INTERNATIONAL STANDARD

ISO 9825

Second edition
2005-05-15

Hydrometry — Field measurement of discharge in large rivers and rivers in flood

Hydrométrie — Mesurage in situ du débit des grandes rivières et des débits de crue

Reference number
ISO 9825:2005(E)

PDF disclaimer

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

Page

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 2.

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 document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 9825 was prepared by Technical Committee ISO/TC 113, *Hydrometry*.

This second edition cancels and replaces the first edition (ISO 9825:1994), which has been technically revised.

Hydrometry — Field measurement of discharge in large rivers and rivers in flood

1 Scope

This International Standard deals specifically with the measurement of discharge in large rivers and the measurement of rivers in flood. It also describes the relevant field measurements when it becomes necessary to use indirect methods of estimating discharge.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 748, *Measurement of liquid flow in open channels — Velocity-area methods*

ISO 772, *Hydrometric determinations — Vocabulary and symbols*

ISO 772, Amendment 1:2002

ISO 1070, *Liquid flow measurement in open channels — Slope-area method*

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

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

ISO 3847, *Liquid flow measurement in open channels by weirs and flumes — End-depth method for estimation of flow in rectangular channels with a free overfall*

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

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

ISO 4369, *Measurement of liquid flow in open channels — Moving-boat method*

ISO 4371, *Measurement of liquid flow in open channels by weirs and flumes — End depth method for estimation of flow in non-rectangular channels with a free overfall (approximate method)*

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

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

ISO 6416, *Hydrometry — Measurement of discharge by the ultrasonic (acoustic) method*

ISO 6420, *Liquid flow measurement in open channels — Position fixing equipment for hydrometric boats*

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

ISO 9213, *Measurement of total discharge in open channels — Electromagnetic method using a full-channel-width coil*

ISO 9555-1, *Measurement of liquid flow in open channels — Tracer dilution methods for the measurement of steady flow — Part 1: General*

ISO 9555-2, *Measurement of liquid flow in open channels — Tracer dilution methods for the measurement of steady flow — Part 2: Radioactive tracers*

ISO 9555-3, *Measurement of liquid flow in open channels — Tracer dilution methods for the measurement of steady flow — Part 3: Chemical tracers*

ISO 9555-4, *Measurement of liquid flow in open channels — Tracer dilution methods for the measurement of steady flow — Part 4: Fluorescent tracer*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 772 and Amendment 1 apply.

4 Units of measurement

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

5 Appropriate techniques

Due to the dimensions of large rivers and the hazards associated with measuring flood flows, some of the techniques available for discharge measurement on smaller rivers under normal flow conditions may not be appropriate, or may need modification if used.

River dimensions, stream conditions, feasibility of measurements, measuring instruments and equipment, purpose and available funds will, in a general sense, dictate the choice of methodology. In many instances, the choice of technique will be decided upon by the physical conditions at the site. Hazards discussed in this International Standard are confined to those peculiar to the measurement of discharge of large rivers and rivers in flood.

Those techniques that may be partially or entirely appropriate within certain limitations imposed by degree of difficulty of operation are the following:

a) velocity-area methods in accordance with ISO 748, ISO 4369, ISO 6416, ISO 6420, ISO 9213.

b) Tracer dilution methods in accordance with ISO 9555, Parts 1 to 4.

c) Weirs and flumes in accordance with ISO 1438-1, ISO 3846, ISO 3847, ISO 4359, ISO 4360, ISO 4371, ISO 4374, ISO 4377, ISO 8333.

d) Indirect methods in accordance with ISO 1070.

6 Nature of difficulties likely to be encountered

6.1 Measured parameters

When any of the three parameters used to determine discharge (width, depth and velocity) is abnormally large, it may cause problems that are not usually encountered.

Great width may pose problems for position fixing in the horizontal, and for measurement of velocity on any overbank spill portion.

Great depth may create difficulty in locating a measuring device at the desired depth.

High velocities cause problems with regard to maintaining station, position fixing and location of measurements in both the horizontal and vertical. The current meter is required to be calibrated to cover a high range of velocities, for which facilities are generally not readily available.

These difficulties are accentuated by problems caused by floating debris, high turbulence and vortices, and movement of large bed forms.

6.2 Logistical problems

The basic problems in the measurement of discharge of large rivers and rivers in flood are logistic, associated either with the time required for measurement or with the need for special resources to be employed. However, flood measurements may be accompanied by significant additional hazards to personnel and equipment.

An additional logistical problem is access to the flood measurement site, both in being able to reach the site and getting to the site in time to measure a high flow. Because of this, indirect measurements assume great importance in the case of rivers in flood.

7 Measurement of discharge in large rivers

7.1 Problems of scale

The problems relating to measurement of discharge in large rivers are essentially those of the following scales.

7.1.1 Great width

For most methods, great width presents difficulties in ascertaining the location of the measurement with respect to the cross-section, since the orthodox means using tag-lines and optical survey instruments, depending upon the actual dimensions, may preclude accurate results. More sophisticated position-fixing equipment may be needed to overcome this problem, in accordance with ISO 6420.

7.1.2 Great depth

Great depth may call for a greater number of points on the vertical to be measured to sample mean velocity, particularly if the vertical velocity distribution is not uniform due to the section being non-uniform.

7.1.3 High velocity

In many cases, high velocity creates difficulties, both with regard to locating a measuring platform at the desired position on the horizontal and in maintaining that position, as well as enabling the desired point on the vertical to be sampled. The turbulence, which usually accompanies high velocity, both compounds the problems of sampling and reduces the accuracy of the measurement. In addition, high velocities require the use of heavy sounding weights, which are difficult to use and increase the risk of injury to field personnel. When using current meters, wet-line distortions lead to time-consuming corrections, and even then the measurement point may well deviate from the cross-sectional line with which it is meant to conform.

7.2 Current-meter method

The standard method for measuring the discharge of large rivers is the velocity-area method using a current meter, from a bridge, cableway, or powerboat or motor launch fitted with an echo-sounder. During high velocity, fixing of position and other parameters may be made by cableway with a trolley for rivers up to 500 m wide. From river widths of 500 m up to 1 km, a boat may be moved across the river with the help of a cableway. For river widths greater than 1 km, the use of cableways is excluded. Stationary boats anchored with great care and using conventional survey methods can be located for rivers up to 2 km wide, but for greater widths more sophisticated position-fixing equipment may become necessary.

The care required in such operations, coupled with the need for an adequate number of verticals to be measured, inevitably results in a single measurement becoming a very lengthy procedure. This can be partially reduced by the use of several teams with several boats and current meters. Similarly, advance notice of likely river-stage behaviour enables measurements to be planned to take advantage of stable stage conditions, to counter the problem of lengthy measuring periods. Significant river traffic may cause further delay.

7.3 Moving-boat technique

The moving-boat technique is a modification of the current-meter method that reduces the time required to make a measurement of manageable proportions. Nevertheless, the problem of tracking the boat becomes greater with increasing river width. The fixed depth of the current meter presents problems of uncertainty in determining the mean velocity if the river section varies in depth. It may become necessary to define a number of uniform sections, each of which shall be calibrated by a stationary boat at varying stages.

7.4 Acoustic Doppler method

An alternative method is the use of acoustic Doppler meters or profilers for making velocity-area measurements for computation of discharge. The Doppler profiler is deployed from a powerboat and includes software that computes the river discharge as the boat traverses the river. The Doppler profilers have 3 or 4 transmitter/receiver nodes that transmit acoustic beams through the water column, usually at a 20° angle from vertical. One beam is used to measure depth and the other beams measure the components of velocity. The Doppler profilers also have an internal compass and bottom-tracking software for measuring distance. The processing software produces a discharge measurement that is similar to velocity-area measurements that are made with current meters or the moving-boat technique. The output includes a cross-section profile, area, continuous velocity profiles, and discharge.

The Doppler profilers are ideal for measuring wide and deep rivers, because measurements can be made quickly with a 2-person crew of a boat operator and a technician experienced with Doppler profilers. A typical discharge measurement made using a current profiler will consist of two or more traverses of the powerboat. The discharges derived from each traverse are averaged to obtain the discharge of the measurement.

7.5 Other methods

The remaining techniques tend to be less appropriate, largely because of various difficulties when the river is very large.

7.5.1 Floats

Floats generally are not used for measuring large rivers because of the difficulty in releasing the floats at the correct location and observing their movement. However, by stationing observation boats across the observation sections at some convenient interval, it might be possible to overcome the difficulty of large width of rivers. The increase in logistical and procedural problems might be considered tolerable if equipment for the acoustic Doppler, stationary-boat , or moving- boat techniques are not available.

7.5.2 Tracer-dilution techniques

Generally, tracer-dilution techniques are not appropriate for measuring large rivers. However, in special circumstances including remoteness and hostile environment, it has proved possible to drop dyes from airborne platforms into selected river reaches, using sequential air photos to observe the time of travel, and thus estimate the flow velocity; this velocity with the cross-sectional area is then used to compute the discharge. The method requires survey knowledge of the sectional area through the measurement reach.

7.5.3 Engineered structures

The large dimensions of a river involved imply that engineered structures are unlikely to be available. This again is a question of scale. If, however, a barrage exists, it should be considered for the measurement of flow.

NOTE A barrage is a gated weir for controlling up-stream levels; the gates are opened during flood periods.

7.5.4 Indirect methods

Indirect methods, such as the slope-area and contracted-opening methods, may be used on large rivers in situations where other methods of measuring discharge cannot be used.

8 Measurement of flood flows up to bankfull stage

8.1 Problems of flood-flow measurement

The difficulties associated with the measurement of flood flows, although in some cases of a nature similar to those encountered in measuring large river flows, differ in one critical respect; namely, that flood flows are often associated with circumstances which cause additional hazards to the safety of personnel and equipment. As such, this requires trained and experienced crew members and observers. Flood flows also may exhibit rapidly changing conditions, so that timing may be critical and difficult to judge

8.1.1 High velocity creates difficulties in measuring rivers in flood and flows in large rivers (see 7.1.3). Measuring the direction of the current relative to the section can be both difficult and uncertain. However, this problem can be reduced to a certain extent by the use of a direction-reading current meter or an acoustic Doppler profiler.

8.1.2 A permanent measuring section used under normal river conditions may not be appropriate for measuring within-bank flood flows, and it may be necessary to select a more appropriate section.

8.1.3 Rivers in flood tend to discharge varying amounts of debris picked up by the swollen waters. Such debris, coupled with high velocity and turbulence of currents, often makes the use of boats too hazardous, and even cableways and bridges may not be usable as platforms for current meters because of the damage likely to occur to the meters and suspension cables. However, up to certain limits, it should be possible to obtain at least surface velocity measurements from cableways and bridges. The mean velocity may be assessed if, during normal stage measurements, the relationship between surface velocity and mean velocity has been demonstrated and continues to hold at the flood stage.

The problem of rapidly changing flow conditions can be addressed by short-cut methods, such as half-counts of current meter revolutions and fewer verticals for measuring depth and velocity. Although these short-cut methods will produce a representative discharge of the mean stage during the measurement, there will be greater uncertainty.

8.2 Use of floats

Floats and the use of floating debris for measuring surface velocity provide a means of reducing the hazard to safety of personnel and equipment. Preparations for flood measurement by these means should be made at normal stages, with a survey of the banks of the reach selected and soundings of the sections to be used. The team of observers should be trained with a full awareness of their duties.

The difficulties that relate to the use of floats lie in the tracking of the floats through the section, so that the accurate length of flow path will be known, and the positioning of the floats into trajectories which will adequately sample the whole width of river. The first of these difficulties implies the use of conventional survey equipment by experienced operators, while the second implies the use of some kind of catapult equipment to lob the floats into the river so that they fall at varying ranges across the river.

If a bridge is conveniently located, the floats may be dropped from the bridge at the desired distances from the bank. Floats may also be dropped from a helicopter, but surface waves caused by the rotor blades should be kept to a minimum. As with all surface velocity measurements, corrections are necessary to estimate mean velocities.

Weighted floats may also be used to eliminate the necessity for mean velocity corrections. Weighted floats with longer lengths (up to 5 m) are made so that they float vertically and give more or less average velocities (integral of vertical velocity distribution over the float length, which may be more or less equal to the depth of flow). However, it is desirable to check the accuracy of the weighted float by carrying out periodic calibrations. In flood flows up to bankfull stage, the depth of flow may be high and weighted floats may not normally be feasible, in particular because flow depth is required to be nearly uniform across the section.

8.3 Moving-boat technique

The moving-boat technique may be used for making flood measurements when there is little or no floating or submerged debris. This technique will allow for an accurate determination of area and discharge where the bank and the bed of the river are subject to extensive scouring and filling, thereby affecting the shape and characteristics of the wetted perimeter during measurement. Consequent changes in the vertical velocity curves may require corrections to the velocity coefficients.

8.4 Acoustic Doppler method

The measurements can be made much faster and with fewer people than conventional current-meter measurements. The method is also faster than the moving-boat technique because there is no set-up time for horizontal-position equipment on shore. The method is not currently recommended when the depth is less than 0,5 m. If the river being measured has a moving bed, the Doppler profiler shall include an auxiliary global-positioning system to accurately monitor the traverses of the boat across the measuring section.

8.5 Radar

Advances in radar technology make it possible to deploy radar units from a helicopter to measure flood discharges. The radar units include a high-frequency, pulsed Doppler radar for measuring surface velocity and a low-frequency radar for measuring the cross-sectional area. The low-frequency radar is ground-penetrating radar, normally used for near-surface geophysical investigations. Helicopter-deployed radar enables a small crew to make many flood measurements in 1 day. As with floats and other surface-velocity-measuring techniques, the radar technique requires a correction coefficient to estimate mean velocity in the cross-section.

8.6 Weirs

Where engineered structures such as weirs exist in the river, they can be used for estimation of the discharge based on surveys of the high-water marks and the geometry of the structure. In the case of a barrage, the flood flows can be measured with a good degree of accuracy by observing gate openings and the upstream and downstream water levels, and then applying hydraulic formulae.

8.7 Tracer dilution methods

Tracer dilution methods require a coordinated effort, and permission and suitable access for both injection and sampling are necessary. The appropriate environmental protection authorities should be contacted before any tracer dilution methods are used. The methods require large amounts of chemicals that may be difficult to handle conveniently and, if radioactive tracers are used, safety precautions must be strictly followed in accordance with ISO 9555, Parts 1 to 4. Moreover, the mixing lengths are likely to be very large, probably involving inflows or spills. However, in the case of mountain torrents in flood, the dilution method may be the only method suitable.

8.8 Indirect methods

8.8.1 Indirect determinations of discharge after the passage of a flood may be the only way to measure the flow. Such methods make use of the energy equation for computing discharge. Though specific equations differ for different types of flow, they will all have the following general factors:

a) physical characteristics of the channel, i.e. dimensions and shape of the channel within the reach, and boundary conditions;

b) water-surface elevation at the time of peak discharge, to define the upper limit of the cross-sectional areas and the slope in the water surface between two or more cross-sections;

c) hydraulic factors, e.g. roughness coefficients and discharge coefficients, based on physical characteristics, water-surface elevations and discharge.

The data to be collected by field survey include:

a) elevation and location of high-water marks corresponding to peak stage;

b) cross-sections of the channel along the reach;

c) collection of relevant data to assess the roughness coefficient.

Selection of a roughness coefficient will be dictated by factors such as depth, character of stream-bed material, cross-section irregularities, the presence of vegetation and alignment of the channel.

8.8.2 The slope-area technique is the most commonly used indirect method. In this method, discharge is computed on the basis of a uniform or non-uniform flow equation involving channel characteristics, water-surface profiles and a roughness or retardation coefficient. The slope in water-surface profile for a uniform reach of channel represents energy losses caused by bed and bank roughness (see ISO 1070).

8.8.3 The contracted-opening method can be used where there is a bridge across the river, and it creates an abrupt drop in water-surface elevation between an approach section and the contracted section under the bridge. The head on the contracted section is defined by high-water marks, which must be surveyed, and the geometry of the bridge and channel, also defined by survey (see *WMO Manual on Stream Gauging*). When the bed may scour, the cross-section should ideally be surveyed when the flood is passing. Since the geometry of the channel can, however, only be surveyed after the subsidence of the flood, this method is applicable only if scour in the contracted opening is small or absent.

8.8.4 Where there are no straight reaches for application of slope-area methods, and where no abrupt contractions exist and no engineered structures are available, the method using super elevation in the bend of the stream may be employed.

The deformation of the free surface in a bend results from centrifugal force. Thus, the water level rises on the outside bend and lowers on the inside bend. Field survey defines the channel shape and the difference in the water-surface elevation between the banks. The discharge should be estimated at each of several bends and the mean value accepted (see WMO *Manual on Stream Gauging*).

8.8.5 Depending on the size of the river and related structures, other indirect methods may be used. These include various weirs and critical depth methods.

9 Measurement of flood flows above bankfull stage

The total measurement of flood flow requires measurement of the portion of flow contained within the banks and the portion of overbank flow. With overbank flow, interaction between the within-bank flow and floodplain flow occurs, which may lead to a reduction of water discharge in the channel (a kinematics effect of the free-flow condition).

