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Hydrometric determinations — Flow measurements in open channels using structures — Use of vertical underflow gates

Déterminations hydrométriques — Mesure de débit dans les canaux découverts au moyen de structures — Emploi de portes verticales à passage subaquatique

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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.

The main task of technical committees is to prepare International Standards. 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.

ISO 13550 was prepared by Technical Committee ISO/TC 113, *Hydrometric determinations*, Subcommittee SC 2, *Notches, weirs and flumes*.

Hydrometric determinations — Flow measurements in open channels using structures — Use of vertical underflow gates

1 Scope

This International Standard specifies methods for the determination of discharge in open channels in steady flow conditions using vertical underflow gates on a flat horizontal floor between vertical side walls under modular or non-modular conditions.

NOTE Generally, gate controls are not designed with discharge determination as a primary function and this International Standard is intended to help the development of stage-discharge relations at existing gate structures, and to incorporate into new structures features which will provide good facilities for the establishment of stage-discharge relations.

When a better accuracy of measurement (i.e. better than specified in 9.4) is required, the structure is to be calibrated with actual measurement of discharge using an appropriate method.

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, *Hydrometric determinations — Vocabulary and symbols*

ISO 4373, *Measurement of liquid flow in open channels — Water-level measuring devices*

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

3 Terms, definitions and symbols

For the purposes of this International Standard, the terms, definitions and symbols given in ISO 772 apply together with the following.

3.1
vertical underflow gate
vertical gate situated in a channel of rectangular cross-section with a flat bottom for regulating the water level upstream of the gate or the discharge through the gate opening

NOTE 1 The gate is movable in vertical slots and it can be raised or lowered by hand or mechanically.

NOTE 2 The underflow is two-dimensional except at vertically narrow gate openings.

4 Units of measurement

The units of measurement used in this International Standard are SI units.

5 General requirements

5.1 General

Conditions regarding preliminary survey, selection of site, approach channel, installation and maintenance of structures, gauge wells and measurement of head which are generally necessary for flow measurement are given in 5.2 and 5.3. The operational requirements for vertical underflow gates are given separately in 8.5.

5.2 Site selection

A preliminary survey shall be made of the physical and hydraulic features of the proposed site, to check that it conforms (or can be made to conform) to the requirements necessary for the discharge determination using gates.

Particular attention shall be paid to the following features:

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

b) flow velocity distribution;

c) absence of a steep channel, if possible;

d) effects of any increase in upstream water level due to the measuring structure;

e) sediment content of the stream and possibility of deposition of floating debris just upstream of the gate, affecting its performance;

f) permeability of the ground on which the structure is to be founded and the need for piling, grouting or other means of controlling seepage;

g) necessity for flood banks to confine the maximum discharge to the channel;

h) stability of the banks and the necessity for trimming and/or revetment of natural channels;

i) removal of rocks or boulders from the bed of the approach channel;

j) effects of wind, which can have a considerable effect on the flow in a river or under a gate, especially when the channel is wide and the head is small, and when the prevailing wind is in a transverse direction;

k) in a natural channel, the necessity or otherwise to provide facilities for the passage of fish.

If the site does not possess the characteristics necessary for satisfactory measurement, the site shall be rejected unless suitable improvements are practicable.

If an inspection of the stream shows that the existing velocity distribution is regular, then it may be assumed that the velocity distribution will remain satisfactory after the construction of the gate.

If the existing velocity distribution is irregular and no other site for a gauge is feasible, the distribution shall be checked after the installation of the gate and improved if necessary.

Several methods are available for obtaining a more precise indication 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 using a current meter. Further information on the use of current meters is given in ISO 748.

5.3 Installation conditions

5.3.1 General

The complete measuring installation consists of an approach channel, a measuring structure and a downstream channel. The condition of each of these components affects the overall accuracy of the measurements.

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

The distribution and direction of velocity have an important influence on the performance of a gate, which is determined by the features mentioned above.

Once an installation has been designed and constructed, the user shall avoid any change which could affect the discharge characteristics.

5.3.2 Approach channel

On 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. These criteria can usually be verified by inspection or measurement. In the case of natural streams or rivers, they can only be met by a long straight approach channel free from projections either at the side or on the bed. Unless otherwise specified in the appropriate clauses, the approach channel shall comply with the following general requirements.

The change in flow conditions due to construction of the gate may cause build-up of floating debris upstream of the structure, which in time might affect the flow conditions.

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 measured from the upstream side of the abutments.

If entry of 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 greater length of straight approach channel will be required to achieve a regular velocity distribution. Baffles in the approach channel shall not be closer to the point of measurement than a distance of 10 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 not less than 30 times the maximum head upstream, flow measurement will be feasible, subject to confirmation that a regular velocity distribution exists at the approach to the weir. If a standing wave occurs within this distance, the approach conditions and/or the gauging device shall be modified.

5.3.3 Measuring structure

The structure shall be rigid, watertight and capable of withstanding flood flow conditions without displacement, distortion or fracture. It shall be at right angles to the direction of flow and shall conform to the dimensions given in the relevant clauses.

The surface of the sill and the side walls of the channel in which the gate is located shall be smooth, particularly in the section from some distance upstream to some distance downstream of the gate.

The bottom, sill and side walls may be constructed of concrete with a smooth cement finish.

The lower edge of the gate shall be horizontal, regular in shape and straight.

The construction shall satisfy the following tolerances:

- on the width of the channel (b) in which the gate is located: 0,5 % of the width;
- on point deviations from a plane surface of the flat bottom: 0,2 % of b, with an absolute maximum of 0,01 m;
- on point deviations from a horizontal plane of the lower edge of the gate: 0,2 % of b, with an absolute maximum of 0,01 m.

5.3.4 Downstream of the structure

The channel downstream of the structure is usually of no importance if the weir has been designed to operate under modular conditions. However, if the weir is designed to measure the flow under non-modular conditions, the downstream channel shall be straight for a length of at least eight times the maximum head to be measured. In that case, the flow shall be subcritical at the downstream face of the gate.

A downstream gauge shall be provided to obtain the submergence ratio. An additional gauge located a short distance just downstream of the gate is recommended to check the existence of modular or non-modular flow.

6 Maintenance

Maintenance of the measuring structure and the approach channel is an important factor for accurate continuous measurements.

It is essential that the approach channel to the gates and the channel downstream of the gates be kept clean and free from silt and vegetation as far as is practicable for at least the distances specified in 5.3.2 and 5.3.4. The float well and the entry from the approach channel shall also be kept clean and free from deposits. The gate structure shall be kept clean and free from clinging or floating debris, and care shall be taken during cleaning to avoid damage to the gate.

7 Measurement of head

7.1 General

The heads upstream and downstream of the measuring structure may be measured by a hook gauge, point gauge or staff gauge where spot measurements are required, or by a float-operated recording gauge or presssure-sensing gauge where a continuous record is required. It is preferable to measure heads in a separate stilling well to reduce the effects of water surface irregularities. Other head measuring methods may be used provided that a measurement accuracy of ± 5 mm is obtainable.

A gauge or other measuring device is needed to measure the opening of the gate with respect to the sill of the gate. The accuracy shall be of the same order as that for the head measurement devices.

If very hot or very cold conditions prevail, causing a significant temperature difference between the liquid in a stilling well and the liquid in a channel, a correction for differences in liquid density may have to be made in the calculation of rates of discharge.

7.2 Stilling or float well

The stilling well should be vertical and have sufficient length so that, at the maximum water level estimated to be recorded in the well, the counterweight will not rest on top of the float or be submerged. An additional margin of 0,6 m is recommended.

The well shall be connected to the channel by an inlet pipe or slot, large enough to permit the water in the well to follow the rise and fall of head without significant delay. The connecting pipe or slot shall, however, be as small as possible consistent with ease of maintenance, or shall alternatively be fitted with a constriction to damp out oscillations due to short-period waves. In general, the diameter of the intake pipe will not be smaller than 0,1 times the diameter of the well.

The well and the connecting pipe or slot shall be watertight. Where accommodation of the float of a water level recorder is provided for, the well shall be of adequate diameter and depth to accommodate the float. The well shall also be deep enough to accommodate any sediment which may enter, without the float grounding. The float well arrangement may include an intermediate chamber between the stilling well and the approach channel, of similar proportions to the stilling well to enable sediment to settle.

Specifications for stilling wells are given in ISO 4373.

7.3 Zero setting

A means of checking the zero settings of the head measuring devices shall be provided, consisting of a pointer or staff gauge, set at a fixed level with respect to the sill of the gate and fixed permanently in the approach or downstream channel, separate from the stilling well or float well. Benchmarks, related to a National Datum to facilitate their relationship to the topography of the channel basin, should be established nearby and settings of the gauges checked annually by levels.

The opening of the gate also varies. The elevation of the lower crest of the gate with respect to the sill of the gate can be read from a fixed gauge. A typical method for measuring the elevation of a vertical gate is by installation of this gauge, fixed at the abutment and parallel to the gate, on which a horizontal strip indicates the elevation of the gate. Gate openings can be recorded by gearing a recorder to a cable attached to the gate or the gate gears or shafts.

8 Vertical underflow gates

8.1 Description of vertical underflow gates

Gated structures with undershot flow are used as head regulators and as offtakes. Vertical gates are raised and lowered in vertical slots which are constructed in the vertical abutments and intermediate piers (see Figure 1). In this way discharges can be regulated and measured.

It is strongly recommended that intake structures be designed in such a way that only one type of flow will occur (modular flow or submerged flow) so as to prevent discontinuities during operation. This shall be achieved by selecting the bottom elevation of the sluice gate sufficiently high (for free flow) or low (for submerged flow) with relation to the downstream water level.

The discharge through vertical slide gates may be determined by measuring the gate opening a, the upstream and downstream water levels h_1 and h_2 and by applying the correct discharge equation for modular flow or submerged flow.

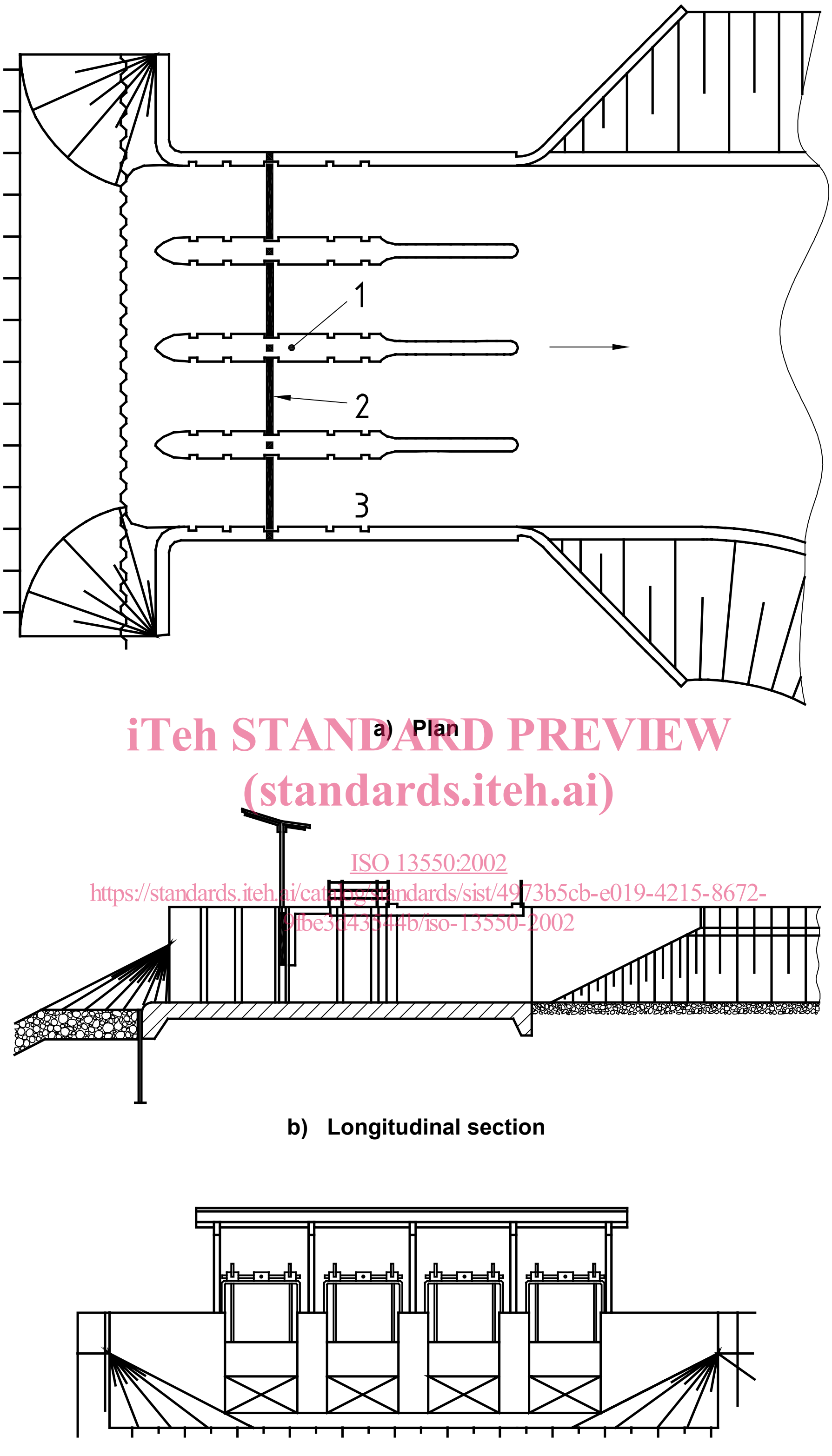
All discharge equations given in 9.1 are based on two-dimensional flow. Therefore the gates are operated in a rectangular section formed by vertical walls and a level horizontal floor. In the case of two-dimensional flow, the upstream and downstream water levels shall be measured in the rectangular section between the abutments and intermediate piers, for each gate separately.

In many field structures, however, the upstream and downstream water levels are measured at one location upstream of the upstream face and downstream of the downstream face of the abutments and piers. The effect of additional losses is defined in 9.2 (three-dimensional gate flow).

The general layout of a structure with vertical underflow gates is given in Figure 1.

A sketch of the bottom of the gate is given in Figure 2.

The radius r of the circular rounding of the bottom edge may vary as follows: $0 \leqslant r \leqslant e$.



a) Plan

b) Longitudinal section

c) Upstream view

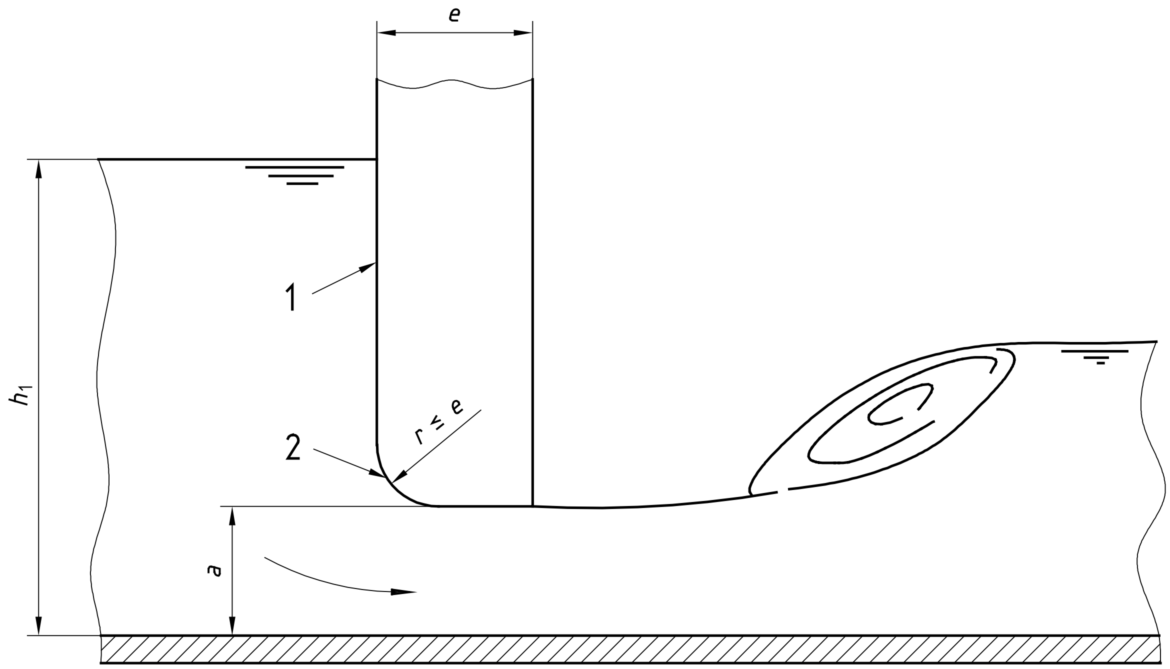
Key

1 Pier

2 Gate

3 Abutment

Figure 1 — Gated intake structure



Key

1 Upstream face

2 Bottom edge

Figure 2 — Bottom edge of a gate

8.2 Location of the head measurement section

The water level gauging station upstream of the gate shall be located at a sufficient distance upstream from the gate to avoid the region of eddies. On the other hand, it shall be close enough to the gate to ensure that the energy loss between the section of measurement and the control section under the gate is negligible. It is recommended that the head-measurement section be located upstream from the gate at a distance not exceeding twice the maximum head over the gate.

8.3 Location of the tailwater level measurement section

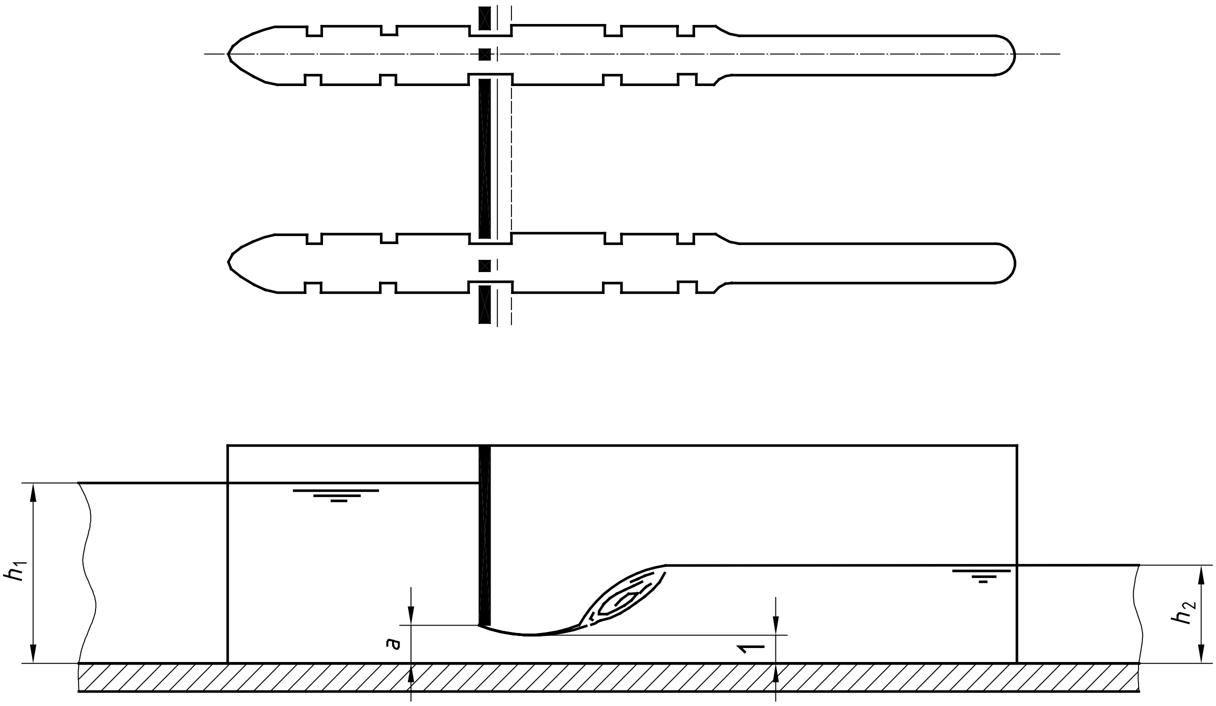
The water-level gauging station downstream of the gate used to measure the downstream head in the case of submerged flow shall be located at a sufficient distance downstream from the gate to avoid regions of fluctuations. Generally, it is recommended that the tailwater level measurement section be located at a distance of 10 times the tailwater depth downstream from the gate, so that the measurement is free of unstable water surface.

An additional water-level gauging station, to check if modular or submerged flow exists, shall be located as close to the gate as possible.

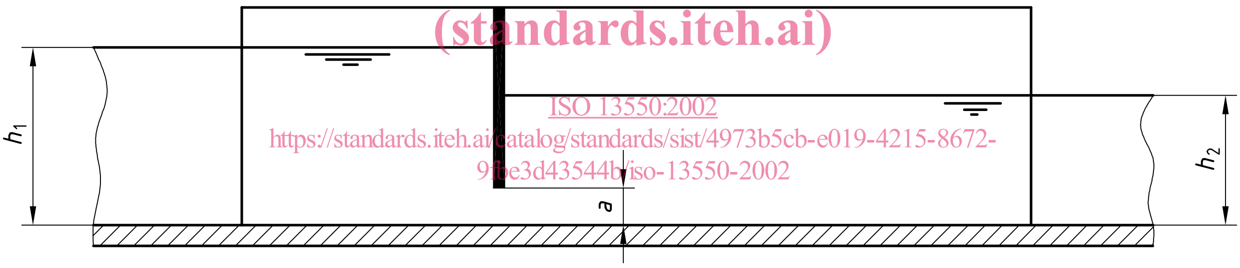
8.4 Flow types

The discharge capacity of any structure is governed by the shape and dimensions of its control section and by the head losses upstream and downstream of this section.

For a gated intake structure, the control section is defined by the “vena contracta” which is the minimum cross section at a short distance downstream of the gate (see Figure 3). Contraction of streamlines in the vertical direction predominates.



a) **Modular gate flow**



b) **Submerged gate flow**

Key

1 Vena contracta

Figure 3 — Different flow types in a gated structure

Depending on the interrelation between the parameters h_1, h_2 and a, the following flow types (indicated in Figure 3) can occur in a gated structure.

a) **Modular gate flow** (referred to also as free flow): The contraction of streamlines towards the gate opening is strong in the vertical plane. The higher the h_1/a value (see Figure 4) the stronger is the curvature of streamlines and the lower the discharge coefficient C_D. C_D is a function of C_C, a and h_1, where C_C is the contraction coefficient. For modular flow, the downstream water level is low enough so that the capacity of the structure will not be affected. A free jet leaves from the gate opening, and a hydraulic jump is located at some distance downstream of the gate. The discharge Q is as follows:

$$Q = f(h_1, a, C_C)$$