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Hydrometry — Selection, establishment and operation of a gauging station

Hydrométrie — Sélection, établissement et exploitation d'une station hydrométrique

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Foreword

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The committee responsible for this document is ISO/TC 113, *Hydrometry*, Subcommittee SC 1, Velocity area methods.

ISO 18365 cancels and replaces ISO 1100-1:1996 and ISO/TR 8363:1997, which have been merged and technically revised.

Hydrometry — Selection, establishment and operation of a gauging station

1 Scope

This International Standard gives requirements for the establishment and operation of a gauging station for the measurement of stage, or stage and discharge, of a lake, reservoir, river or canal or other artificial open channel. It also describes how a gauging station utilizing one of the measurement methods listed should be operated and maintained.

Requirements are provided for stage only measurement stations, stage–discharge stations and direct-discharge measurement stations in natural channels, as well as for stage–discharge stations with artificial structures. Additionally, some requirements are given for measurements under difficult conditions, such as under ice conditions.

2 Normative references

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

ISO 772, *Hydrometry — Vocabulary and symbols*

3 Terms, definitions and symbols

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

4 General requirements and considerations

4.1 Requirements

Before commencing work on establishment and operation of a gauging station, the following requirements shall be identified:

a) range of levels required to be measured;

b) range of flows required to be measured;

c) customer's requirements for type of data;

d) customer's requirements for timeliness of data;

e) allowable uncertainty in the results;

f) other potential users of the data;

g) life expectancy of the station;

h) available budget;

i) agreements for access to land and construction permits.

4.2 Other constraints

In addition to the requirements as in 4.1, other constraints shall be identified including the following:

a) local environmental issues;

b) accessibility of the site under all conditions of flow;

c) availability of power and communication links;

d) stability of the watercourse embankments;

e) stability of the watercourse bed;

f) identification of any proposed hydraulic modifications planned for the future;

e.g. bridges, tunnels (including pipe crossings), harbours or piers;

g) potential of vandalism;

h) influence of submergence of the gauging site due to downstream impounding

structures (lakes, dams, weirs);

i) potential stream losses in karst areas;

j) aquatic weed growth in the watercourse;

k) ice conditions during winter in cold and arctic regions.

Knowledge of the above requirements and local constraints will ensure the provision of appropriate measurement and recording facilities as well as the adoption of an appropriate maintenance philosophy.

5 Water level (Stage) only gauging stations

5.1 Preliminary survey and selection criteria

5.1.1 General

The site selected for determination of stage shall be selected according to the purpose for which the readings are required. Accessibility of the site and the availability of an observer if the gauge is to be non-recording are important criteria as is the availability of an appropriate power supply and data communication capabilities if the gauge is to be recording.

Gauges on lakes and reservoirs are normally located near the outlet, but shall be located sufficiently far away from the zone where an increase in velocity causes a drawdown in water level. Gauges on large bodies of water shall also be located so as to reduce the effect of strong winds which may cause misleading data which may not be representative of the body of water being measured. Hydraulic conditions (preferably a sufficiently long uniform stretch of water channel with uniform bed topography) are important factors in site selection in open channels, particularly where water levels may later be used in the computation of discharge. To ensure repeatability of the readings, ideally a bed or channel control shall be present, which itself shall be stable and sensitive to changes in the level of the water. For the purpose of monitoring water levels e.g. for flood warning purposes, this may not be a strict requirement.

5.1.2 Preliminary survey

A detailed examination of a 1:50,000 or larger scale map of the area is required in the first instance. Aerial surveys, satellite imagery, or maps available in the public domain such as Google Earth can be used as a basis for selecting potential sites, which can then be evaluated more precisely by ground reconnaissance. This will include a detailed visual examination. Enquiries shall be made to determine whether or not any plans exist for the modification of the river reach which would modify the stream bed regime and would have an impact on the proposed gauging station.

Enquiries shall also be made into any known past flow history including low water events, floods and other high water events, existence of any overflow area leading to flow by-passing the site, and very importantly, any knowledge of bed instability.

It may be appropriate to discuss and outline proposals at an early stage with the owners of the site identified to ensure they are amenable to the proposed installation.

Surveys of channel geometry and flow velocity patterns using an Acoustic Doppler Current Profiler may provide useful information.

Collection of data from hydrometric measurement stations is dominated by the use of telemetry; availability and quality of methods of data transmission shall be investigated.

5.1.3 Selection criteria

A list of potential sites shall be established with their advantages and disadvantages identified. Site selection can then be made according to the criteria identified in Clause 4. The establishment of the gauge zero shall be chosen so as to avoid negative readings. Thus it shall be set well below the level of the control feature. This zero point shall be correlated with a national datum through a station benchmark and should be checked annually with respect to this benchmark. This will ensure that, should loss or damage to the reference gauge occur, it can be replaced at exactly the same level.

The benchmark itself shall be checked regularly in order to confirm that it still represents the national datum. The frequency of such checks shall be dependent on local soil dynamics.

5.2 Stage measurement and recording

5.2.1 General

The reading of stage may be required as a single instantaneous measurement, as a short series of instantaneous measurements or as a continuous or practically continuous record of the fluctuations of stage. The basis of any of the above shall include the installation of a vertical staff gauge, a ramp gauge, or a wire-weight gauge.

5.2.2 Vertical staff gauge

A vertical staff gauge comprises a scale (normally 1 metre in length with graduations or scale divisions of 5 or 10 mm) marked on or securely attached to a suitable and stable vertical surface. The gauge shall be made of material with a low coefficient of expansion. Where the range of measurement required exceeds the capacity of a single vertical gauge, other gauges shall be installed on the line of a cross-section normal to the direction of flow. The scales on such a series of stepped staff gauges shall overlap by not less than 15 cm in order to safeguard continuity of readings and also to confirm their consistency with each other.

5.2.3 Ramp or inclined gauge

A ramp or inclined gauge consists of a scale marked on or securely attached to a suitable and stable inclined surface, which conforms closely to the contour of the river bank. The gauge shall be made of material with a low coefficient of expansion. Throughout its length the gauge may lie on one continuous slope or may be a compound of two or more slopes. The gauge shall lie on a line of a cross-section normal to the direction of flow.

5.2.4 Wire or tape weight gauge

A wire or tape weight gauge consists of a weight which is manually lowered until the weight touches the surface of the water. The wire or tape may be wound on a drum attached to a winding mechanism or it may be a hand reel. The wire or tape gauge can be equipped with electrical contacts to improve measurements, when there is a large vertical distance between the measuring point and the water surface.

5.2.5 Other methods

It may be appropriate in some cases to use alternative methods for single or continuous determinations of water level. Such methods, including maximum level gauges, are described in ISO 4373.

5.2.6 Stage recording

Customer requirements shall dictate the method of recording stage. It may be that a single record of stage taken daily and read manually will suffice in which case a suitable person to do this work should be identified.

It is more common to provide a continuous record of stage utilizing water level sensors, such as floats, pressure transducers, and echo sounders, interfaced with a digital recorder (logger or telemetry) or analog recorder (chart). Details of such systems, including the use of stilling wells, can be found in ISO 4373. Modern gauging stations typically have two independent systems for stage measurement to avoid or reduce data losses.

When a recorder is used, visits by the observer should be made from time to time to ensure satisfactory performance of the sensor and recorder. It is recommended that the observer notes the time and date of such checks along with the staff gauge and recorder values. It is essential that the staff gauge itself is maintained in such a way as to be safely accessible and directly legible to the observer.

Comments on the state of the channel, river banks, presence of any obstruction, prevailing flow conditions, etc. shall also be noted.

The frequency of such visits shall be subject to country-specific requirements but it is important that a site visit shall follow a major hydraulic event to confirm continued measurement and recording of data.

6 Stage-discharge gauging stations

6.1 General

When records of water level are to be used as a basis for computation of discharge, the relation between water level and flow must be determined.

In a stable channel with an appropriate control feature which is stable and sensitive, a single relation may exist between water level and discharge. In this case, the relation can be determined by taking discharge measurements throughout the range of levels and flows required to be measured.

Several techniques are available for this purpose including, but not limited to, current meter gauging and float gauging (see ISO 748), dilution gauging (see ISO 9555-1, ISO 9555-3 and ISO 9555-4), transit time acoustic methods (see ISO 6416), Doppler velocity meters (see ISO 15769), electromagnetic current meters (see ISO/TS 15768) or acoustic Doppler current meters (see ISO/TR 24578).

The frequency of any maintenance or operational performance shall be such that the accuracy and timeliness of data provision meets the user's requirements.

6.2 Main elements of a stage-discharge gauging station

6.2.1 General

The main elements required for the purpose of determining discharge in a stream from water level records are as follows:

a) a stage measuring device (see 5.2.1);

b) a stage sensing and recording device (see 5.2.6);

c) a control section or reach (see 6.2.2);

d) a section suitable for discharge measurements (see 6.1 and 6.2.3);

e) discharge measurements for defining a stage-discharge relation (see 6.2.4).

6.2.2 Control section or control reach

A control section or control reach of a channel is a natural or artificial section or reach whose physical characteristics can be measured and used to determine the relationship between stage and discharge.

In a control section any change in the stage downstream of the control does not affect the stage upstream of the control. Whatever the discharge in the control section, a critical stage can be determined.

It shall be stable, i.e. no change shall occur over time to its physical characteristics. Regular inspection of the control section shall be carried out to ensure that no changes have taken place which would alter the relationship between stage and discharge at this site.

More than one control section may be required for discharge measurement at one gauging station particularly when the range of levels and flows is substantial. For example, under certain flow conditions a downstream control reach may create a water level which submerges an upstream weir which had been acting as a control.

The sensitivity of a control section or reach shall be such that any significant change in discharge shall result in either a measurable change in stage (for control sections) or a measurable change in stage at one extremity of the control reach.

6.2.3 Section suitable for discharge measurements

Regardless of the method of measurement, the discharge through the discharge measuring section shall be the same as the discharge normal to the reference staff gauge, over the range of flows to be measured. Different measuring sections or different methods of measurement may be used to cover the range of flows required.

A full description of a site suitable for measurement of discharge using current meters or floats is given in ISO 748. Site requirements for dilution gauging are given in ISO 9555 Parts 1, 3, and 4. Site requirements for the application of acoustic transit time velocity measurement techniques are given in ISO 6416. Site requirements for the application of acoustic velocity meters using the Doppler and echo correlation techniques are given in ISO 15769. Site requirements for the application of electromagnetic techniques are given in ISO 9213.

6.2.4 Discharge measurements

Discharge measurements using the above techniques shall be related to a stage reading taken at the beginning and end of the discharge measurement and during the measurement if the stage is changing rapidly or inconsistently. When sufficient numbers of discharge measurements have been taken, a stage–discharge relationship can be computed (see ISO 1100-2). Subsequent to the formulation of this stage-discharge relationship, only occasional discharge measurements need be taken at flows in the normal range to confirm the robustness of the relationship unless the site is subject to shifting control conditions. Opportunities should be taken to carry out discharge measurements in extreme events in order to extend the stage–discharge relationship.

Discharge measurements made using the velocity-area methods can be performed using rotating-element current meters, electromagnetic current meters, acoustic Doppler velocimeters, or acoustic Doppler current profilers. These can be made by wading the stream or small river with the meter mounted to a wading rod or by suspending the meter and a sounding weight from a bridge, cableway (see ISO 4375) or stationary boat. Velocity-area methods using floats are another option when the presence of floating debris or very turbulent conditions precludes the use of current meters. Acoustic Doppler current profilers deployed from powerboats, remote-control boats, or tethered rafts also can be used (see ISO/TR 24578). Tethered rafts typically are deployed from bridges or cableways. Another variation of velocity area methods is the slope-area method, which is typically used to compute flood discharge indirectly by surveying the cross-sectional properties and water-surface profile after the flood (see ISO 1070). The applicable conditions for using the different equipment and techniques are listed in Annex-A.

Where a pre-surveyed cross-section is used for the purpose of discharge measurement, then the section shall be checked following any major hydraulic events e.g. over and above a bank full flow.

6.2.5 Tracer dilution methods for measuring discharge

Dilution techniques using chemical or fluorescent tracers can be used in small and medium-sized turbulent streams, which do not have suitable reaches for making a discharge measurement using velocity-area methods. See Table A.1 for applicable conditions.

7 Stage- discharge gauging stations using hydraulic structures

7.1 General

When physical and hydraulic conditions permit, an artificial control consisting of a fixed, undeformable hydraulic structure may be constructed. The stage-discharge relation shall then depend on the geometrical characteristics of such a structure and shall be defined by either

a) the application of the relevant International Standard or

b) by calibration using other methods.

7.2 Site selection

A preliminary survey shall be made of the physical and hydraulic features of the proposed site to check that it conforms (or may be constructed or modified so as to conform) to the requirements necessary for measurement of discharge by the structure as specified in the relevant International Standard.

If the site does not possess the characteristics necessary for adequate measurements, or if an inspection of the watercourse shows that the velocity distribution in the approach channel deviates substantially from uniformity, the site should not be used.

7.3 Types of hydraulic structures

There are a number of hydraulic measuring structures which are the subject of International Standards and these are listed below and in Annex -A.

a) thin-plate, sharp crest, v-notch weirs;

b) thin-plate, sharp crest, rectangular weirs;

c) broad-crested weirs with a sharp upstream edge;

d) broad-crested weirs with a rounded upstream edge;

e) triangular profile weirs;

f) streamlined, triangular profile weirs;

g) triangular profile, flat-V weirs;

h) v-shaped, broad-crested weirs;

i) trapezoidal profile weirs;

j) rectangular flumes;

k) trapezoidal flumes;

l) u-shaped flumes;

m) Parshall flumes;

n) SANIIRI flumes;

o) rectangular free overfalls;

p) non-rectangular free overfalls;

q) vertical underflow gates;

r) compound gauging structures.

The choice of structure may be influenced by the criteria set out in Clause 4 and ISO 8368. Structures that have negative ecological or environmental effects on the natural stream channels should be avoided.

Non-standard structures are also permissible provided they are calibrated by an approved method. A combination of different structures is also permissible.

Normally a water level recorder is installed to provide a continuous record of stage from which discharge can be computed. The position of the water level sensor is discussed in the relevant International Standard.

8 Velocity-discharge gauging stations

8.1 Applications and types of instrument

Conventional methods of flow measurement using stage-discharge relationships from either open channel rated sections or calibrated structures are not always feasible. This may be because of channel size, unstable stage-discharge relationships, or other physical, hydraulic, or environmental considerations (such as aesthetic, navigation and fisheries impacts) and costs. This clause deals with the following acoustic and electromagnetic velocity measurement techniques.

a) Transit time (ISO 6416)

b) Ultrasonic Doppler

— bed mounted systems (ISO 15769)

— side looking systems

c) Acoustic (echo) correlation velocity meters (ISO 15769)

d) Electromagnetic river flow gauges (ISO 9213)

8.2 Site selection

For velocity-discharge gauging stations a control section or reach is not normally necessary unless a simple head raising device is required to maintain a minimum depth at low flows. Thus they provide a means of stream flow measurement without obstructing either the flow, navigation or the passage of fish. The following are general selection criteria for velocity-discharge stations. Specific site selection criteria for each type of instrument are described in the appropriate standard.

a) The channel at the measuring site shall be straight and of uniform cross-section and slope in order to minimize abnormal velocity distribution. When the length of the channel is restricted, it is recommended that the straight length upstream shall be at least twice that downstream;

b) Flow directions for all points on any vertical across the width shall be parallel to one another and at right angles to the measurement section;

c) The bed and margins of the channels shall be stable and well defined at all stages of flow in order to facilitate accurate measurement of the cross-section. The cross-section shall be constant with time;

d) The curves of the distribution of velocities shall be regular in the vertical and horizontal planes of measurement;

e) Sites displaying vortices, reverse flow or dead water are best avoided;

f) Sites above moveable weirs shall be avoided;

g) The flow in the measuring reach should be tranquil i.e. highly turbulent sections, where there is visible white water and significant waves, should be avoided;

h) There should be a suitable cross-section for making discharge measurements at, or within an acceptable distance from, the instrument location.

8.3 Calibration

With the exception of multi-path transit time ultrasonic systems with a significant number of operational paths (see 8.4) all the devices covered in this clause require calibration.

For single, or limited path time of flight, ultrasonic Doppler and echo correlation systems the instruments only measure velocity in part of the cross-section. As such, the measured velocity needs to be related to the mean velocity in the measuring section for any given stage and flow. A relationship between stage and cross-sectional area is also required. In order to establish such a relationship independent measurements of discharge are made using a gauging technique such as current meter gauging. Velocities and stage readings are to be noted. If the discharge obtained by gauging is divided by the cross-sectional area at the velocity sensing device i.e. the area obtained from the stage-area relationship, the mean velocity in the instrument measuring section is obtained. A relationship can then be derived to obtain the mean velocity from the measured velocity. The measured velocity is often referred to as the index velocity. There are two types of relationship that are commonly used, *i.e.* mean velocity as a function of index velocity or mean velocity as a function of both index velocity and stage.

The electromagnetic river flow gauge estimates the mean velocity in the entire cross-section, but the theory on which the gauge is based does not totally translate into reality. Therefore, the factory calibration may need adjusting. The calibration requirements are described in ISO 9213.

8.4 Transit time (acoustic) method

The technique is based upon the principle that the time taken for sound pulses to be transmitted through flowing water, over a known distance, is different to the time taken for the pulse to travel the same distance when that water is stationary. When pulses are transmitted at a known angle to the direction of flow the velocity of the pulse in the downstream direction will be increased by the effect of the velocity of the flowing water. The velocity of the pulse in the upstream direction will be decreased. The difference in the travel times in each direction between the same points will be proportional to the vector component of the water velocity along the "flight path" taken by the signal. When the component of the water velocity along the "flight path" has been obtained the water velocity along the line of flow can be calculated using the known angle of the flight path with respect to the direction of flow. The pulses of sound are transmitted and received by ultrasonic transducers located diagonally opposite each other on each bank of the watercourse. Reflector systems can be used whereby the far bank transducers are replaced by a passive reflector. This obviates the need to take cables across the river. Cross-path systems are often installed where skew flow is a problem. This is when lines of transducers are installed diagrammatically opposite each other to compensate for any errors in the determination of the angle between the line of the transducers and the flow direction which is required to estimate the velocity normal to the measuring section.

The principles of the method together with the requirements for the selection of site, design, construction and operation are described in ISO 6416.

8.5 Doppler

This velocity measurement technique, and thus flow estimation, is based on the principle of 'Doppler Shift' which describes the difference, or shift, in the frequency of sound waves as they are reflected back from a moving body.

The sensors of Doppler systems normally contain a transmitting and a receiving device. A sound wave of high frequency is transmitted into the flow of water and is reflected back at a different frequency by tiny particles or air bubbles (reflectors). The 'shift' between transmitted and reflected frequencies is proportional to the movement of particles relative to the position of the sound source (i.e. the sensor). The velocity of the particles is assumed to be the same as the velocity of the water along the direction of the particles.

All Dopplers fit into one of four general categories, based upon the method by which the measurements are made:

— continuous wave Dopplers;

— pulsed incoherent profiling Dopplers (including narrow band);

— pulse-to-pulse coherent;

— spread spectrum or broadband.

The last three of these four categories are all range gated. Range gating breaks the signal into successive segments and processes each segment independently of the others. This allows the instrument to measure the profile of the velocity at different distances from the instrument, with precise knowledge of the location of each velocity measurement. Side looking/horizontal Acoustic Doppler Current Profilers (ADCPs) use this approach as do several of the more sophisticated bed mounted devices. Continuous wave Dopplers are usually bed mounted devices whereas the other three types can either be bed or side mounted. The former tend to sample vertically upwards whereas the latter tend to sample horizontally across the channel.

The applicability of a Doppler system will be dependent on instrument design, the nature of the site where measurements are required and the operational experience of the user. However, the following are provided as a general guideline:

a) continuous wave bed mounted Dopplers: Typically channel widths of 0,5 – 3,0 m and depths of 0,1 – 2,0 m;

b) bed mounted profiling/ADCP Dopplers: Typically channel widths of 0,5 – 5,0 m and depths of 0,2 – 4,0 m;

c) horizontal ADCPs/side-lookers: Channel widths of 0,5 – 500 m and greater and depths of 0,5 to 50 m.

There are a number of factors that should be considered in selecting a site, which may influence performance at a chosen location (see ISO 15769 for details).

8.6 Acoustic (echo) correlation velocity meters

The echo (cross) correlation velocity meter is very similar to a bed mounted Doppler in terms of size and shape and application. However, even though it is dependent on transmitted sound pulses being reflected back from moving particles in the water it works on a somewhat different principle.

An ultrasonic transducer transmits a short ultrasonic pulse (or pulse code) into the water. These pulses are reflected by particles or air bubbles. The reflected ultrasonic echo from the first pulse is received as a characteristic pattern. This is digitized and stored as the first scan of the dated echo pattern. Another ultrasonic pulse is then transmitted and the incoming echo patterns are digitized and stored. This is the second scan pattern. Using the travel time difference between the transmission and reception time, the position of the particles in the flow cross-section can be determined. By means of cross-correlation the echo patterns are checked within a number of different time windows for agreement. The cross-correlation also delivers the temporal movement of the characteristic pattern in the second scan. This temporal movement of the pattern under consideration can be directly converted to the velocity of flow for this particular beam. The process is repeated a large number of times per second and single velocities at different distances are computed in real time. The instrument effectively divides the water column in front of it into a number of cells so it is possible to accurately determine the velocity profile in the vertical.

The principles of the method together with the requirements for the selection of site, design, construction and operation are described in ISO 15769.

8.7 Electromagnetic method (Full channel width coil)

The Electromagnetic gauge operates on a principle similar to that of an electric dynamo. If a length of conductor moves through a magnetic field, a voltage is generated between the ends of the conductor.

In the Electromagnetic gauge, the magnetic field is generated by a horizontal coil, which is installed either above or below the river, canal or other water body. The conductor in this case is the fluid, which moves through the magnetic field. The small voltages generated are sensed by electrodes on either bank. The faster the fluid moves the greater is the voltage generated. The technique integrates the entire velocity in the cross-section to produce a mean velocity.

The principles of the method together with the requirements for the selection of site, design, construction and operation are described in ISO 9213.

9 Measurement under difficult conditions

9.1 Ice and frost conditions

9.1.1 General

Weather conditions such as ice or frost can impede the operation of the stage-sensing device or recorder thus affecting the stability of the stage-discharge relationship.

9.1.2 Stilling well

Any stilling well and inlet pipes shall be constructed in such a manner that the system will remain in operation during periods of freezing temperatures

9.1.3 Diaphragm pressure sensor

Precautions should be taken to protect a diaphragm pressure sensor under ice conditions.

9.2 Weed growth

Weed growth in a watercourse can change the hydraulic flow conditions in the measuring reach, and hence the stage-discharge relationship. Seasonal plant development may make it necessary to correct computed discharge data in order to follow the variation in the stage-discharge relationship. This can be achieved by carrying out sufficient current meter or other flow measurements to allow the deviation to be calculated. In some cases the weed growth patterns may change in such a regular and repeatable pattern that a seasonal stage-discharge relation may be defined.

9.3 Extreme sedimentation conditions

Care has to be taken to prevent or remedy significant siltation of the inlet tube and/ or the stilling well itself. The risk of siltation is very much dependent on local conditions.

The stage-discharge relations of stations operated in alluvial channels are subject to shifting-control conditions and more frequent measurements typically are required to define a family of shift curves (see ISO 1100-2 and ISO/TR 11332).

10 Operation and maintenance

10.1 General

The level of operational maintenance given to hydrometric measurement stations will be proportional to the uncertainty in the end product, the level or flow being measured. This level will vary according to the criteria set out in Clause 4.

10.2 Water level (Stage) only gauging stations

The following operation and maintenance items shall be considered:

a) maintenance of the agreed access to the site including safety;

b) cleaning of staff gauges;

c) flushing and desilting of stilling wells;

d) data recording equipment maintained according to manufacturer's manual;

e) performance checking of data loggers and/or telemetry;

f) performance checking of water level sensors (dual sensors may be installed for resilience) including calibration where necessary;

g) availability of spare equipment should a fault be identified;

h) a periodic full quality audit of all features of the station including checks of the station datum, condition of any buildings, fences and gates and any signage advising the general public of any risk to public safety;

i) a record of site checks carried out with any actions clearly recorded. A copy of this shall be retained on site.

10.3 Stage-discharge gauging stations

Most of the stations which fall into this category will have water level measurement facilities as part of the equipment. Operation and maintenance of this equipment should be as in 10.2. In addition to this, the following actions are essential.

a) Regular flow determinations shall be carried out and related to the water level at the time of measurement. Methods which can be used are listed in 6.1. The frequency of these measurements will probably decrease with time after a stage-discharge relationship has been confirmed. Further measurements shall be carried out should any doubt exist about the accuracy of the stage-discharge relationship and also after a bankfull or higher flood event.

b) The control feature described in 6.2.2 shall be inspected at regular intervals and again after any high flow event. Any damage or disturbance to a natural or artificial control including vegetation or weed growth affecting the performance of the control shall be reported to the responsible supervisor or office, so that remedial action can be taken.

c) Any factors affecting the modularity of the control feature, such as changes to the river regime downstream of the control feature, shall also be reported with particular reference to weed growth in the channel.

10.4 Stage-discharge gauging stations using hydraulic structures

Most of the stations which fall into this category will have water level measurement facilities as part of the equipment. Operation and maintenance of this equipment should be as in 10.2. In addition to this, the following actions are essential.

a) The crest and wing walls of any structure shall be kept as free as possible from algal growth which can affect the accuracy of level measurement, thus affecting the computed flow;

b) The approach channel shall also be kept free of excessive sedimentation and weed and other aquatic growth for a distance of four times the channel width;

c) Checks of the downstream water level shall be noted to ensure that the structure is operating under modular conditions;

d) Flow determinations using any of the methods listed in 6.1 shall be carried out to confirm the stage–discharge relationship;

e) Checks of the dimensions and datum values of the structure shall be carried out periodically;

f) An engineering asset inspection shall also be carried out periodically.

10.5 Velocity-discharge gauging stations

Most of the stations which fall into this category will have water level measurement facilities as part of the equipment. Operation and maintenance of this equipment should be as in 10.2. In addition to this, the following actions are essential.

a) The bed and cross-section of the measuring reach shall be checked at regular intervals and again following bankfull or higher flow events. Changes identified which are likely to cause inaccurate flow determination shall be followed by changes to the equipment software to eliminate this;

b) Weed growth in the channel which might affect the performance of an ultrasonic or Doppler type gauge should be cleared out. In addition, with an ultrasonic flow gauge, any vegetation which is likely to interrupt the signal reception of paths which are currently above water level should be removed;

c) Occasional flow determinations shall be carried out using one of the methods listed in 6.1 to confirm the performance of the equipment.

Annex A
(informative)

Applicable conditions for selection of discharge measurement method

Table A.1 — Applicable conditions for selection of discharge measurement method

Method	Relevant Standard	Width	Depth	Velocity	Sediment Load	Approach Condition	Time Factor	Approximate Minimum Uncertainty %	Comment
Velocity-area methods									
Rotating-element or electromagnetic current meters									
Wading	ISO 748	L,M,S	S	S		b,c,d	J,K	5	A,B
Bridge or cableway	ISO 748	L,M,S	L,M,S	L,M,S		b,c,d	J,K	5	A,B,C,D
Boat	ISO 748	L,M,S	L,M	L,M,S		b,c,d	J,K	5	A,B,C,E
Acoustic meters									
Wading	ISO 748	L,M,S	S	S		b,c,d	J,K	5	A,B
Remote-controlled or powerboat	ISO/TR 24578	L,M,S	L,M	L,M,S		b,c,d	J,K	5	E
Tethered raft	ISO/TR 24578	L,M,S	L,M	L,M,S		b,c,d	J,K	5	E
Floats	ISO 748	L,M,S	L,M,S	L,M,S		b,c,d	J,K	10	F
Slope-area method	ISO 1070	L,M	L,M	L,M		b,c,d	K,N	10	Q
Dilution method									
Chemical tracer	ISO 9555-1, ISO 9555-3, ISO/TR 11656	M,S	M,S	M,S		c,g,k	K	5	
Fluorescent tracer	ISO 9555-1, ISO 9555-4, ISO/TR 11656	M,S	M,S	M,S		c,g,k	K	5	
Structures									
Thin-plate, sharp crest, V-notch weir	ISO 1438	S	S	S	I	a,b,e,j	J,G	1	
Thin-plate, sharp crest, rectangular weir	ISO 1438	M,S	S	S	I	a,b,e,f,j	J,G	3	
Broad crested weir with sharp edge	ISO 3846	M,S	S	M,S	I	a,b,e,f,j	J,G	3	
Broad crested weir with rounded edge	ISO 4374	M,S	S	M,S	I	a,b,e,h,j	J,G	5	
Triangular profile weir	ISO 4360	M,S	M,S	M,S	I	a,b,e,h,j	J,G	5	
Streamlined, triangular profile weir	ISO 9827	M,S	M,S	M,S	I	a,b,e,j	J,G	5	
Triangular profile, flat-V weir	ISO 4377	M,S	M,S	M,S	I	a,b,e,j	J,G	5	

Table A.1 *(continued)*

Method	Relevant Standard	Width	Depth	Velocity	Sediment Load	Approach Condition	Time Factor	Approximate Minimum Uncertainty %	Comment
V-shaped, broad-crested weir	ISO 8333	M,S	M,S	M,S	I	a,b,i	J,G	5	
Trapezoidal profile weir	ISO 4362	M,S	M,S	M,S	I	a,b,e	J,G	5	
Rectangular flume	ISO 4359	M,S	M,S	M,S	I	a,b	J,G	5	
Trapezoidal flume	ISO 4359	M,S	M,S	M,S		a,b	J,G	5	
U-shaped flume	ISO 4359	M,S	M,S	M,S	I	a,b,i	J,G	5	
Parshall flume	ISO 9826	M,S	S	M,S	I	a,b,e,I	J,G	5	
SANIIRI flume	ISO 9826	M,S	S	M,S	I	a,b,e,I	J,G	5	
Free overfalls, rectangular channels	ISO 3847	M,S	M,S	M,S	I	a,b,e,j	J,G	10	
Free overfalls, non-rectangular channels	ISO 4371	M,S	M,S	M,S	I	a,b,e,j	J,G	10	
Vertical gates	ISO 13550	M,S	M,S	M,S		a,b,e,j	J,G	10	
Compound structures	ISO 14139	M,S	M,S	M,S	I	a,b,e,j	J,G	5	
Multi-path transit time ultrasonic	ISO 6416	L,M,S	L,M	L,M,S	R	b,c,d	G,J	5	T,U
Cubature	ISO 2425						K	10	H

NOTES:			
a	Flow should be sub-critical	E	Major error can be due to drift, obstruction of boat and heaving action
b	Flow should have no cross-currents	F	This method is recommended for use only when the effect of the wind is small and where no other will serve. Such conditions are likely to be so variable that no representative accuracies can be quoted, but usually the accuracy of this method is lower than conventional methods using current meters and higher than the slope-area method
c	Channel should be relatively free from vegetation	G	Method suitable for more frequent discharge measurements
d	Channel should be fairly straight and uniform in cross-section	H	Method suitable for reverse flows
e	Channel should be fairly straight and symmetrical in cross-section for about 10 channel widths upstream	I	Heavy sediment concentration in approach section will invalidate the method
f	Channel should have vertical walls and a level floor for a distance upstream of not less than 10 times the width of the nappe at maximum head	J	Quick method (less than 1 h)
g	Flow in the channel should be turbulent (even including a hydraulic jump) to ensure mixing	K	Slow method (1 h to 6 h)
h	Channel should be rectangular for a distance upstream of at least twice the maximum head	L	Large width (more than 50 m) or high velocity (more than 3 m/s) or large depth (more than 5 m)
i	Channel should be nearly U-shaped	M	Medium width (between 5 m and 50 m) or medium velocity (between 1 m/s and 3 m/s) or medium depth (between 1 m and 5 m)
j	Velocity distribution should be fairly uniform	N	Very slow method (more than 6 h)
k	Channel should be free from recess in the banks and depressions in the bed	Q	Approximate method used when velocity-area method not feasible and slope can be determined with sufficient accuracy
A	For velocity-area method, with velocity observed at 0,6 times the depth, or with two-point method, the minimum uncertainty may be up to 5 %	R	Suspended material concentration needs to be low enough to avoid a loss of acoustic signal; for the same reason, the flow should be free from bubbles

NOTES:			
B	For velocity-area method, with velocity observed at surface, the minimum uncertainty may be up to 10 %	S	Narrow width (less than 5 m) or shallow depth (less than 1 m) or low velocity (less than 1 m/s)
C	Corrections may be required because of distance or air- and wet-line effects	T	May be used in rivers with weed growth and moving bed material
D	Major error can be caused by pier effects	U	Measuring section must have stable bed

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