual section of the compound structure (see Figure B.1). This minimizes the variations in velocity across the width of the approach channel.

The compound flow-measuring structure shall be capable of withstanding flood flow conditions without damage from outflanking or from downstream erosion. The structure and the immediate approach channel can be constructed of concrete with a smooth cement finish or surfaced with a smooth non-corrodible material.

NOTE 2 In laboratory installations, the finish should be equivalent to rolled sheet metal or planed, sanded and painted timber.

The surface finish is particularly important near the crest or throat invert, but can be relaxed a distance along the profile of 0,5 H_{max} upstream and downstream of the crest or throat. Details of tolerances for the finish and alignment of individual weirs or flumes are given in the appropriate International Standard.

A typical design for a compound flow-measuring structure is shown in Figure B.1.

NOTE 3 The lengths of the divide piers are not crucial but they should extend preferably from the upstream recording section to the downstream limit of individual weirs or flumes.

The height of the divide piers should normally be the same as that of the vertical side walls. If less, then errors will arise in the computation of discharge when water levels exceed the height of the divide piers. These errors will depend on the dimensions of the compound structure and the actual height of the divide piers.

5.2.4 Downstream conditions

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

When making these calculations or observations particular care shall be taken to ensure that influences that may be periodic or seasonal such as tides shall be taken into account.

NOTE Confluences with other streams, sluice-gates, mill dams and other features such as weed growth may also influence tailwater levels.

If the downstream channel is erodible, the extent of protective works necessary to dissipate the additional energy generated by the raised water level upstream of the structure shall be taken into account in the assessment of the site.

6 Maintenance

Maintenance of the flow-measuring structure and the approach channel is important to ensure accurate continuous measurements.

It is essential that the approach channel to weirs be kept clean and free from silt and vegetation as far as practicable, and for at least the distance specified in 5.2.2. The stilling 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 crest.

NOTE The presence of divide piers between weir sections will inevitably increase maintenance requirements for the structure, particularly if floating debris is prevalent.

7 Measurement of head

7.1 General

The head upstream of the flow-measuring structure may be measured by a hook-gauge, point-gauge or staff-gauge where spot measurements are required, or by a recording-gauge where a continuous record is required; in many cases it is necessary to measure head in a separate stilling well, in particular to measure the crest-tapping head. Stilling wells also eliminate surface turbulence which is necessary for tailwater head measurement.

The discharges given by the working equation in the appropriate standard for the particular structure are volumetric figures, and the liquid density does not affect the volumetric discharge for a given head provided that the operative head is gauged in liquid of identical density. If the gauging is carried out in a separate well, a correction for the difference in density may be necessary if the temperature in the well is significantly different from that of the flowing liquid. However, it is assumed in this International Standard that the densities are equal.

7.2 Stilling well

It is usual to measure the upstream head in a stilling well to reduce the effects of water surface irregularities.

NOTE 1 When this is done, it is also desirable to measure the head in the approach channel periodically.

Where the structure is designed to operate in the drowned flow range a gauge well is required to measure the downstream head as follows:

— for triangular profile weirs the piezometric head developed within the separation pocket immediately downstream of the crest;

— for the other weirs the downstream water level in the downstream channel section according to the appropriate standard.

The gauge well shall be vertical and of sufficient height and depth to cover the full range of water levels and shall have a minimum height of 0,6 m above the maximum water level expected. The gauge well shall be connected to the appropriate head measurement position by means of a pipe or a slot.

Both the well and the connecting pipe 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 and beneath the float at all stages. The float shall be no nearer than 0,075 m to the wall of the well.

The pipe shall have its invert no less than 0,06 m below the lowest level to be gauged.

The pipe connection to the upstream head measurement position shall terminate flush with the boundary of the approach channel and preferably 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 from the centreline of the connection. A pipe that is oblique to the wall is acceptable only if it is fitted with a removable cap or plate, and set flush with the wall, through which a number of holes are drilled. The edges of these holes shall not be rounded or burred.

Where the individual section of the compound structure is a two-dimensional triangular profile weir the pipe connection to the head measurement position for the separation pocket head shall be as given in ISO 4360.

Where the individual section of the compound structure is a flat-V weir, the pipe connection to the head measurement position for the separation pocket head shall be as given in ISO 4377.

Adequate additional depth shall be provided in the well to avoid the danger of floats grounding either on the bottom or on any accumulation of silt or debris.

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 shall be as small as possible, consistent with ease of maintenance, to damp out oscillations due to short period waves.

NOTE 2 No firm rule can be laid down for determining the size of the connecting pipe, 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 100 mm diameter pipe is usually suitable for a flow measurement in the field, as compared with the 3 mm diameter pipe that is appropriate for precision head measurement with steady flows in the laboratory.

7.3 Zero setting

Accurate initial setting of the zeros of the head measuring devices with reference to the level of the crest, or invert, and regular checking of these settings thereafter, is essential if overall accuracy is to be attained.

A means of checking the zero setting of the head-measuring devices shall be provided, consisting of a datum related to the level of the weir.

A zero check based on the level of the water when the flow ceases is liable to serious errors from surface tension effects and shall not be used.

NOTE As the size of the weir and the head on it reduces, small errors in construction and in the zero setting and reading of the head-measuring device become of greater importance.

7.4 Location of head measurement section(s)

The upstream head shall be measured at any one of the individual sections of the compound structure but preferably at the section with the lowest crest or invert. The tapping shall be in the vertical side wall if the individual section is adjacent to the bank, or in the divide pier if the individual section is mid-stream. In this latter case the divide piers shall extend at least H_{max} upstream of the head measurement position.

The distance of the measurement section from crest or invert is usually expressed as a multiple of the maximum total head with a value appropriate to the individual section of three to four. For precise locations for each type of structure, see the appropriate International Standard.

The presence of divide piers is not considered to have a significant influence, and the position of the head measurement section need only satisfy the requirements noted in this subclause.

If a triangular profile or flat-V weir is used as one of the individual sections of the compound structure, and it is designed to operate in the non-modular (drowned) flow range, then a separate crest tapping and associated gauge well shall be provided (see ISO 4360 and ISO 4377).

8 Computation of discharge

8.1 Modular flow conditions

Modular flow calibrations are based on measurements of upstream water levels. Where a single (non-compound) structure is used, the recorded water level is used directly in the computation of discharge. However, it is not usually economical to measure water levels upstream of each individual section of a compound weir, and hence it is necessary to make assumptions about the relationships between flow conditions at the various sections when calculating the total flow.

Research has shown that the total head level can be assumed constant over the full width of a compound flow-measuring structure and that it can be obtained by adding to the observed water level the velocity head appropriate to the individual section at which the water level is observed. Thus the basis of the method of computing the total discharge over a compound structure is to calculate the total head level at the individual section at which the water level is measured, as if it were a simple non-compound structure, and to use the same value of total head level to calculate individual discharges at other sections. Successive approximation or coefficient of velocity techniques are applied at the section of the structure where the water level is recorded to convert gauged to total heads. Discharge equations in terms of total heads are used at other sections of the compound structure and no conversions are required. An example calculation is given in annex C.

8.2 Non-modular (drowned) flow conditions

When a compound structure is designed to operate in the non-modular flow range, a triangular profile or flat-V weir with a crest tapping shall be used in those sections of the compound weir that are likely to drown. For trapezoidal profile weirs, Parshall flumes, streamlined triangular weirs and V-shaped broad-crested weirs, only one gauge well is required in the downstream channel.

Upstream total heads are determined as for the modular flow case but discharges at those individual sections of the compound structure that are drowned are obtained by considering both the upstream total head and the crest-tapping pressure or downstream water level. An example calculation is given in annex C.

9 Errors in flow measurement

9.1 General

The total uncertainty of any flow measurement can be estimated if the uncertainties from various sources are combined. The assessment of these contributions to the total uncertainty will indicate whether the rate of flow can be measured with sufficient accuracy for the intended purpose. This clause is intended to provide sufficient information for the user of this International Standard to estimate the uncertainties of measurements of discharges.

The error is the difference between the true rate of flow and that calculated in accordance with the equations in the appropriate standard for the particular structure used for calibrating the flow-measuring structure (which is assumed to be constructed and installed in accordance with this International Standard). The term 'uncertainty' is used here to denote the deviation from the true rate of flow within which the measured flow is expected to lie some 19 times out of 20 (with 95 % confidence limits).

9.2 Sources of error

The sources of error in the discharge measurement for each individual section of the compound structure are as given in the errors sections of the International Standards relating to the appropriate type of structure (see B.1). Additional errors arise due to the method used for estimating water levels or total head levels at individual sections, when (as is usual) these are not measured separately at each section. Available evidence is limited, but it suggests that the percentage uncertainty in discharge, X_{tu}, associated with transposing upstream water levels or total head levels is random, with a magnitude within the range of $\pm$ 5 %. In particular cases, more reliable estimates can be made of this value by making field or laboratory observations. For cases involving drowned flow, little information is available about the possible value of X_{td} the additional uncertainty in discharge associated with transposing downstream water levels or total head levels, which is likely to be of the order of $\pm$ 10 %.

9.3 Kinds of error

9.3.1 Errors can be classified as random or systematic, the former affecting the reproducibility (precision) of measurement and the latter affecting its true accuracy.

9.3.2 The standard deviation of a set of n measurements of a quantity, y, under steady conditions can be estimated from the equation:

$$s_y = \left(\frac{\sum_1^n (y_1 - \bar{y})^2}{n-1} \right)^{1/2} \quad (1)$$

where $\bar{y}$ is the arithmetic mean of the n measurements.

The standard deviation of the mean is then given by the equation:

$$s_{\bar{y}} = \frac{s_y}{\sqrt{n}} \quad (2)$$

and the uncertainty of the mean is $2s_{\bar{y}}$ (for 95 % probability)[2]. This uncertainty is the contribution of the observation of y to the total uncertainty.

9.3.3 A measurement can also be subject to systematic error; the mean of very many measured values would thus still differ from the true value of the quantity being measured. An error in setting the zero of a water level gauge to invert level, for example, produces a systematic difference between the true mean measured head and the actual value. As repetition of the measurement does not eliminate systematic errors, the actual value can only be determined by an independent measurement known to be more accurate.

9.4 Errors in coefficient values and errors in measurement

These errors are dealt with in the error clauses of the appropriate International Standards relating to the individual sections of the compound flow-measuring structure (see B.1).

9.5 Combinations of uncertainties to give overall uncertainty in total discharge

9.5.1 For the section at which the upstream water level is measured, the percentage uncertainty $X_{Q,1}$[3] in the section flow Q_1 is calculated by reference to the International Standard appropriate to that type of weir or flume (see B.1).

9.5.2 The percentage uncertainties, $X_{Q,2}$, $X_{Q,3}$ ...., in the section flows, Q_2, Q_3 ...., for other sections are similarly computed, assuming the same uncertainty on water level measurement (not percentage) as in 9.5.1. Uncertainties due to transferring water levels or heads are ignored at this stage of the calculation.

9.5.3 The uncertainty in the total flow, Q, is the weighted mean of the uncertainties for the flows, Q_i, in the individual sections, with the inclusion of terms for the uncertainty of transposing water levels or heads, estimated from the equation:

$$X_Q = \pm \frac{1}{Q} \left[\sum_1^n Q_i \sqrt{\left(X_{Q_i}^2 + X_{\text{tu}}^2 + X_{\text{td}}^2 \right)} \right] \quad (3)$$

9.5.4 If the weir is submerged, then X_{td} is omitted for any sections at which the crest pressure is measured, but included for any other sections. For cases of submergence it does not follow automatically that X_{tu} is to be omitted at sections where the upstream water level are measured. A transfer of upstream heads as well as downstream heads may be involved in assessing crest pressures at such sections.

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2) This factor of 2 assumes that n is large. For $n = 6$ the factor is 2,6, for $n = 8$ it is 2,4, for $n = 10$ it is 2,3, for $n = 15$ it is 2,1.

3) All uncertainties have a plus or minus value.

9.6 Presentation of results

Although it is desirable, and frequently necessary, to list total random and total systematic uncertainties separately, a simpler presentation of results may be required.

For this purpose, random and systematic uncertainties may be combined as described in ISO/TR 5168.

Annex A
(normative)

Velocity distribution

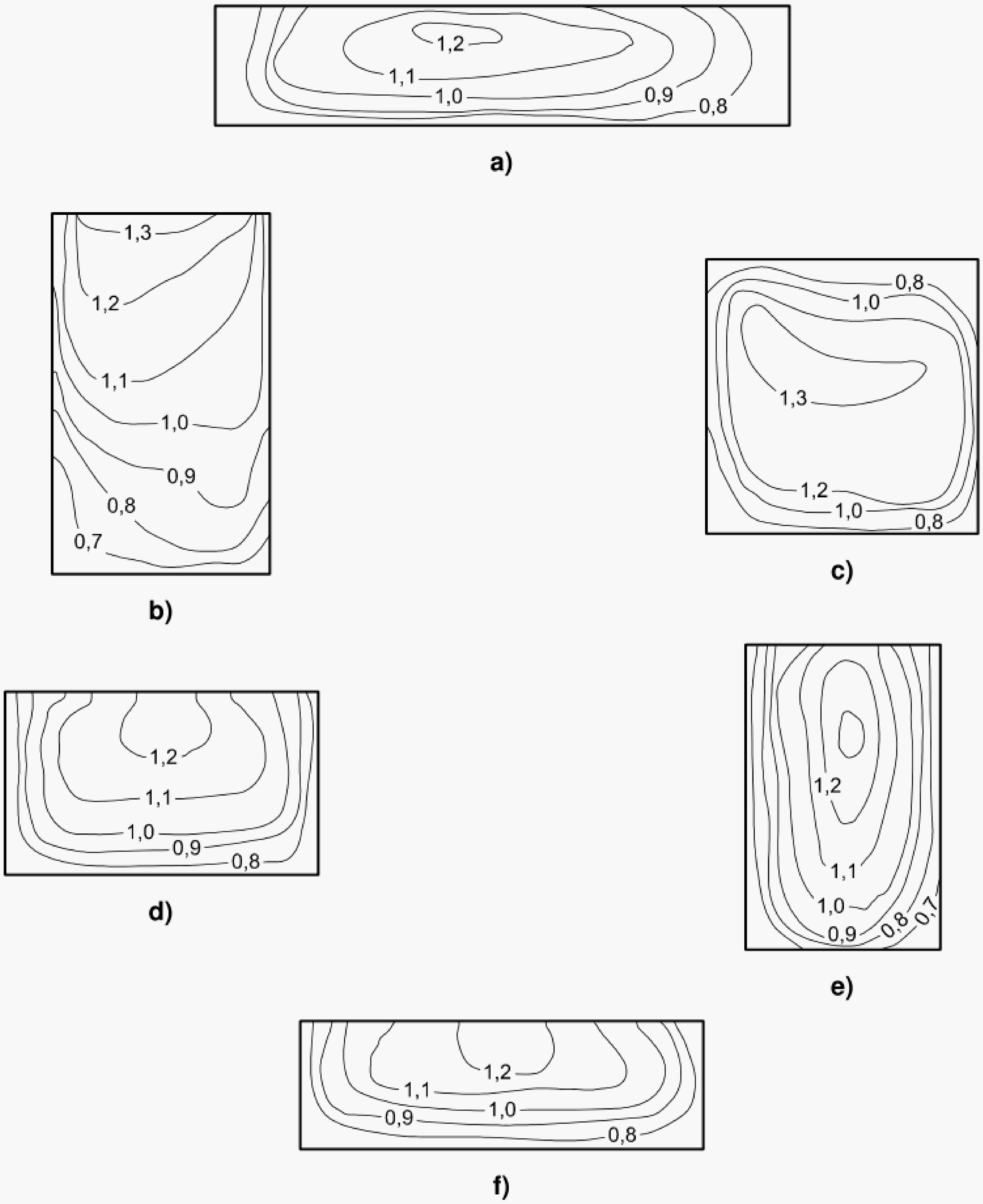
An even distribution of velocity over the cross-section of the approach channel in the region of the gauging station is necessary for high accuracy of measurement of discharge by means of weirs, notches and flumes. This is because the recommended coefficients are empirical values obtained by various investigations and were usually obtained under ideal laboratory conditions. These involved either the use of screens to ensure an approximately uniform velocity over the cross-section, or a long straight approach channel conducive to the establishment of a normal distribution of velocities.

Normal velocity distribution is defined as the distribution of velocities attained in a channel over a long uniform straight reach. A characteristic feature of flow in such a channel is that the velocity is at maximum close to the water surface, with the average velocity occurring at about 0,4 of the depth above invert.

Any deviation from the ideal conditions of either very uniform velocity or a normal velocity distribution may lead to errors in flow measurement, but quantitative information on the influence of velocity distribution is inadequate to define the acceptable limits of departure from the ideal distributions. With the uncertainties on discharge coefficients quoted in the relevant International Standards (see B.1) in mind, Figure A.1 provides some guidance on the type of velocity distribution and evenness thereof that are acceptable in practice.

In Figure A.1 different patterns of isovels are shown. These isovels are contours of equal velocity in the direction of flow.

The percentage difference in the value of α left and α right is shown in Figure A.1. Figure A.1 c) shows the extreme value for the departure from ideal approach conditions for the uncertainties quoted in the relevant International Standards (see B.1) and this percentage difference may be regarded as the maximum permissible. This distribution gives a Coriolis energy coefficient of 1,44.



a) $\left(\frac{\alpha \text{ left}}{\alpha \text{ right}} - 1\right) \times 100 = 6{,}9\ \%$

b) $\left(\frac{\alpha \text{ left}}{\alpha \text{ right}} - 1\right) \times 100 = 9{,}0\ \%$

c) $\left(\frac{\alpha \text{ left}}{\alpha \text{ right}} - 1\right) \times 100 = 12{,}3\ \%$

d) $\left(\frac{\alpha \text{ left}}{\alpha \text{ right}} - 1\right) \times 100 = 1{,}2\ \%$

e) $\left(\frac{\alpha \text{ left}}{\alpha \text{ right}} - 1\right) \times 100 = 0{,}6\ \%$

f) $\left(\frac{\alpha \text{ left}}{\alpha \text{ right}} - 1\right) \times 100 = 0{,}9\ \%$

Figure A.1 — Examples of velocity profiles in the approach channel

Annex B
(normative)

Non-modular (drowned) flow

B.1 General

Structures that are standardized for operation in the modular range are as follows:

— thin-plate weirs: ISO 1438-1;

— triangular profile weirs: ISO 4360;

— trapezoidal broad-crested weirs: ISO 4362;

— flumes: ISO 4359;

— rectangular broad-crested weirs: ISO 3846;

— round-nose horizontal crest weirs: ISO 4374;

— flat-V weirs: ISO 4377;

— V-shaped broad-crested weirs: ISO 8333;

— Parshall and SANIIRI flumes: ISO 9826;

— streamlined triangular profile weirs: ISO 9827.

Structures which are additionally standardized for operation in the non-modular range for use in mild drowned flow conditions are

— Parshall flumes, and

— streamlined triangular profile weirs.

Structures which are additionally standardized for operation in the non-modular range for use with significant drowned conditions are:

— SANIIRI flumes;

— flat-V weirs;

— triangular profile weirs;

— V-shaped broad-crested weirs.

These weirs may be used in the non-modular flow range if a crest tapping is provided. They are commonly used as one or more of the sections of a compound structure, the method of operation being described in B.2.

B.2 gives the procedure to calculate discharges under drowned flow characteristics for the use of the triangular profile weir. In a similar way drowned flow through other standard weirs can be calculated using the appropriate standard.

NOTE Uncertainty calculations under drowned conditions.

a) Parshall and SANIIRI flumes do specify their accuracy of measurement under drowned flow conditions.

b) The streamlined triangular profile weir incurs an additional uncertainty of 2,5 % when operating under drowned conditions: an increase from 2,5 % to 5 %.

c) The uncertainty of flow measurement of flat-V and triangular profile weirs increases in inverse proportion to the drowned flow reduction factor across the full drowned flow operating range.

B.2 Non-modular flow compound 2-dimensional triangular profile weirs with 1:2 and 1:5 slopes

B.2.1 Method of operation

If a weir complying with ISO 4360 is to be used for gauging in the non-modular range, a crest tapping should be provided together with a separate gauge well in addition to the other requirements for gauging within the modular range. Double gauging with this type of structure will give reliable flow recording in the non-modular range. The modular discharge coefficient is approximately constant throughout its range. In the non-modular range the reduction factor $C_{dr} = Q/Q_{mod}$ is uniquely related to the ratio h_p/H_1 where h_p is the crest-tapping pressure head and H_1 is the upstream total head.

Essentially, the crest tapping removes the difficulty of obtaining accurate reading of the downstream water level where some degree of turbulence is invariably present.

Allowing a 1 % uncertainty in the modular discharge value, drowning is considered to take place where h_p/H_1 exceeds 0,24.

For the purpose of checking, at the design stage, whether this type of weir is likely to drown, the submergence ratio at the modular limit is approximately 0,75. It is rare that a design would require the upper structures to drown.

It is recommended that if a triangular profile weir is to be used, then a crest tapping should be installed to provide for possible drowned conditions.

It is recommended that, in cases of doubt as to whether or not a weir may become non-modular, a crest tapping should be provided together with a separate gauge well.

A typical design for a compound structure of this type and crest tapping details are given in Figures B.1 and B.2 respectively.

B.2.2 Computation of non-modular flows

B.2.2.1 General

Two methods for the computation of non-modular discharge for a triangular profile weir complying with ISO 4360 are described in this subclause. They are:

a) the successive approximation method;

b) the coefficient of velocity method.

Examples of these methods, as applied to a compound weir, are given in annex C. For non-modular flow the standard discharge equation is modified to

$$Q = C_D \cdot \sqrt{g} \cdot b \cdot C_{dr} \cdot H_1^{3/2}$$

where C_{dr} is the drowned flow reduction factor. The other symbols are defined in clause 3.

B.2.2.2 Successive approximation method

The basis of the successive approximation method is to calculate the total head at the section of the weir at which the head is measured (gauging section) as if it were for a single weir, and to use the same value to calculate the individual discharge of each other section of the weir. On the assumption that a crest tapping is fitted to the lowest crest only, it is then necessary to determine if and to what degree the other crest(s) is/are drowned by reference to the ratio of downstream to upstream total head (H_2/H_1) calculated from the single reading of the crest tapping.

Superscripts G, T and S and suffixes 1 and 2 are defined in clause 3.

A double superscript applied to the difference in height of two crests (Δ) indicates the two crests involved.

Weir sections that have the same crest level and weir height p are treated as one crest even if physically separated.

The drowned flow reduction factor C_{dr} can be obtained from Figure B.3 or from the following equations:

$$C_{dr} = 1{,}04\left[0{,}945 - (h_p/H_1)^{1{,}5}\right]^{0{,}256} \text{ in the range : } 0{,}24 < h_p/H_1 < 0{,}95 \quad (4)$$

in terms of crest-tapping pressure heads; or

$$C_{dr} = 1{,}035\left[0{,}817 - (H_2/H_1)^4\right]^{0{,}0647} \text{ in the range : } 0{,}75 < H_2/H_1 < 0{,}93 \text{ and} \quad (5)^{4)}$$

$$C_{dr} = 8{,}686 - 8{,}403\left(H_2/H_1\right) \text{ in the range : } 0{,}93 < H_2/H_1 < 0{,}985 \quad (6)^{4)}$$

in terms of downstream total heads.

Equations (5) and (6) should be used only where no crest tapping exists, as the factor C_{dr} is a function of the ratio of downstream to upstream total head (H_2/H_1) and is extremely sensitive to small errors in either head measurements. This method is not recommended for regular gauging of non-modular flows. However, in the case of a compound weir operating in the non-modular range it is necessary to use this method for sections not equipped with a crest tapping.

If the gauging point and crest tapping are at the same section $\Delta^{TG} = 0$ and $C_{dr}{}^{G} = C_{dr}{}^{T}$ steps 2 f) and 2 h) and step 4 are therefore omitted from the following calculation procedures.

Step 1

If h^G is zero or negative (i.e. there is no flow over the gauging section of the weir) then:

$Q^G = 0$, $H_1 = h_1{}^G$, calculate steps 2 d) to 2 g) and continue from step 4.

Otherwise calculate the cross-sectional area at the upstream gauging section.

$$A^G = (h_1{}^G + p^G) \times b^G$$

For the first calculation only of step 2 a), assume $Q^G = 0$.

4) Ackers, White, Perkins and Harrison, *Weirs and flumes for flow measurement.* Whitney. ISBN 0 471 99637 8.

Step 2

a) $\bar{v}_1^{\mathrm{G}} = Q^{\mathrm{G}} / A^{\mathrm{G}}$

b) $h_{\mathrm{v},1}{}^{\mathrm{G}} = \left(\bar{v}_1{}^{\mathrm{G}}\right)^2 / 2g$

c) $H_1{}^{\mathrm{G}} = h_1{}^{\mathrm{G}} + h_{\mathrm{v},1}{}^{\mathrm{G}}$

d) $H_1{}^{\mathrm{T}} = H_1{}^{\mathrm{G}} + \Delta^{\mathrm{TG}}$ 5)

e) Calculate $h_{\mathrm{p}} / H_1{}^{\mathrm{T}}$, determine $C_{\mathrm{dr}}{}^{\mathrm{T}}$ and also $H_2{}^{\mathrm{T}}/H_1{}^{\mathrm{T}}$ from Figure B.3 or equation (4), (5) or (6).

f) $H_2{}^{\mathrm{T}} = \left(H_2{}^{\mathrm{T}} / H_1{}^{\mathrm{T}}\right) H_1{}^{\mathrm{T}}$

This is a basic assumption of the method.

g) $H_2{}^{\mathrm{G}} = H_2{}^{\mathrm{T}} - \Delta^{\mathrm{TG}}$ 5)

h) Calculate $(H_2{}^{\mathrm{G}}/H_1{}^{\mathrm{G}})$ and determine $C_{\mathrm{dr}}{}^{\mathrm{G}}$ from Figure B.3 or equation (5) or (6).

i) $Q^{\mathrm{G}} = 0{,}633 \sqrt{g} \cdot b^{\mathrm{G}} \cdot C_{\mathrm{dr}}{}^{\mathrm{G}} \cdot \left(H_1{}^{\mathrm{G}}\right)^{3/2}$

Step 3

Repeat steps 2 a) to 2 i) using the new value of Q^{G} obtained in 2 i) until two successive values of Q^{G} in step 2 i) differ by less than a predetermined limit of accuracy. Note the final values of Q^{G}, $H_1{}^{\mathrm{G}}$, $H_1{}^{\mathrm{T}}$ and $C_{\mathrm{dr}}{}^{\mathrm{T}}$.

Step 4

For the crest-tapping section of the weir

$$Q^{\mathrm{T}} = 0{,}633 \sqrt{g} \cdot b^{\mathrm{T}} \cdot C_{\mathrm{dr}}{}^{\mathrm{T}} \left(H_1{}^{T}\right)^{3/2}$$

Step 5

For any other section of the weir calculate:

a) $H_1{}^{\mathrm{S}} = H_1{}^{\mathrm{G}} + \Delta^{\mathrm{SG}}$ 6)

b) $H_2{}^{\mathrm{S}} = H_2{}^{\mathrm{G}} + \Delta^{\mathrm{SG}}$ 6)

c) Calculate $H_2{}^{\mathrm{S}}/H_1{}^{\mathrm{S}}$ and determine $C_{\mathrm{dr}}{}^{\mathrm{S}}$ from Figure B.3 or equation (5) or (6).

d) $Q^{\mathrm{S}} = 0{,}633 \sqrt{g} \cdot b^{\mathrm{S}} \cdot C_{\mathrm{dr}}{}^{\mathrm{S}} \cdot \left(H_1{}^{\mathrm{S}}\right)^{3/2}$

---

5) If the crest-tapping section, T, is higher than the gauging section, G, replace Δ^{TG} with $-\Delta^{\mathrm{TG}}$

6) If the section under consideration, S, is higher than the gauging section, G, replace Δ^{SG} with $-\Delta^{\mathrm{SG}}$

Step 6

Total $Q = Q^{\mathrm{G}} + Q^{\mathrm{T}} + \sum Q^{\mathrm{S}}$.

B.2.2.3 Coefficient of velocity method

The basis of this method is identical with that given for the successive approximation method and the same notation is used.

Step 1

To determine Q^{T}:

a) calculate $h_1^{\mathrm{T}} = h_1^{\mathrm{G}} + \Delta^{\mathrm{TG}}$ 7);

b) calculate $h_{\mathrm{p}}/h_1^{\mathrm{T}}$ and $h_1^{\mathrm{T}}/(h_1^{\mathrm{T}} + p^{\mathrm{T}})$;

c) determine $C_{\mathrm{dr}}^{\mathrm{T}}$ from Figure B.4;

d) calculate $C_{\mathrm{dr}}^{\mathrm{T}}\left[h_1^{\mathrm{T}}/\left(h_1^{\mathrm{T}} + p^{\mathrm{T}}\right)\right]$ from b) and c) above;

e) determine $C_{\mathrm{v}}^{\mathrm{T}}$ from Table C.1;

f) $Q^{\mathrm{T}} = 0{,}633\, C_{\mathrm{v}}^{\mathrm{T}} \sqrt{g} \cdot b^{\mathrm{T}} \cdot C_{\mathrm{dr}}^{\mathrm{T}} \cdot \left(h_1^{\mathrm{T}}\right)^{3/2}$;

g) $H_1^{\mathrm{T}} = \left(C_{\mathrm{v}}^{\mathrm{T}}\right)^{2/3} h_1^{\mathrm{T}}$.

Step 2

Determine Q^{S} for any other sections including the gauging section (if it is not also the crest-tapping section) as follows:

a) calculate $H_2^{\mathrm{T}}/H_1^{\mathrm{T}}$ from $C_{\mathrm{dr}}^{\mathrm{T}}$ in Figure B.3;

b) calculate $H_2^{\mathrm{T}} = \left(H_2^{\mathrm{T}}/H_1^{\mathrm{T}}\right) H_1^{\mathrm{T}}$;

c) calculate $H_1^{\mathrm{S}} = H_1^{\mathrm{T}} - \Delta^{\mathrm{ST}}$ 8);

d) calculate $H_2^{\mathrm{S}} = H_2^{\mathrm{T}} - \Delta^{\mathrm{ST}}$ 8);

e) calculate $H_2^{\mathrm{S}}/H_1^{\mathrm{S}}$;

f) determine $C_{\mathrm{dr}}^{\mathrm{S}}$ from Figure B.3;

---

7) If the crest-tapping section is higher than the gauging section, Δ^{TG} is replaced by $-\Delta^{\mathrm{TG}}$. If they are the same section, $\Delta^{\mathrm{TG}} = 0$.

8) If the section under consideration, S, is lower than the crest-tapping section, T, then Δ^{ST} is replaced by $-\Delta^{\mathrm{ST}}$.

g) $Q^{\mathrm{S}} = 0{,}633\sqrt{g}\, b^{\mathrm{S}} C_{\mathrm{dr}} \left(H_1{}^{\mathrm{S}}\right)^{3/2}$;

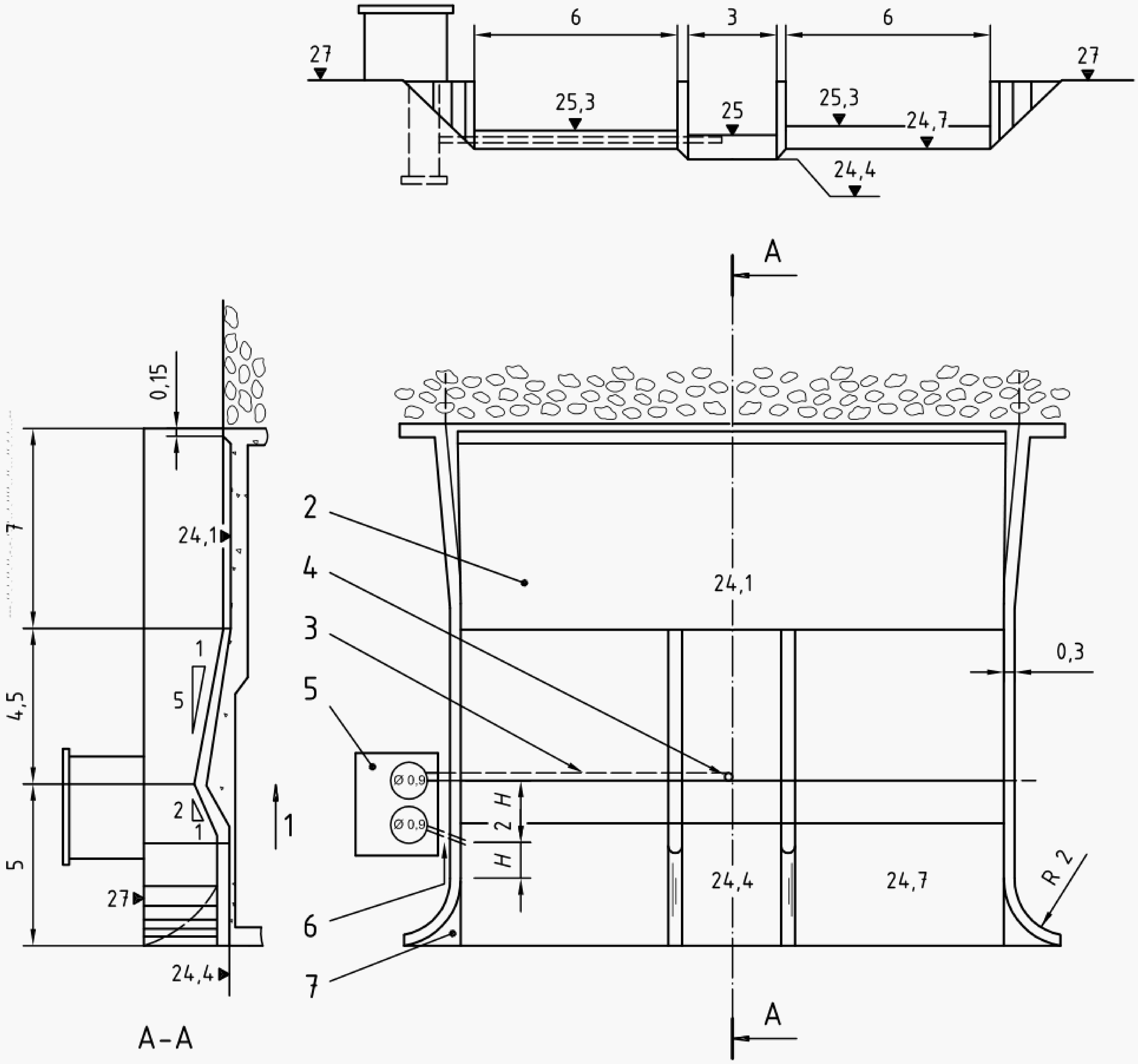
Step 3

Total $Q = Q^{\mathrm{T}} + \sum Q^{\mathrm{S}}$.

B.2.2.4 Accuracy of computational methods

Successive approximation and coefficient of velocity methods of calculation are equally effective for determining modular and non-modular flows at compound structures with one exception. That exception is the non-modular operation of a compound structure at which upstream water level and crest-tapping pressure are measured at different sections of the structure. In these circumstances the inaccurate assumption that water surface level is equal at all sections of the structure has to be made in the coefficient of velocity method. Example C.2 gives a difference of 100 (41,39 – 39,58)/39,58 = 4,6 %. In this situation, therefore the method of successive approximation should always be used.

Dimensions in metres

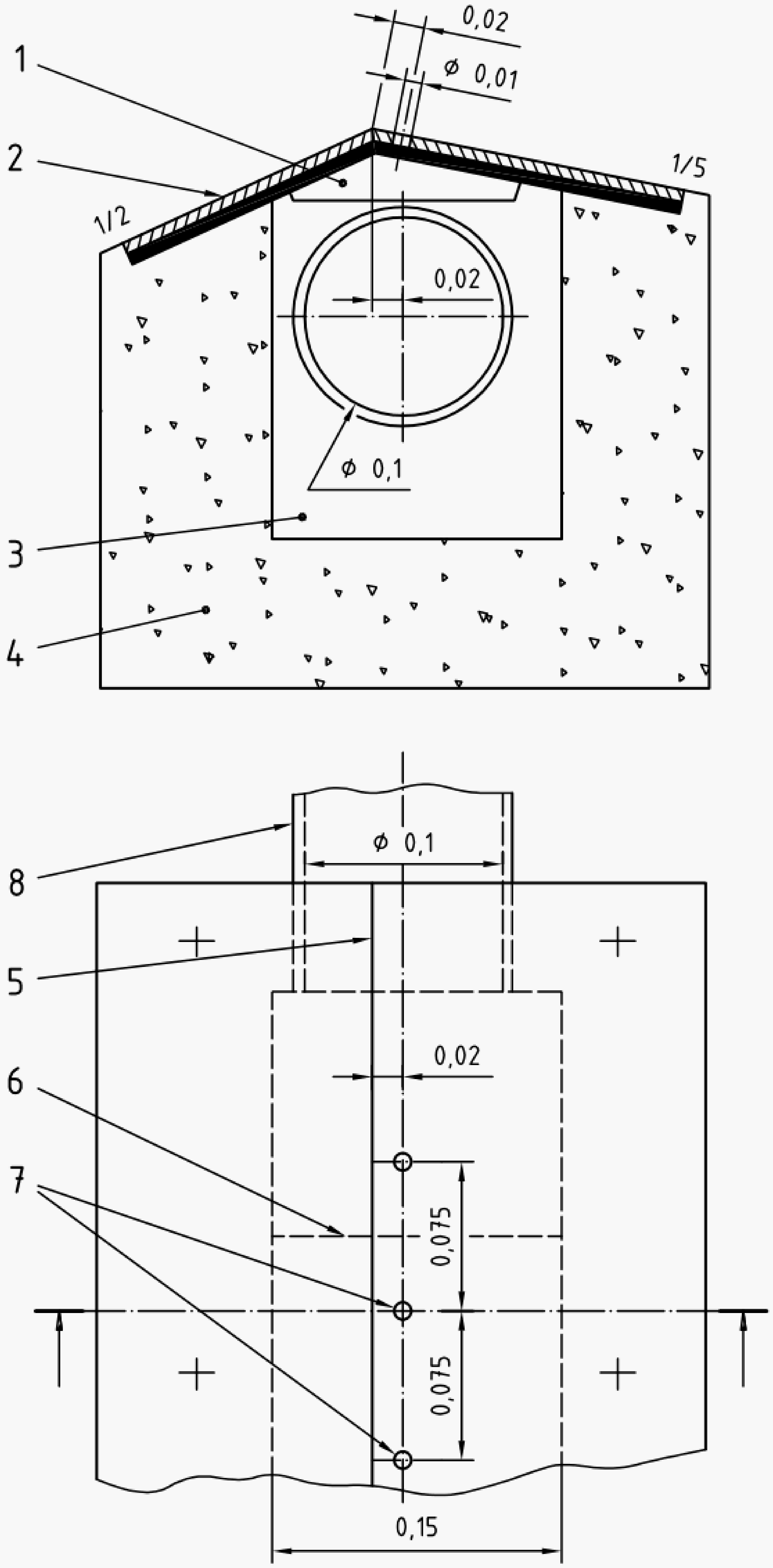


Key

1 Flow
2 Stilling basin
3 Crest-tapping pipe: ∅ 0,1
4 Crest to crest-tapping box (0,3 × 0,6 × 0,15): ∅ 0,01
5 Recorder housing
6 Intake: ∅ 0,1
7 Transition formed

Figure B.1 — Examples of compound weir design

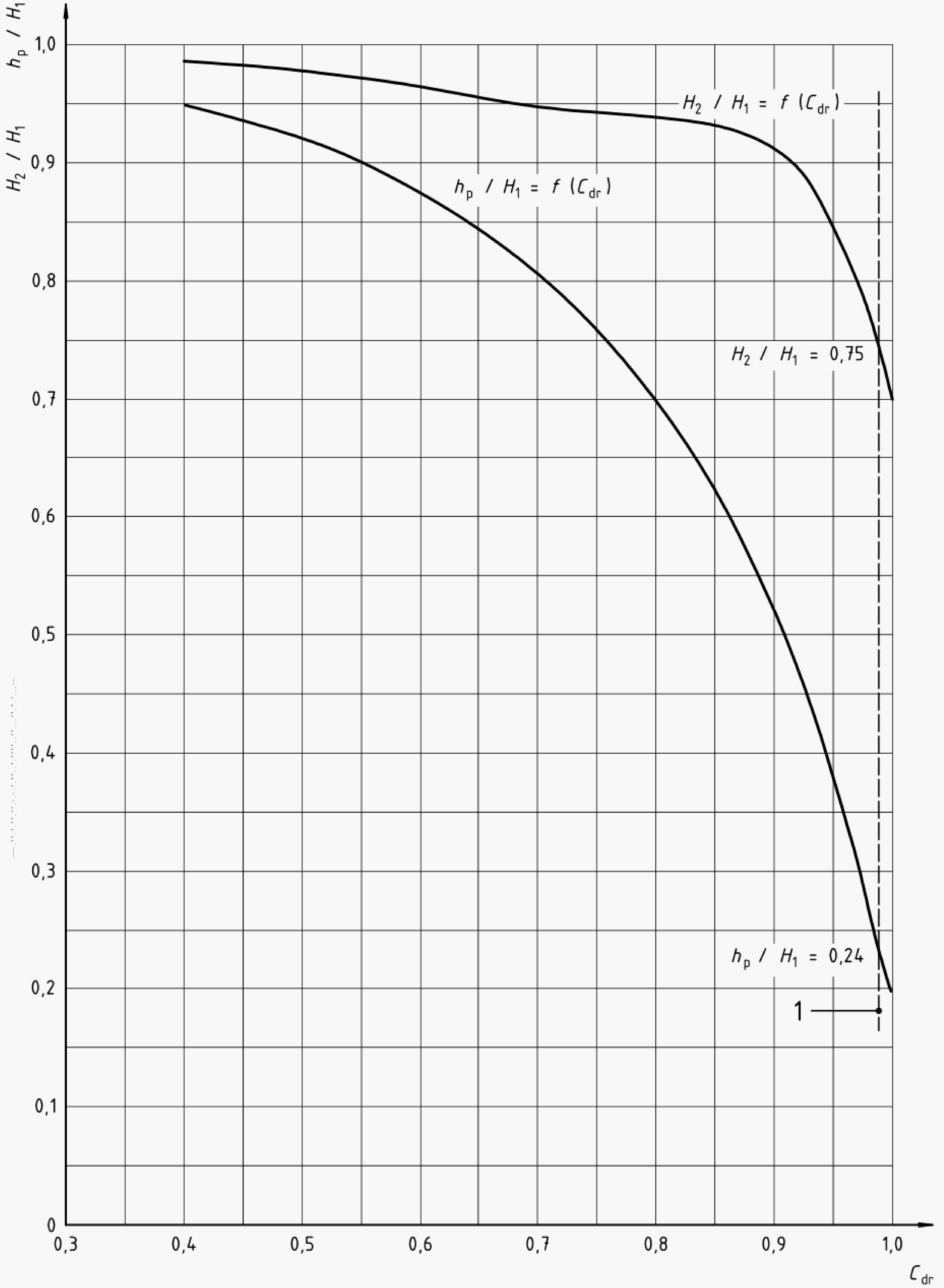
Dimensions in metres



Key

1 Stiffener plate
2 Bronze plate seated on rubber gasket
3 Crest-tapping chamber: 0,6 long × 0,15 wide
4 Cast concrete crest block
5 Crest
6 Stiffeners at 0,15 between centres
7 Crest-tapping holes: ∅ 0,01
8 Pipe to float well

Figure B.2 — Details of crest tappings for triangular profile weirs



Key

1 1 % tolerance line

Figure B.3 — Drowned-flow characteristics expressed in terms of h_p/H_1 and H_2/H_1 as a function of C_{dr} for triangular profile weirs

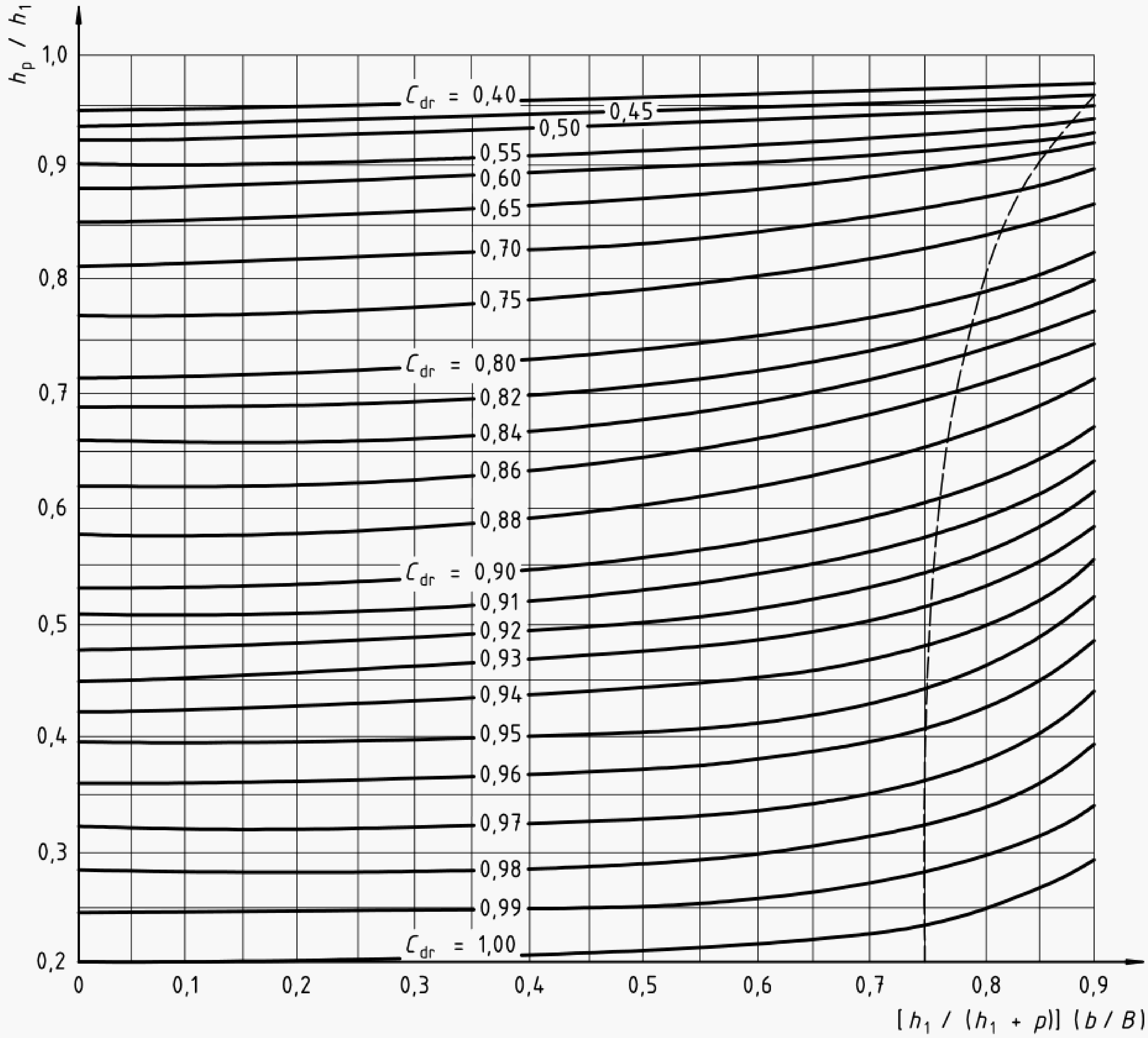


Figure B.4 — Drowned-flow reduction factor C_{dr} in terms of h_p/h_1 and $\left(\frac{h_1}{h_1 + p}\right)\frac{b}{B}$ for triangular profile weirs

Annex C
(normative)

Methods of calculations

C.1 Modular flow

C.1.1 General

Calculate the discharge for a three-part compound structure comprising a rectangular-throated control flume with a level invert flanked by round-nosed broad-crested weirs of equal crest elevation and differing widths. Flow within the individual sections is to be within the modular range. (See also ISO 4359 and ISO 4374.)

Relevant conditions are as follows:

Flank weirs:

width	a) 6,4 m
	b) 3,7 m
crest heights	1,15 m above datum
crest lengths in direction of flow	1,8 m

Central flume:

width at entrance	2,5 m
width at throat	1,5 m
invert level	0,0 m above datum
throat length	2,0 m

Water level measured at flank weir 2,90 m above datum.

Surface finish smooth, i.e. $\delta/L = 0{,}003$.

It is assumed in this example that the water level is measured by a recorder having a resolution, e_r, of 1 mm with an uncertainty, e_h, of ± 3 mm. The zero is measured in each case, e_z to ± 1 mm. A series of readings of a constant head produced a standard deviation of the mean of 1,5 mm. The uncertainty in width measurement may be taken as ± 2 mm.

C.1.2 Discharge flank weirs

$$Q = (2/3)^{3/2} C_D \cdot C_v \cdot b\sqrt{g} \cdot h^{3/2}$$

[from 8.1.2 of ISO 4374: 1990, equation (2)]

where

$$C_D = (1 - 0{,}006L/b)(1 - 0{,}003L/h)^{3/2}$$

[from 8.2.3 of ISO 4374:1990, equation (6) a), δ/L taken as 0,003]

therefore $C_D = 0{,}994$.

Hence

$$C_D \cdot b \cdot h/A = 0{,}60$$

therefore $C_v = 1{,}10$

(from Figure 3 of ISO 4374: 1990)

$$Q = 43{,}59\,\text{m}^3/\text{s}.$$

C.1.3 Transfer of total head levels

Flank weir gauged head, $h = 1{,}75$ m.

Flank weir coefficient of velocity, $C_v = 1{,}10$.

Therefore flank weir total head, $H = hC_v{}^{2/3} = 1{,}86$ m.

Therefore total head level = (1,86 + 1,15) = 3,01 m above datum.

Therefore flume total head, $H = hC_v{}^{2/3} = 3{,}01$ m.

C.1.4 Discharge of central flume

$$Q = (2/3)^{3/2} C_D \cdot b\sqrt{g} \cdot C_v \cdot h^{3/2}$$

[from 10.4.1 of ISO 4359, equation (20)]

where

$$C_D = (1 - 0{,}006L/b)\ (1 - 0{,}003L/h)^{3/2}$$

[from 10.4.1 of ISO 4359, equation (25), δ/L taken as 0,003].

For the purposes of calculating C_D an approximate gauged head for the flume of 2,90 m may be taken although in practice there will be a depression of the water level upstream of the central flume.

Hence

$$C_D = 0{,}989$$

$$Q = 13{,}21\ \text{m}^3/\text{s}$$

C.1.5 Total discharge for the compound structure

Total $Q = 43{,}59 + 13{,}21 = 56{,}80\ \text{m}^3/\text{s}$.

C.1.6 Uncertainty in flow measurement

C.1.6.1 Flank weirs

$$X_h = \pm 100/h \times \left[e_r{}^2 + e_h{}^2 + e_z{}^2 + (2 \times 1{,}5)^2 \right]^{1/2}$$

$$= \pm 100/1750 \times \left[1^2 + 3^2 + 1^2 + (2 \times 1{,}5)^2 \right]^{1/2}$$

$$= \pm\ 0{,}26\ \%.$$

In this example the two flank weirs are taken together as having one width, 10,1 m. Since uncertainties are to be weighted according to discharge, and since the uncertainty in width measurement in each of the flank weirs is ± 2 mm, an uncertainty on the overall width may be taken as $(2^2 + 2^2)^{1/2} = 2{,}8$ mm.

Then

$$X_b = 2{,}8/10\,100 \times 100 = 0{,}03\ \%.$$

From C.1.2, $C_D = 0{,}994$.

From 8.4, 9.4 and 9.6 of ISO 4374, the percentage uncertainty in the discharge coefficient (including C_v) can be calculated as follows:

$$X_C = \sqrt{[2 + 0{,}15\ (1{,}80/1{,}86)]^2 + 1^2}$$

$$= 2{,}37\ \%$$

Therefore, the percentage uncertainty in the flow over the flank weirs is:

$$X_{Q,1} = \left(X_C{}^2 + X_b{}^2 + 1{,}5^2 X_h{}^2 \right)^{1/2}$$

$$= \pm\ [2{,}37^2 + 0{,}03^2 + (1{,}5 \times 0{,}26)^2]^{1/2}$$

$$= \pm\ 2{,}40\ \%$$

C.1.6.2 Central flume

$$X_h = 100/2\,900\ [1^2 + 3^2 + 1^2 + (2 \times 1{,}5)^2]^{1/2}$$

$$= 0{,}15\ \%$$

$$X_b = \frac{2}{1\,500} \times 100 = 0{,}13\ \%$$

From ISO 4359, equation (28), the percentage uncertainty in the combined coefficient $C_v \cdot C_D$ is

$$X_C = \pm\ [1 + 20\ (C_v - C_D)]\ \%$$

From C.1.4, $C_D = 0{,}989$, and since the discharge (13,21 m^3/s) and H_1 (3,01 m) are known, C_v can be determined as follows.

In a process of successive approximation, a first trial value for the velocity of approach may be taken as:

$$\overline{v}_1 = 13{,}21/(2{,}5 \times 3{,}01) = 1{,}755\ \text{m/s}$$

Hence

$$\overline{v}_1{}^2/2g = 0{,}16\ \text{m}$$

and

$$h_1 = 3{,}01 - 0{,}16 = 2{,}85\ \text{m}$$

A second trial value for $\overline{v}_1 = 13{,}21/(2{,}5 \times 2{,}85) = 1{,}85$ m/s and further trials result in a value for h_1 of 2,83 m.

Hence

$$C_\text{v} = (H_1/h_1)^{3/2} = (3{,}01/2{,}83)^{3/2} = 1{,}097$$

$$X_C = [1 + 20\ (1{,}097 - 0{,}989)]$$

$$= 3{,}16\ \%$$

Therefore, the percentage uncertainty in the flow through the central flume is:

$$X_{Q,2} = \pm\,[3{,}16^2 + 0{,}13^2 + (1{,}5 \times 0{,}16)^2]^{1/2}$$

$$= 3{,}17\ \%$$

C.1.6.3 Overall uncertainty

There is an additional uncertainty X_{tu} = 5 % (see 9.2) in the discharge through the central flume, due to transferring the upstream total head level from the gauged flank weir to the flume. Hence, from equation 3,

$$X_Q = (1\ /\ 56{,}80)\left[43{,}59 \times 2{,}40 + 13{,}21\sqrt{(3{,}17^2 + 5^2)}\right]$$

$$= 3{,}22\ \%$$

C.2 Drowned (non-modular) flow

C.2.1 General

Calculate the discharge for a two-part compound triangular profile weir in the non-modular flow range with head measurement taken at the flank weir and crest tapping taken at the low weir.

Relevant conditions are as follows:

Flank weir width	6,10 m
Flank weir height	0,61 m
Low weir width	3,05 m
Low weir height	0,61 m
Difference in crest levels	0,305 m

Gauged head (flank weir)	1,504 m
Crest-tapping pressure (h_p)	1,067 m
Adopted limit of accuracy of Q	1 %

The same accuracy of water level measurement, crest-tapping pressure measurement and width measurement are assumed as in C.1.

C.2.2 Use of successive approximation method (see B.2.2.2)

In this case the flank weir is the gauging section, G, and the low weir is the crest-tapping section T. Since there are no other sections step 5 of B.2.2.2 does not apply. The crest-tapping section is lower than the gauging section, therefore Δ^{TG} is positive.

Step 1

$$A^G = (1,504 + 0,61)\ 6,10 = 12,895\ m^2$$

Step 2

1st approximation

a) $\bar{v}_1^G = 0$

b) $h_{v,1}^G = 0$

c) $H_1^G = 1,504 + 0 = 1,504$ m

d) $H_1^T = 1,504 + 0,305 = 1,809$ m

e) $h_p/H_1^T = 1,067/1,809 = 0,590$

$C_{dr}^T = 0,88$ and $H_2^T/H_1^T = 0,93$ from Figure B.3

f) $H_2^T = 0,93 \times 1,809 = 1,682$ m

g) $H_2^G = 1,682 - (0,305) = 1,377$ m

h) $H_2^G/H_1^G = 1,377/1,504 = 0,916$

$C_{dr}^G = 0,91$ from Figure B.3

i) $Q^G = 0,633 \times \sqrt{(9,81)} \times 6,10 \times 0,91 \times 1,504^{3/2} = 20,299\ m^3/s$

Step 3

2nd approximation

a) $\bar{v}_1^G = 20,299/12,895 = 1,574$ m/s

b) $h_{v,1}^G = 1,574^2/(2 \times 9,81) = 0,126$ m

c) $H_1^G = 1,504 + 0,126 = 1,630$ m

d) $H_1^{\mathrm{T}} = 1{,}630 + 0{,}305 = 1{,}935$ m

e) $h_\mathrm{p}/H_1^{\mathrm{T}} = 1{,}067/1{,}935 = 0{,}551$

$C_{\mathrm{dr}}^{\mathrm{T}} = 0{,}89$ and $H_2^{\mathrm{T}}/H_1^{\mathrm{T}} = 0{,}925$ from Figure B.3

f) $H_2^{\mathrm{T}} = 0{,}925 \times 1{,}935 = 1{,}790$ m

g) $H_2^{\mathrm{G}} = 1{,}790 - 0{,}305 = 1{,}485$ m

h) $H_2^{\mathrm{G}}/\mathrm{H}_1^{\mathrm{G}} = 1{,}485/1{,}630 = 0{,}911$

$C_{\mathrm{dr}}^{\mathrm{G}} = 0{,}915$ from Figure B.3

i) $Q^{\mathrm{G}} = 12{,}094 \times 0{,}915 \times 1{,}630^{3/2} = 23{,}029$ m^3/s

Difference in successive values of $Q^{\mathrm{G}} = 11{,}9$ %

3rd approximation

a) $\bar{v}_1^{\mathrm{G}} = 23{,}029/12{,}895 = 1{,}786$ m/s

b) $h_{\mathrm{v},1}^{\mathrm{G}} = 1{,}786^2/(2 \times 9{,}81) = 0{,}163$ m

c) $H_1^{\mathrm{G}} = 1{,}504 + 0{,}163 = 1{,}667$ m

d) $H_1^{\mathrm{T}} = 1{,}667 + 0{,}305 = 1{,}972$ m

e) $h_\mathrm{p}/H_1^{\mathrm{T}} = 1{,}067/1{,}972 = 0{,}541$

$C_{\mathrm{dr}}^{\mathrm{T}} = 0{,}895$ and $H_2^{\mathrm{T}}/H_1^{\mathrm{T}} = 0{,}92$ from Figure B.3

f) $H_2^{\mathrm{T}} = 0{,}92 \times 1{,}972 = 1{,}814$ m

g) $H_2^{\mathrm{G}} = 1{,}814 - 0{,}305 = 1{,}509$ m

h) $H_2^{\mathrm{G}}/H_1^{\mathrm{G}} = 1{,}509/1{,}667 = 0{,}905$

$C_{\mathrm{dr}}^{\mathrm{G}} = 0{,}92$ from Figure B.3

i) $Q^{\mathrm{G}} = 12{,}094 \times 0{,}920 \times 1{,}667^{3/2} = 23{,}948$ m^3/s

Difference in successive values of $Q^{\mathrm{G}} = 3{,}8$ %

4th approximation

a) $\bar{v}_1^{\mathrm{G}} = 23{,}948/12{,}895 = 1{,}857$ m/s

b) $h_{\mathrm{v},1}^{\mathrm{G}} = 1{,}857^2/(2 \times 9{,}81) = 0{,}176$ m

c) $H_1^{\mathrm{G}} = 1{,}504 + 0{,}176 = 1{,}680$ m

d) $H_1{}^{\mathrm{T}}$ = 1,680 + 0,305 = 1,985 m

e) $h_{\mathrm{p}}/H_1{}^{\mathrm{T}}$ = 1,067/1,985 = 0,538

$C_{\mathrm{dr}}{}^{\mathrm{T}}$ = 0,895 and $H_2{}^{\mathrm{T}}/H_1{}^{\mathrm{T}}$ = 0,92 from Figure B.3

f) $H_2{}^{\mathrm{T}}$ = 0,92 × 1,985 = 1,826 m

g) $H_2{}^{\mathrm{G}}$ = 1,826 − 0,305 = 1,521 m

h) $H_2{}^{\mathrm{G}}/H_1{}^{\mathrm{G}}$ = 1,521/1,680 = 0,905

$C_{\mathrm{dr}}{}^{\mathrm{G}}$ = 0,92 from Figure B.3

i) Q^{G} = 12,094 × 0,92 × 1,680$^{3/2}$ = 24,228 m^3/s

Difference in successive values of Q^{G} = 1,2 %

5th approximation

a) $\bar{v}_1{}^{\mathrm{G}}$ = 24,228/12,895 = 1,879 m/s

b) $h_{\mathrm{v},1}{}^{\mathrm{G}}$ = 1,879^2/(2 × 9,81) = 0,180 m

c) $H_1{}^{\mathrm{G}}$ = 1,504 + 0,180 = 1,684 m

d) $H_1{}^{\mathrm{T}}$ = 1,684 + 0,305 = 1,989 m

e) $h_{\mathrm{p}}/H_1{}^{\mathrm{T}}$ = 1,067/1,989 = 0,536 m

$C_{\mathrm{dr}}{}^{\mathrm{T}}$ = 0,90 and $H_2{}^{\mathrm{T}}/H_1{}^{\mathrm{T}}$ = 0,92 from Figure B.3

f) $H_2{}^{\mathrm{T}}$ = 0,92 × 1,989 = 1,830 m

g) $H_2{}^{\mathrm{G}}$ = 1,830 − 0,305 = 1,525 m

h) $H_2{}^{\mathrm{G}}/H_1{}^{\mathrm{G}}$ = 1,525/1,684 = 0,906

$C_{\mathrm{dr}}{}^{\mathrm{G}}$ = 0,92 from Figure B.3

i) Q^{G} = 12,094 × 0,92 × 1,684$^{3/2}$ = 24,315 m^3/s

Difference in successive values of Q^{G} = 0,36 %

Step 4

$$Q^{\mathrm{T}} = 0{,}663 \times \sqrt{9{,}81} \times 3{,}05 \times 0{,}90 \times 1{,}989^{3/2} = 15{,}266 \mathrm{m}^3/\mathrm{s}$$

Step 5

Total Q = 24,315 + 15,266 = 39,58 m^3/s

C.2.3 Use of coefficient of velocity method (see B.2.2.3)

Calculate the discharge of a compound weir in the non-modular flow range under the same conditions as in C.2.2.

As the flank weir is the gauging section, G, and the lower weir is the crest-tapping section, T, Δ^{TG} and Δ^{ST} are positive.

Step 1

a) $h_1^{T} = 1{,}504 + 0{,}305 = 1{,}809$ m

b) $h_p / h_1^{T} = 1{,}067/1{,}809 = 0{,}590$

$h_1^{T}/(h_1^{T} + p^{T}) = 1{,}809/(1{,}809 + 0{,}61) = 0{,}748$

c) $C_{dr}^{T} = 0{,}902$ from Figure B.4

d) $C_{dr}^{T}\,[h_1^{T}/(h_1^{T} + p^{T})] = 0{,}902 \times 0{,}748 = 0{,}675$

e) $C_v^{T} = 1{,}199$ from Table C.1

f) $q^{T} = 4{,}824$ m^3/s per metre of crest from Table C.2

g) $Q^{T} = 3{,}05 \times 0{,}902\ (1{,}199 \times 4{,}824) = 15{,}912$ m^3/s

h) $H_1^{T} = 1{,}199^{2/3} \times 1{,}809 = 2{,}042$ m

Step 2

To determine Q^{S} (flank weir), (in this case, the gauging section, G):

a) $H_2^{T}/H_1^{T} = 0{,}92$ from Figure B.3

b) $H_2^{T} = 0{,}92 \times 2{,}042 = 1{,}879$ m

c) $H_1^{S} = 2{,}042 - 0{,}305 = 1{,}737$ m

d) $H_2^{S} = 1{,}879 - 0{,}305 = 1{,}574$ m

e) $H_2^{S}/H_1^{S} = 1{,}574/1{,}737 = 0{,}906$

f) $C_{dr}^{S} = 0{,}92$ from Figure B.3

g) $q^{S} = 4{,}539$ m^3/s per metre of crest from Table C.2

h) $Q^{S} = 6{,}10 \times 0{,}92 \times 4{,}539 = 25{,}473$ m^3/s

Step 3

Total $Q = 15{,}912 + 25{,}473 = 41{,}39$ m^3/s

C.2.4 Uncertainty in flow measurement (relating to the successive approximation method described in C.2.2).

C.2.4.1 Flank weir

X_h = (100/1 504) × [$1^2 + 3^2 + 1^2 + (2 \times 1{,}5)^2]^{1/2}$

= 0,30 %

X = (100/1 067) × [$1^2 + 3^2 + 1^2 + (2 \times 1{,}5)^2]^{1/2}$

= 0,42 %

X_b = 2/6 100 × 100

= 0,03 %

From ISO 4360 the uncertainty in the discharge coefficient (including C_v) is:

$X_C = (10C_v - 9)$ %

From the final (5th) approximation in C.2.2, $C_{dr}^G = 0{,}92$

Also, $h_1^G = 1{,}504$ and weir height $p = 0{,}61$

Hence $C_{dr}^G \times h_1/(h_1 + p) = 0{,}65$

From Table C.1, $C_v = 1{,}177$

$X_C = (10 \times 1{,}177) - 9 = 2{,}77$ %

In addition, there is some uncertainty in the relationship for the drowned flow reduction factor. This has been estimated as:

$X_{C,dr} = 3$ %

Hence, the uncertainty in discharge over the flank weir, ignoring water level and head transfer effects, is:

$$X_{Q,1} = \left(X_C^2 + X_b^2 + X_{C,h}^2 + 1{,}5^2 X_h^2 + 1{,}5^2 X_{h,p}^2\right)^{1/2}$$

$= [2{,}77^2 + 0{,}03^2 + 3^2 + (1{,}5^2 \times 0{,}30^2) + (1{,}5^2 \times 0{,}42^2)]^{1/2}$

= 4,16 %

C.2.4.2 Low weir

X_h = (100/1 809) × [$1^2 + 3^2 + 1^2 + (2 \times 1{,}5)^2]^{1/2}$

= 0,25 %

$X_{h,p}$ = 0,42 %

X_b = 2/3 050 × 100

= 0,06 %

For the approach channel to the low weir, the height h_1 of the water surface level above the weir crest is not known. Since the discharge (15,266 m^3/s) and H_1 (1,989 m) are known, h_1 can be determined by a method of successive approximation.

A first trial value for the velocity of approach may be taken as:

$$\bar{v}_1 = 15{,}266 / [(1{,}989 + 0{,}305) \times 3{,}05] = 2{,}182 \text{ m/s}$$

Hence

$$\frac{\bar{v}_1^2}{2g} = 2{,}182^2 / (2 \times 9{,}81) = 0{,}242 \text{ m}$$

$$h_1 = 1{,}989 - 0{,}242 = 1{,}747 \text{ m}$$

A second trial value is:

$$\bar{v}_1 = 15{,}266/[(1{,}747 + 0{,}305) \times 3{,}05] = 2{,}439 \text{ m/s}$$

and further trials result in a value for h_1 of 1,67 m. Also, the weir height p = 0,305 m and, from the 5th approximation in C.2.2, C_{dr}^T = 0,90

$$C_{dr}^T \times h_1/(h_1 + p) = 0{,}90 \times [1{,}67/(1{,}67 + 0{,}305)] = 0{,}76$$

From Table C.1, C_v = 1,302

$$X_C = (10 \times 1{,}302 - 9)$$

$$= 4{,}02 \text{ \%}$$

$$X_{C,dr} = 3 \text{ \% as before}$$

Hence the uncertainty in the discharge over the low weir, ignoring water level and head transfer effects, is:

$$X_{Q,2} = [4{,}02^2 + 0{,}06^2 + 3^2 + (1{,}5^2 \times 0{,}25^2) + (1{,}5^2 \times 0{,}42^2)]^{1/2}$$

$$= 5{,}07 \text{ \%}$$

C.2.4.3 Overall uncertainty

For the low weir, an additional uncertainty X_{tu} = 5 % has to be included, due to the transfer of the upstream total head level from the gauged flank weir.

Calculation of the submerged flow over the flank weir requires transferring the upstream total head level to the low weir, as well as transferring the downstream total head level from the low weir to the flank weir. Hence additional uncertainties of X_{tu} = 5 % and X_{td} = 10 % have to be included.

$$X_Q = 1/39{,}58 \left[24{,}315\sqrt{(4{,}16^2 + 5^2 + 10^2)} + 15{,}266 \sqrt{(5{,}07^2 + 5^2)} \right]$$

$$= 10{,}1 \text{ \%}$$

Table C.1 — Values of C_v in terms of $C_{dr}\left(\frac{h_1}{h_1 + p}\right)$ for rectangular profile weirs

$C_{dr}\left(\frac{h_1}{h_1+p}\right)$	Values of C_v									
	Increments of $C_{dr}\left(\frac{h_1}{h_1+p}\right)$									
	0,00	**0,01**	**0,02**	**0,03**	**0,04**	**0,05**	**0,06**	**0,07**	**0,08**	**0,09**
0,0	1,000	1,000	1,000	1,001	1,001	1,001	1,001	1,002	1,002	1,003
0,1	1,003	1,004	1,004	1,005	1,006	1,007	1,008	1,009	1,010	1,011
0,2	1,012	1,013	1,015	1,016	1,017	1,019	1,021	1,022	1,024	1,026
0,3	1,028	1,030	1,032	1,034	1,037	1,039	1,042	1,044	1,047	1,050
0,4	1,053	1.056	1,059	1,062	1,065	1,069	1,072	1,076	1,080	1,084
0,5	1,088	1,093	1,097	1,102	1,107	1,112	1,117	1,123	1,129	1,135
0,6	1,141	1,147	1,154	1,162	1,169	1,177	1,185	1,194	1,204	1,214
0,7	1,224	1,234	1,246	1,258	1,272	1,286	1,302			

NOTE 1 C_{dr} = 1 in the modular flow range ($h_p / H_1 \leqslant 0,24$).

NOTE 2 A rectangular approach channel is assumed.

Table C.2 — Modular discharge over a triangular profile weir per metre of crest in terms of upstream head

Head *H* m	Modular discharge *q* m³/s Increments of head, *H* m									
	0,000	**0,001**	**0,002**	**0,003**	**0,004**	**0,005**	**0,006**	**0,007**	**0,008**	**0,009**
0,000	0,000 00	0,000 06	0,000 18	0,000 33	0,000 50	0,000 70	0,000 92	0,001 16	0,001 42	0,001 69
0,010	0,001 98	0,002 29	0,002 61	0,002 94	0,003 28	0,003 64	0,004 01	0,004 39	0,004 79	0,005 19
0,020	0,005 61	0,006 03	0,006 47	0,006 92	0,007 37	0,007 84	0,008 31	0,008 80	0,009 29	0,009 79
0,030	0,010 30	0,010 82	0,011 35	0,011 89	0,012 43	0,012 98	0,013 54	0,014 11	0,014 69	0,015 27
0,040	0,015 86	0,016 46	0,017 07	0,017 68	0,018 30	0,018 93	0,019 56	0,020 20	0,020 85	0,021 50
0,050	0,022 17	0,022 83	0,023 51	0,024 19	0,024 88	0,025 57	0,026 27	0,026 98	0,027 69	0,028 41
0,060	0,029 14	0,029 87	0,030 61	0,031 35	0,032 10	0,032 86	0,033 62	0,034 38	0,035 16	0,035 93
0,070	0,036 72	0,037 51	0,038 30	0,039 10	0,039 91	0,040 72	0,041 54	0,042 36	0,043 19	0,044 02
0,080	0,044 86	0,045 71	0,046 55	0,047 41	0,048 27	0,049 13	0,050 00	0,050 88	0,051 76	0,052 64
0,090	0,053 53	0,054 43	0,055 32	0,056 23	0,057 14	0,058 05	0,058 97	0,059 90	0,060 82	0,061 76
0,100	0,062 70	0,063 64	0,064 59	0,065 54	0,066 49	0,067 46	0,068 42	0,069 39	0,070 37	0,071 35
0,110	0,072 33	0,073 32	0,074 31	0,075 31	0,076 31	0,077 32	0,078 33	0,079 34	0,080 36	0,081 39
0,120	0,082 42	0,083 45	0,084 48	0,085 53	0,086 57	0,087 62	0,088 67	0,089 73	0,090 79	0,091 86
0,130	0,092 93	0,094 00	0,095 08	0,096 16	0,097 25	0,098 34	0,099 44	0,100 54	0,101 64	0,102 74
0,140	0,103 86	0,104 97	0,106 09	0,107 21	0,108 34	0,109 47	0,110 60	0,111 74	0,112 88	0,114 03
0,150	0,115 18	0,116 33	0,117 49	0,118 65	0,119 82	0,120 99	0,122 16	0,123 34	0,124 52	0,125 70
0,160	0,126 89	0,128 08	0,129 27	0,130 47	0,131 68	0,132 88	0,134 09	0,135 30	0,136 52	0,137 74
0,170	0,138 97	0,140 19	0,141 43	0,142 66	0,143 90	0,145 14	0,146 39	0,147 64	0,148 89	0,150 15
0,180	0,151 41	0,152 67	0,153 94	0,155 21	0,156 48	0,157 76	0,159 04	0,160 32	0,161 61	0,162 90
0,190	0,164 20	0,165 50	0,166 80	0,168 10	0,169 41	0,170 72	0,172 04	0,173 36	0,174 68	0,176 00
0,200	0,177 33	0,178 66	0,180 00	0,181 34	0,182 68	0,184 02	0,185 37	0,186 72	0,188 08	0,189 43
0,210	0,190 80	0,192 16	0,193 53	0,194 90	0,196 27	0,197 65	0,199 03	0,200 41	0,201 80	0,203 19
0,220	0,204 58	0,205 98	0,207 38	0,208 78	0,210 19	0,211 60	0,213 01	0,214 43	0,215 84	0,217 27
0,230	0,218 69	0,220 12	0,221 55	0,222 98	0,224 42	0,225 86	0,227 30	0,228 75	0,230 20	0,231 65
0,240	0,233 11	0,234 57	0,236 03	0,237 49	0,238 96	0,240 43	0,241 90	0,243 38	0,244 86	0,246 34
0,250	0,247 83	0,249 32	0,250 81	0,252 30	0,253 80	0,255 30	0,256 80	0,258 31	0,259 82	0,261 33
0,260	0,262 84	0,264 36	0,265 88	0,267 41	0,268 93	0,270 46	0,271 99	0,273 53	0,275 07	0,276 61
0,270	0,278 15	0,279 70	0,281 25	0,282 80	0,284 36	0,285 92	0,287 48	0,289 04	0,290 61	0,292 18
0,280	0,293 75	0,295 32	0,296 90	0,298 48	0,300 07	0,301 65	0,303 24	0,304 83	0,306 43	0,308 02
0,290	0,309 62	0,311 23	0,312 83	0,314 44	0,316 05	0,317 67	0,319 28	0,320 90	0,322 52	0,324 15
0,300	0,325 78	0,327 41	0,329 04	0,330 68	0,332 31	0,333 96	0,335 60	0,337 25	0,338 89	0,340 55
0,310	0,342 20	0,343 86	0,345 52	0,347 18	0,348 85	0,350 51	0,352 18	0,353 86	0,355 53	0,357 21
0,320	0,358 89	0,360 58	0,362 26	0,363 95	0,365 64	0,367 34	0,369 03	0,370 73	0,372 43	0,374 14
0,330	0,375 85	0,377 55	0,379 27	0,380 98	0,382 70	0,384 42	0,386 14	0,387 87	0,389 59	0,391 33
0,340	0,393 06	0,394 79	0,396 53	0,398 27	0,400 01	0,401 76	0,403 51	0,405 26	0,407 01	0,408 77
0,350	0,410 53	0,412 29	0,414 05	0,415 82	0,417 58	0,419 35	0,421 13	0,422 90	0,424 68	0,426 46
0,360	0,428 24	0,430 03	0,431 82	0,433 61	0,435 40	0,437 20	0,439 00	0,440 80	0,442 60	0,444 40
0,370	0,446 21	0,448 02	0,449 83	0,451 65	0,453 47	0,455 29	0,457 11	0,458 93	0,460 76	0,462 59
0,380	0,464 42	0,466 26	0,468 09	0,469 93	0,471 78	0,473 62	0,475 47	0,477 31	0,479 17	0,481 02
0,390	0,482 88	0,484 73	0,486 59	0,488 46	0,490 32	0,492 19	0,494 06	0,495 93	0,497 81	0,499 69

Table C.2 — Modular discharge over a triangular profile weir per metre of crest in terms of upstream head *(continued)*

Head H m	Modular discharge q m^3/s									
	Increments of head, H m									
	0,000	0,001	0,002	0,003	0,004	0,005	0,006	0,007	0,008	0,009
0,400	0,501 57	0,503 45	0,505 33	0,507 22	0,509 11	0,511 00	0,512 89	0,514 79	0,516 69	0,518 59
0,410	0,520 49	0,522 40	0,524 31	0,526 22	0,528 13	0,530 04	0,531 96	0,533 88	0,535 80	0,537 72
0,420	0,539 65	0,541 58	0,543 51	0,545 44	0,547 38	0,549 32	0,551 26	0,553 20	0,555 14	0,557 09
0,430	0,559 04	0,560 99	0,562 94	0,564 90	0,566 86	0,568 82	0,570 78	0,572 74	0,574 71	0,576 68
0,440	0,578 65	0,580 63	0,582 60	0,584 58	0,586 56	0,588 54	0,590 53	0,592 52	0,594 50	0,596 50
0,450	0,598 49	0,600 49	0,602 48	0,604 48	0,606 49	0,608 49	0,610 50	0,612 51	0,614 52	0,616 53
0,460	0,618 55	0,620 57	0,622 59	0,624 61	0,626 64	0,628 66	0,630 69	0,632 72	0,634 76	0,636 79
0,470	0,638 83	0,640 87	0,642 91	0,644 96	0,647 00	0,649 05	0,651 10	0,653 15	0,655 21	0,657 27
0,480	0,659 33	0,661 39	0,663 45	0,665 52	0,667 58	0,669 65	0,671 73	0,673 80	0,675 88	0,677 96
0,490	0,680 04	0,682 12	0,684 20	0,686 29	0,688 38	0,690 47	0,692 57	0,694 66	0,696 76	0,698 86
0,500	0,700 96	0,703 06	0,705 17	0,707 28	0,709 39	0,711 50	0,713 62	0,715 73	0,717 85	0,719 97
0,510	0,722 09	0,724 22	0,726 35	0,728 47	0,730 61	0,732 74	0,734 87	0,737 01	0,739 15	0,741 29
0,520	0,743 44	0,745 58	0,747 73	0,749 88	0,752 03	0,754 18	0,756 34	0,758 50	0,760 66	0,762 82
0,530	0,764 98	0,767 15	0,769 32	0,771 49	0,773 66	0,775 83	0,778 01	0,780 19	0,782 37	0,784 55
0,540	0,786 74	0,788 92	0,791 11	0,793 30	0,795 49	0,797 69	0,799 88	0,802 08	0,804 28	0,806 49
0,550	0,808 69	0,810 90	0,813 11	0,815 32	0,817 53	0,819 74	0,821 96	0,824 18	0,826 40	0,828 62
0,560	0,830 85	0,833 07	0,835 30	0,837 53	0,839 76	0,842 00	0,844 23	0,846 47	0,848 71	0,850 96
0,570	0,853 20	0,855 45	0,857 69	0,859 94	0,862 20	0,864 45	0,866 71	0,868 96	0,871 22	0,873 49
0,580	0,875 75	0,878 02	0,880 28	0,882 55	0,884 83	0,887 10	0,889 37	0,891 65	0,893 93	0,896 21
0,590	0,898 50	0,900 78	0,903 07	0,905 36	0,907 65	0,909 94	0,912 24	0,914 53	0,916 83	0,919 13
0,600	0,921 44	0,923 74	0,926 05	0,928 36	0,930 67	0,932 98	0,935 29	0,937 61	0,939 93	0,942 25
0,610	0,944 57	0,946 89	0,949 22	0,951 54	0,953 87	0,956 20	0,958 54	0,960 87	0,963 21	0,965 55
0,620	0,967 89	0,970 23	0,972 58	0,974 92	0,977 27	0,979 62	0,981 97	0,984 33	0,986 68	0,989 04
0,630	0,991 40	0,993 76	0,996 12	0,998 49	1,000 86	1,003 23	1,005 60	1,007 97	1,010 34	1,012 72
0,640	1,015 10	1,017 48	1,019 86	1,022 24	1,024 63	1,027 02	1,029 41	1,031 80	1,034 19	1,036 59
0,650	1,038 98	1,041 38	1,043 78	1,046 18	1,048 59	1,050 99	1,053 40	1,055 81	1,058 22	1,060 64
0,660	1,063 05	1,065 47	1,067 89	1,070 31	1,072 73	1,075 15	1,077 58	1,080 01	1,082 44	1,084 87
0,670	1,087 30	1,089 74	1,092 17	1,094 61	1,097 05	1,099 50	1,101 94	1,104 39	1,106 83	1,109 28
0,680	1,111 74	1,114 19	1,116 64	1,119 10	1,121 56	1,124 02	1,126 48	1,128 95	1,131 41	1,133 88
0,690	1,136 35	1,138 82	1,141 29	1,143 77	1,146 24	1,148 72	1,151 20	1,153 69	1,156 17	1,158 65
0,700	1,161 14	1,163 63	1,166 12	1,168 61	1,171 11	1,173 60	1,176 10	1,178 60	1,181 10	1,183 61
0,710	1,186 11	1,188 62	1,191 13	1,193 64	1,196 15	1,198 66	1,201 18	1,203 70	1,206 22	1,208 74
0,720	1,211 26	1,213 78	1,216 31	1,218 84	1,221 37	1,223 90	1,226 43	1,228 97	1,231 50	1,234 04
0,730	1,236 58	1,239 12	1,241 67	1,244 21	1,246 76	1,249 31	1,251 86	1,254 41	1,256 96	1,259 52
0,740	1,262 08	1,264 64	1,267 20	1,269 76	1,272 32	1,274 89	1,277 46	1,280 03	1,282 60	1,285 17
0,750	1,287 75	1,290 32	1,292 90	1,295 48	1,298 06	1,300 64	1,303 23	1,305 82	1,308 40	1,310 99
0,760	1,313 59	1,316 18	1,318 77	1,321 37	1,323 97	1,326 57	1,329 17	1,331 78	1,334 38	1,336 99
0,770	1,339 60	1,342 21	1,344 82	1,347 43	1,350 05	1,352 67	1,355 29	1,357 91	1,360 53	1,363 15
0,780	1,365 78	1,368 41	1,371 03	1,373 67	1,376 30	1,378 93	1,381 57	1,384 20	1,386 84	1,389 48
0,790	1,392 13	1,394 77	1,397 42	1,400 06	1,402 71	1,405 36	1,408 02	1,410 67	1,413 33	1,415 98

Table C.2 — Modular discharge over a triangular profile weir per metre of crest in terms of upstream head *(continued)*

Head H m	Modular discharge q m³/s									
	Increments of head, H m									
	0,000	0,001	0,002	0,003	0,004	0,005	0,006	0,007	0,008	0,009
0,800	1,418 64	1,421 30	1,423 97	1,426 63	1,429 30	1,431 96	1,434 63	1,437 30	1,439 98	1,442 65
0,810	1,445 33	1,448 00	1,450 68	1,453 36	1,456 05	1,458 73	1,461 41	1,464 10	1,466 79	1,469 48
0,820	1,472 17	1,474 87	1,477 56	1,480 26	1,482 96	1,485 66	1,488 36	1,491 06	1,493 77	1,496 48
0,830	1,499 19	1,501 90	1,504 61	1,507 32	1,510 04	1,512 75	1,515 47	1,518 19	1,520 91	1,523 64
0,840	1,526 36	1,529 09	1,531 82	1,534 54	1,537 28	1,540 01	1,542 74	1,545 48	1,548 22	1,550 96
0,850	1,553 70	1,556 44	1,559 18	1,561 93	1,564 68	1,567 43	1,570 18	1,572 93	1,575 68	1,578 44
0,860	1,581 20	1,583 96	1,586 72	1,589 48	1,592 24	1,595 01	1,597 77	1,600 54	1,603 31	1,606 08
0,870	1,608 86	1,611 63	1,614 41	1,617 18	1,619 96	1,622 75	1,625 53	1,628 31	1,631 10	1,633 89
0,880	1,636 67	1,639 46	1,642 26	1,645 05	1,647 85	1,650 64	1,653 44	1,656 24	1,659 04	1,661 85
0,890	1,664 65	1,667 46	1,670 27	1,673 07	1,675 89	1,678 70	1,681 51	1,684 33	1,687 15	1,689 97
0,900	1,692 79	1,695 61	1,698 43	1,701 26	1,704 08	1,706 91	1,709 74	1,712 57	1,715 41	1,718 24
0,910	1,721 08	1,723 91	1,726 75	1,729 59	1,732 44	1,735 28	1,738 13	1,740 97	1,743 82	1,746 67
0,920	1,749 52	1,752 38	1,755 23	1,758 09	1,760 95	1,763 81	1,766 67	1,769 53	1,772 39	1,775 26
0,930	1,778 13	1,781 00	1,783 87	1,786 74	1,789 61	1,792 49	1,795 36	1,798 24	1,801 12	1,804 00
0,940	1,806 88	1,809 77	1,812 65	1,815 54	1,818 43	1,821 32	1,824 21	1,827 10	1,830 00	1,832 89
0,950	1,835 79	1,838 69	1,841 59	1,844 50	1,847 40	1,850 30	1,853 21	1,856 12	1,859 03	1,861 94
0,960	1,864 85	1,867 77	1,870 69	1,873 60	1,876 52	1,879 44	1,882 37	1,885 29	1,888 21	1,891 14
0,970	1,894 07	1,897 00	1,899 93	1,902 86	1,905 80	1,908 73	1,911 67	1,914 61	1,917 55	1,920 49
0,980	1,923 43	1,926 38	1,929 33	1,932 27	1,935 22	1,938 17	1,941 13	1,944 08	1,947 03	1,949 99
0,990	1,952 95	1,955 91	1,958 87	1,961 83	1,964 80	1,967 76	1,970 73	1,973 70	1,976 67	1,979 64
1,000	1,982 61	1,985 59	1,988 57	1,991 54	1,994 52	1,997 50	2,000 48	2,003 47	2,006 45	2,009 44
1,010	2,012 43	2,015 42	2,018 41	2,021 40	2,024 39	2,027 39	2,030 39	2,033 39	2,036 38	2,039 39
1,020	2,042 39	2,045 39	2,048 40	2,051 41	2,054 41	2,057 42	2,060 44	2,063 45	2,066 46	2,069 48
1,030	2,072 50	2,075 52	2,078 54	2,081 56	2,084 58	2,087 61	2,090 63	2,093 66	2,096 69	2,099 72
1,040	2,102 75	2,105 79	2,108 82	2,111 86	2,114 90	2,117 94	2,120 98	2,124 02	2,127 06	2,130 11
1,050	2,133 15	2,136 20	2,139 25	2,142 30	2,145 35	2,148 41	2,151 46	2,154 52	2,157 58	2,160 64
1,060	2,163 70	2,166 76	2,169 83	2,172 89	2,175 96	2,179 03	2,182 10	2,185 17	2,188 24	2,191 31
1,070	2,194 39	2,197 47	2,200 55	2,203 63	2,206 71	2,209 79	2,212 87	2,215 96	2,219 05	2,222 13
1,080	2,225 22	2,228 32	2,231 41	2,234 50	2,237 60	2,240 70	2,243 79	2,246 89	2,250 00	2,253 10
1,090	2,256 20	2,259 31	2,262 41	2,265 52	2,268 63	2,271 74	2,274 86	2,277 97	2,281 09	2,284 20
1,100	2,287 32	2,290 44	2,293 56	2,296 69	2,299 81	2,302 93	2,306 06	2,309 19	2,312 32	2,315 45
1,110	2,318 58	2,321 72	2,324 85	2,327 99	2,331 13	2,334 27	2,337 41	2,340 55	2,343 69	2,346 84
1,120	2,349 99	2,353 13	2,356 28	2,359 43	2,362 59	2,365 74	2,368 89	2,372 05	2,375 21	2,378 37
1,130	2,381 53	2,384 69	2,387 85	2,391 02	2,394 19	2,397 35	2,400 52	2,403 69	2,406 86	2,410 04
1,140	2,413 21	2,416 39	2,419 57	2,422 74	2,425 92	2,429 11	2,432 29	2,435 47	2,438 66	2,441 85
1,150	2,445 03	2,448 22	2,451 42	2,454 61	2,457 80	2,461 00	2,464 19	2,467 39	2,470 59	2,473 79
1,160	2,477 00	2,480 20	2,483 40	2,486 61	2,489 82	2,493 03	2,496 24	2,499 45	2,502 66	2,505 88
1,170	2,509 09	2,512 31	2,515 53	2,518 75	2,521 97	2,525 20	2,528 42	2,531 65	2,534 87	2,538 10
1,180	2,541 33	2,544 56	2,547 79	2,551 03	2,554 26	2,557 50	2,560 74	2,563 98	2,567 22	2,570 46
1,190	2,573 70	2,576 95	2,580 20	2,583 44	2,586 69	2,589 94	2,593 19	2,596 45	2,599 70	2,602 96

Table C.2 — Modular discharge over a triangular profile weir per metre of crest in terms of upstream head *(continued)*

Head H m	Modular discharge q m^3/s — Increments of head, H m									
	0,000	**0,001**	**0,002**	**0,003**	**0,004**	**0,005**	**0,006**	**0,007**	**0,008**	**0,009**
1,200	2,606 21	2,609 47	2,612 73	2,615 99	2,619 26	2,622 52	2,625 79	2,629 05	2,632 32	2,635 59
1,210	2,638 86	2,642 13	2,645 40	2,648 68	2,651 96	2,655 23	2,658 51	2,661 79	2,665 07	2,668 36
1,220	2,671 54	2,674 93	2,678 21	2,681 50	2,684 79	2,688 08	2,691 37	2,694 67	2,697 96	2,701 26
1,230	2,704 56	2,707 85	2,711 15	2,714 46	2,717 76	2,721 06	2,724 37	2,727 68	2,730 98	2,734 29
1,240	2,737 60	2,740 92	2,744 23	2,747 55	2,750 86	2,754 18	2,757 50	2,760 82	2,764 14	2,767 46
1,250	2,770 79	2,774 11	2,777 44	2,780 77	2,784 10	2,787 43	2,790 76	2,794 09	2,797 43	2,800 77
1,260	2,804 10	2,807 44	2,810 78	2,814 12	2,817 47	2,820 81	2,824 16	2,827 50	2,830 85	2,834 20
1,270	2,837 55	2,840 90	2,844 26	2,847 61	2,850 97	2,854 33	2,857 68	2,861 04	2,864 41	2,867 77
1,280	2,871 13	2,874 50	2,877 86	2,881 23	2,884 60	2,887 97	2,891 34	2,894 72	2,898 09	2,901 47
1,290	2,904 84	2,908 22	2,911 60	2,914 98	2,918 37	2,921 75	2,925 13	2,928 52	2,931 91	2,935 30
1,300	2,938 69	2,942 08	2,945 47	2,948 86	2,952 26	2,955 66	2,959 05	2,962 45	2,965 85	2,969 26
1,310	2,972 66	2,976 06	2,979 47	2,982 88	2,986 29	2,989 69	2,993 11	2,996 52	2,999 93	3,003 35
1,320	3,006 76	3,010 18	3,013 60	3,017 02	3,020 44	3,023 86	3,027 29	3,030 71	3,034 14	3,037 57
1,330	3,040 99	3,044 43	3,047 86	3,051 29	3,054 12	3,058 16	3,061 60	3,065 03	3,068 47	3,071 91
1,340	3,075 36	3,078 80	3,082 24	3,085 69	3,089 14	3,092 58	3,096 03	3,099 49	3,102 94	3,106 39
1,350	3,109 85	3,113 30	3,116 76	3,120 22	3,123 68	3,127 14	3,130 60	3,134 06	3,137 53	3,141 00
1,360	3,144 46	3,147 93	3,151 40	3,154 87	3,158 35	3,161 82	3,165 30	3,168 77	3,172 25	3,175 73
1,370	3,179 21	3,182 69	3,186 17	3,189 66	3,193 14	3,196 63	3,200 12	3,203 61	3,207 10	3,210 59
1,380	3,214 08	3,217 58	3,221 07	3,224 57	3,228 07	3,231 56	3,235 07	3,238 57	3,242 07	3,245 57
1,390	3,249 08	3,252 59	3,256 09	3,259 60	3,263 11	3,266 63	3,270 14	3,273 65	3,277 17	3,280 69
1,400	3,284 21	3,287 72	3,291 25	3,294 77	3,298 29	3,301 81	3,305 34	3,308 87	3,312 40	3,315 93
1,410	3,319 46	3,322 99	3,326 52	3,330 06	3,333 59	3,337 13	3,340 67	3,344 21	3,347 75	3,351 29
1,420	3,354 83	3,358 38	3,361 92	3,365 47	3,369 02	3,372 57	3,376 12	3,379 67	3,383 22	3,386 78
1,430	3,390 33	3,393 89	3,397 45	3,401 01	3,404 57	3,408 13	3,411 69	3,415 26	3,418 82	3,422 39
1,440	3,425 96	3,429 53	3,433 10	3,436 67	3,440 24	3,443 82	3,447 39	3,450 97	3,454 55	3,458 13
1,450	3,461 71	3,465 29	3,468 87	3,472 46	3,476 04	3,479 63	3,483 21	3,486 80	3,490 39	3,493 99
1,460	3,497 58	3,501 17	3,504 77	3,508 36	3,511 96	3,515 56	3,519 16	3,522 76	3,526 37	3,529 97
1,470	3,533 57	3,537 18	3,540 79	3,544 40	3,548 01	3,551 62	3,555 23	3,558 84	3,562 46	3,566 08
1,480	3,569 69	3,573 31	3,576 93	3,580 55	3,584 17	3,587 80	3,591 42	3,595 05	3,598 67	3,602 30
1,490	3,605 93	3,609 56	3,613 20	3,616 83	3,620 46	3,624 10	3,627 74	3,631 37	3,635 01	3,638 65
1,500	3,642 29	3,645 94	3,649 58	3,653 23	3,656 87	3,660 52	3,664 17	3,667 82	3,671 47	3,675 12
1,510	3,678 78	3,682 43	3,686 09	3,689 75	3,693 41	3,697 07	3,700 73	3,704 39	3,708 05	3,711 72
1,520	3,715 38	3,719 05	3,722 72	3,726 39	3,730 06	3,733 73	3,737 40	3,741 08	3,744 75	3,748 43
1,530	3,752 11	3,755 79	3,759 47	3,763 15	3,766 83	3,770 52	3,774 20	3,777 89	3,781 57	3,785 26
1,540	3,788 95	3,792 64	3,796 34	3,800 03	3,803 73	3,807 42	3,811 12	3,814 82	3,818 52	3,822 22
1,550	3,825 92	3,829 62	3,833 33	3,837 03	3,840 74	3,844 45	3,848 16	3,851 87	3,855 58	3,859 29
1,560	3,863 00	3,866 72	3,870 43	3,874 15	3,877 87	3,881 59	3,885 31	3,889 03	3,892 76	3,896 48
1,570	3,900 21	3,903 93	3,907 66	3,911 39	3,915 12	3,918 85	3,922 59	3,926 32	3,930 06	3,933 79
1,580	3,937 53	3,941 27	3,945 01	3,948 75	3,952 49	3,956 24	3,959 98	3,963 73	3,967 47	3,971 22
1,590	3,974 97	3,978 72	3,982 47	3,986 23	3,989 98	3,993 74	3,997 49	4,001 25	4,005 01	4,008 77

Table C.2 — Modular discharge over a triangular profile weir per metre of crest in terms of upstream head *(continued)*

Head H m	Modular discharge q m^3/s									
	Increments of head, H m									
	0,000	**0,001**	**0,002**	**0,003**	**0,004**	**0,005**	**0,006**	**0,007**	**0,008**	**0,009**
1,600	4,012 53	4,016 29	4,020 05	4,023 82	4,027 59	4,031 35	4,035 12	4,038 89	4,042 66	4,046 43
1,610	4,050 21	4,053 98	4,057 75	4,061 53	4,065 31	4,069 09	4,072 87	4,076 65	4,080 43	4,084 21
1,620	4,088 00	4,091 78	4,095 57	4,099 36	4,103 15	4,106 94	4,110 73	4,114 52	4,118 32	4,122 11
1,630	4,125 91	4,129 71	4,133 50	4,137 30	4,141 11	4,144 91	4,148 71	4,152 52	4,156 32	4,160 13
1,640	4,163 94	4,167 74	4,171 55	4,175 37	4,179 18	4,182 99	4,186 81	4,190 62	4,194 44	4,198 26
1,650	4,202 08	4,205 90	4,209 72	4,213 54	4,217 37	4,221 19	4,225 02	4,228 85	4,232 68	4,236 51
1,660	4,240 34	4,244 17	4,248 00	4,251 84	4,255 67	4,259 51	4,263 35	4,267 19	4,271 03	4,274 87
1,670	4,278 71	4,282 55	4,286 40	4,290 25	4,294 09	4,297 94	4,301 79	4,305 64	4,309 49	4,313 35
1,680	4,317 20	4,321 05	4,324 91	4,328 77	4,332 63	4,336 49	4,340 35	4,344 21	4,348 07	4,351 94
1,690	4,355 80	4,359 67	4,363 54	4,367 41	4,371 28	4,375 15	4,379 02	3,382 89	4,386 77	4,390 64
1,700	4,394 52	4,398 40	4,402 28	4,406 16	4,410 04	4,413 92	4,417 81	4,421 69	4,425 58	4,429 47
1,710	4,433 35	4,437 24	4,441 13	4,445 03	4,448 92	4,452 81	4,456 71	4,460 60	4,464 50	4,468 40
1,720	4,472 30	4,476 20	4,480 10	4,484 01	4,487 91	4,491 82	4,495 72	4,499 63	4,503 54	4,507 45
1,730	4,511 36	4,515 27	4,519 18	4,523 10	4,527 01	4,530 93	4,534 85	4,538 77	4,542 69	4,546 61
1,740	4,550 53	4,554 45	4,558 38	4,562 30	4,566 23	4,570 16	4,574 09	4,578 02	4,581 95	4,585 88
1,750	4,589 82	4,593 75	4,597 69	4,601 62	4,605 56	4,609 50	4,613 44	4,617 38	4,621 33	4,625 27
1,760	4,629 21	4,633 16	4,637 11	4,641 05	4,645 00	4,648 95	4,652 91	4,656 86	4,660 81	4,664 77
1,770	4,668 72	4,672 68	4,676 64	4,680 60	4,684 56	4,688 52	4,692 48	4,696 45	4,700 41	4,704 38
1,780	4,708 34	4,712 31	4,716 28	4,720 25	4,724 22	4,728 20	4,732 17	4,736 15	4,740 12	4,744 10
1,790	4,748 08	4,752 06	4,756 04	4,760 02	4,764 00	4,767 99	4,771 97	4,775 96	4,779 94	4,783 93
1,800	4,787 92	4,791 91	4,795 90	4,799 90	4,803 89	4,807 88	4,811 88	4,185 88	4,819 88	4,823 88
1,810	4,827 88	4,831 88	4,835 88	4,839 88	4,843 89	4,847 89	4,851 90	4,855 91	4,859 92	4,863 93
1,820	4,867 94	4,871 95	4,875 97	4,879 98	4,884 00	4,888 01	4,892 03	4,896 05	4,900 07	4,904 09
1,830	4,908 12	4,912 14	4,916 16	4,920 19	4,924 22	4,928 25	4,932 27	4,936 30	4,940 34	4,944 37
1,840	4,948 40	4,952 44	4,956 47	4,960 51	4,964 55	4,968 59	4,972 63	4,976 67	4,980 71	4,984 75
1,850	4,988 80	4,992 84	4,996 89	5,000 94	5,004 99	5,009 04	5,013 09	5,017 14	5,021 19	5,025 25
1,860	5,029 30	5,033 36	5,037 41	5,041 47	5,045 53	5,049 59	5,053 66	5,057 72	5,061 78	5,065 85
1,870	5,069 91	5,073 98	5,078 05	5,082 12	5,086 19	5,090 26	5,094 33	5,098 41	5,102 48	5,106 56
1,880	5,110 64	5,114 71	5,118 79	5,122 87	5,126 96	5,131 04	5,135 12	5,139 21	5,143 29	5,147 38
1,890	5,151 47	5,155 56	5,159 65	5,163 74	5,167 83	5,171 92	5,176 02	5,180 11	5,184 21	5,188 31
1,900	5,192 41	5,196 51	5,200 61	5,204 71	5,208 81	5,212 92	5,217 02	5,221 13	5,225 23	5,229 34
1,910	5,233 45	5,237 56	5,241 67	5,245 79	5,249 90	5,254 02	5,258 13	5,262 25	5,266 37	5,270 49
1,920	5,274 61	5,278 73	5,282 85	5,286 97	5,291 10	5,295 22	5,299 35	5,303 48	5,307 61	5,311 74
1,930	5,315 87	5,320 00	5,324 13	5,328 27	5,332 40	5,336 54	5,340 68	5,344 81	5,348 95	5,353 09
1,940	5,357 24	5,361 38	5,365 52	5,369 67	5,373 81	5,377 96	5,382 11	5,386 26	5,390 41	5,394 56
1,950	5,398 71	5,402 87	5,407 02	5,411 17	5,415 33	5,419 49	5,423 65	5,427 81	5,431 97	5,436 13
1,960	5,440 29	5,444 46	5,448 62	5,452 79	5,456 96	5,461 12	5,465 29	5,469 46	5,473 64	5,477 81
1,970	5,481 98	5,486 16	5,490 33	5,494 51	5,498 69	5,502 87	5,507 04	5,511 23	5,515 41	5,519 59
1,980	5,523 78	5,527 96	5,532 15	5,536 33	5,540 52	5,544 71	5,548 90	5,553 09	5,557 29	5,561 48
1,990	5,565 67	5,569 87	5,574 07	5,578 27	5,582 46	5,586 66	5,590 87	5,595 07	5,599 27	5,603 47

Table C.2 — Modular discharge over a triangular profile weir per metre of crest in terms of upstream head *(continued)*

Head H m	Modular discharge q m³/s									
	Increments of head, H m									
	0,000	**0,001**	**0,002**	**0,003**	**0,004**	**0,005**	**0,006**	**0,007**	**0,008**	**0,009**
2,000	5,607 68	5,611 89	5,616 09	5,620 30	5,624 51	5,628 72	5,632 93	5,637 15	5,641 36	5,645 57
2,010	5,649 79	5,654 01	5,658 22	5,662 44	5,666 66	5,670 88	5,675 11	5,679 33	5,683 55	5,687 78
2,020	5,692 00	5,696 23	5,700 46	5,704 69	5,708 92	5,713 15	5,717 38	5,721 62	5,725 85	5,730 09
2,030	5,734 32	5,738 56	5,742 80	5,747 04	5,751 28	5,755 52	5,759 77	5,764 01	5,768 26	5,772 50
2,040	5,776 75	5,781 00	5,785 25	5,789 50	5,793 75	5,798 00	5,802 25	5,806 51	5,810 76	5,815 02
2,050	5,819 28	5,823 54	5,827 79	5,832 06	5,836 32	5,840 58	5,844 84	5,849 11	5,853 37	5,857 64
2,060	5,861 91	5,866 18	5,870 45	5,874 72	5,878 99	5,883 26	5,887 54	5,891 81	5,896 09	5,900 37
2,070	5,904 64	5,908 92	5,913 20	5,917 49	5,921 77	5,926 05	5,930 34	5,934 62	5,938 91	5,943 19
2,080	5,947 48	5,951 77	5,956 06	5,960 35	5,964 65	5,968 94	5,973 24	5,977 53	5,981 83	5,986 13
2,090	5,990 43	5,994 72	5,999 03	6,003 33	6,007 63	6,011 93	6,016 24	6,020 55	6,024 85	6,029 16
2,100	6,033 47	6,037 78	6,042 09	6,046 40	6,050 72	6,055 03	6,059 35	6,063 66	6,067 98	6,072 30
2,110	6,076 62	6,080 94	6,085 26	6,089 58	6,093 91	6,098 23	6,102 56	6,106 88	6,111 21	6,115 54
2,120	6,119 87	6,124 20	6,128 53	6,132 86	6,137 20	6,141 53	6,145 87	6,150 20	6,154 54	6,158 88
2,130	6,163 22	6,167 56	6,171 90	6,176 24	6,180 59	6,184 93	6,189 28	6,193 63	6,197 97	6,202 32
2,140	6,206 67	6,211 02	6,215 38	6,219 73	6,224 08	6,228 44	6,232 79	6,237 15	6,241 51	6,245 87
2,150	6,250 23	6,254 59	6,258 95	6,263 32	6,267 68	6,272 04	6,276 41	6,280 78	6,285 15	6,289 52
2,160	6,293 89	6,298 26	6,302 63	6,307 00	6,311 38	6,315 75	6,320 13	6,324 51	6,328 88	6,333 26
2,170	6,337 64	6,342 02	6,346 41	6,350 79	6,355 18	6,359 56	6,363 95	6,368 33	6,372 72	6,377 11
2,180	6,381 50	6,385 89	6,390 29	6,394 68	6,399 07	6,403 47	6,407 87	6,412 26	6,416 66	6,421 06
2,190	6,425 46	6,429 86	6,434 27	6,438 67	6,443 07	6,447 48	6,451 89	6,456 29	6,460 70	6,465 11
2,200	6,469 52	6,473 93	6,478 35	6,482 76	6,487 17	6,491 59	6,496 01	6,500 42	6,504 84	6,509 26
2,210	6,513 68	6,518 10	6,522 53	6,526 95	6,531 38	6,535 80	6,540 23	6,544 65	6,549 08	6,553 51
2,220	6,557 94	6,562 38	6,566 81	6,571 24	6,575 68	6,580 11	6,584 55	6,588 99	6,593 42	6,597 86
2,230	6,602 30	6,606 75	6,611 19	6,615 63	6,620 08	6,624 52	6,628 97	6,633 42	6,637 86	6,642 31
2,240	6,646 76	6,651 22	6,655 67	6,660 12	6,664 58	6,669 03	6,673 49	6,677 94	6,682 40	6,686 86
2,250	6,691 32	6,695 78	6,700 25	6,704 71	6,709 17	6,713 64	6,718 11	6,722 57	6,727 04	6,731 51
2,260	6,735 98	6,740 45	6,744 92	6,749 40	6,753 87	6,758 35	6,762 82	6,767 30	6,771 78	6,776 26
2,270	6,780 74	6,785 22	6,789 70	6,794 18	6,798 67	6,803 15	6,807 64	6,812 13	6,816 62	6,821 10
2,280	6,825 59	6,830 09	6,834 58	6,839 07	6,843 56	6,848 06	6,852 56	6,857 05	6,861 55	6,866 05
2,290	6,870 55	6,875 05	6,879 55	6,884 05	6,888 56	6,893 06	6,897 57	6,902 08	6,906 58	6,911 09
2,300	6,915 60	6,920 11	6,924 62	6,929 14	6,933 65	6,938 16	6,942 68	6,947 20	6,951 71	6,956 23
2,310	6,960 75	6,965 27	6,969 79	6,974 32	6,978 84	6,983 36	6,987 89	6,992 42	6,996 94	7,001 47
2,320	7,006 00	7,010 53	7,015 06	7,019 59	7,024 13	7,028 66	7,033 20	7,037 73	7,042 27	7,046 81
2,330	7,051 35	7,055 89	7,060 43	7,064 97	7,069 51	7,074 06	7,078 60	7,083 15	7,087 69	7,092 24
2,340	7,096 79	7,101 34	7,105 89	7,110 44	7,115 00	7,119 55	7,124 10	7,128 66	7,133 22	7,137 77
2,350	7,142 33	7,146 89	7,151 45	7,156 01	7,160 58	7,165 14	7,169 70	7,174 27	7,178 83	7,183 40
2,360	7,187 97	7,192 54	7,197 11	7,201 68	7,206 25	7,210 82	7,215 40	7,219 97	7,224 55	7,229 13
2,370	7,233 70	7,238 28	7,242 86	7,247 44	7,252 02	7,256 61	7,261 19	7,265 78	7,270 36	7,274 95
2,380	7,279 54	7,284 12	7,288 71	7,293 30	7,297 89	7,302 49	7,307 08	7,311 67	7,316 27	7,320 87
2,390	7,325 46	7,330 06	7,334 66	7,339 26	7,343 86	7,348 46	7,353 07	7,357 67	7,362 27	7,366 88

Table C.2 — Modular discharge over a triangular profile weir per metre of crest in terms of upstream head *(continued)*

Head H m	Modular discharge q m³/s									
	Increments of head, H m									
	0,000	**0,001**	**0,002**	**0,003**	**0,004**	**0,005**	**0,006**	**0,007**	**0,008**	**0,009**
2,400	7,371 49	7,376 09	7,380 70	7,385 31	7,389 92	7,394 53	7,399 15	7,403 76	7,408 37	7,412 99
2,410	7,417 61	7,422 22	7,426 84	7,431 46	7,436 08	7,440 70	7,445 32	7,449 95	7,454 57	7,459 20
2,420	7,463 82	7,468 45	7,473 08	7,477 71	7,482 33	7,486 97	7,491 60	7,496 23	7,500 86	7,505 50
2,430	7,510 13	7,514 77	7,519 41	7,524 04	7,528 68	7,533 32	7,537 97	7,542 61	7,547 25	7,551 89
2,440	7,556 54	7,561 19	7,565 83	7,570 48	7,575 13	7,579 78	7,584 43	7,589 08	7,593 73	7,598 39
2,450	7,603 04	7,607 70	7,612 35	7,617 01	7,621 67	7,626 33	7,630 99	7,635 65	7,640 31	7,644 97
2,460	7,649 64	7,654 30	7,658 97	7,663 64	7,668 30	7,672 97	7,677 64	7,682 31	7,686 98	7,691 66
2,470	7,696 33	7,701 00	7,705 68	7,710 36	7,715 03	7,719 71	7,724 39	7,729 07	7,733 75	7,738 43
2,480	7,743 21	7,747 80	7,752 48	7,757 17	7,761 86	7,766 54	7,771 23	7,775 92	7,780 61	7,785 30
2,490	7,790 00	7,794 69	7,799 38	7,804 08	7,808 77	7,813 47	7,818 17	7,822 87	7,827 57	7,832 27
2,500	7,836 97	7,841 67	7,846 38	7,851 08	7,855 79	7,860 49	7,865 20	7,869 91	7,874 62	7,879 33
2,510	7,884 04	7,888 75	7,893 46	7,898 18	7,902 89	7,907 61	7,912 33	7,917 04	7,921 76	7,926 48
2,520	7,931 20	7,935 92	7,940 65	7,945 37	7,950 09	7,954 82	7,959 54	7,964 27	7,969 00	7,973 73
2,530	7,978 46	7,983 19	7,987 92	7,992 65	7,997 39	8,002 12	8,006 86	8,011 59	8,016 33	8,021 07
2,540	8,025 81	8,030 55	8,035 29	8,040 03	8,044 77	8,049 52	8,054 26	8,059 01	8,063 76	8,068 50
2,550	8,073 25	8,078 00	8,082 75	8,087 50	8,092 25	8,097 01	8,101 76	8,106 52	8,111 27	8,116 03
2,560	8,120 79	8,125 55	8,130 31	8,135 07	8,139 83	8,144 59	8,149 35	8,154 12	8,158 88	8,163 65
2,570	8,168 42	8,173 18	8,177 95	8,182 72	8,187 49	8,192 27	8,197 04	8,201 81	8,206 59	8,211 36
2,580	8,216 14	8,220 92	8,225 69	8,230 47	8,235 25	8,240 03	8,244 82	8,249 60	8,254 38	8,259 17
2,590	8,263 95	8,268 74	8,273 53	8,278 32	8,283 11	8,287 90	8,292 69	8,297 48	8,302 27	8,307 07
2,600	8,311 86	8,316 66	8,321 45	8,326 25	8,331 05	8,335 85	8,340 65	8,345 45	8,350 25	8,355 06
2,610	8,359 86	8,364 66	8,369 47	8,374 28	8,379 08	8,383 89	8,388 70	8,393 51	8,398 32	8,403 14
2,620	8,407 95	8,412 76	8,417 58	8,422 40	8,427 21	8,432 03	8,436 85	8,441 67	8,446 49	8,451 31
2,630	8,456 13	8,460 96	8,465 78	8,470 61	8,475 43	8,480 26	8,485 09	8,489 92	8,494 75	8,499 58
2,640	8,504 41	8,509 24	8,514 07	8,518 91	8,523 74	8,528 58	8,533 42	8,538 26	8,543 09	8,547 93
2,650	8,552 77	8,557 62	8,562 46	8,567 30	8,572 15	8,576 99	8,581 84	8,586 69	8,591 53	8,596 38
2,660	8,601 23	8,606 08	8,610 93	8,615 79	8,620 64	8,625 50	8,630 35	8,635 21	8,640 06	8,644 92
2,670	8,649 78	8,654 64	8,659 50	8,664 36	8,669 23	8,674 09	8,678 95	8,683 82	8,688 69	8,693 55
2,680	8,698 42	8,703 29	8,708 16	8,713 03	8,717 90	8,722 77	8,727 65	8,732 52	8,737 40	8,742 27
2,690	8,747 15	8,752 03	8,756 91	8,761 79	8,766 67	8,771 55	8,776 43	8,781 32	8,786 20	8,791 09

NOTE 1 Substituting total heads in this table will yield discharges. If gauged heads are used the value should be multiplied by the appropriate C_v (see Table C.1).

NOTE 2 To use Table C.2, evaluate the modular discharge (in m³/s) from this table, the appropriate value of the head (in m) is inserted as a combination of the values in the first column and in the first row (above the horizontal rule).

EXAMPLE The value of modular discharge corresponding to a head of 0,243 is given at the intersection formed by the horizontal line from 0,240 with the vertical line from 0,003, and the modular discharge is therefore = 0,23749

ICS 17.120.20

Price based on 41 pages