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Measurement of liquid flow in open channels — Measurement in meandering rivers and in streams with unstable boundaries

Mesure de débit des liquides dans les canaux découverts — Mesurage en rivières à méandres et en cours d'eau à limites instables

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Contents

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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.

The main task of technical committees is to prepare International Standards, but in exceptional circumstances a technical committee may propose the publication of a Technical Report of one of the following types:

— type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;

— type 2, when the subject is still under technical development or where for any other reason there is the future but not immediate possibility of an agreement on an International Standard;

— type 3, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example).

Technical Reports of types 1 and 2 are subject to review within three years of publication, to decide whether they can be transformed into International Standards. Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

ISO/TR 9210, which is a Technical Report of type 2, was prepared by Technical Committee ISO/TC 113, *Measurement of liquid flow in open channels*, Sub-Committee SC 7, *Special problems and methods of measurements*.

Introduction

Various methods of measurement of discharge in open channels are available, of which the velocity-area method is most extensively used. The principles of this method are published in ISO 748. This Technical Report deals specifically with measurements of flow in meandering and braided rivers and elaborates some of the provisions in ISO 748.

Measurement of liquid flow in open channels — Measurement in meandering rivers and in streams with unstable boundaries

1 Scope

This Technical Report provides guidelines for discharge measurements in meandering and braided rivers, and from bridges, following the provisions of ISO 748.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Technical Report. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Technical Report are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 748:1979, *Liquid flow measurement in open channels — Velocity-area methods.*

ISO 772:1988, *Liquid flow measurement in open channels — Vocabulary and symbols.*

3 Definitions

For the purposes of this Technical Report, the definitions given in ISO 772 and the following definitions apply.

3.1 incised river: River which has cut its channel through part of the valley floor or which has formed its channel by erosion. The sediment carried by such a river is generally dissimilar to that in its bed.

3.2 alluvial river: River which flows through alluvium formed from its own deposits. The sediment which it carries, except for the wash load, is similar to that in its bed.

3.3 meandering river: Channel which follows a sinuous path owing to natural physical causes not imposed by external constraints. The conditions are characterized by curved flow and alternating shoals and bank erosion.

3.4 braided river: River characterized by an extremely wide and shallow channel in which flow passes through a number of small interlaced channels, separated by shoals, with little or no erosion of the main banks. The channel as a whole does not meander, although local meandering in minor channels generally occurs.

3.5 transition; crossover: Stretch of channel between adjacent meander loops where the main flow crosses over from one side of the channel to the other. It is characterized by a reduction in depth of flow.

3.6 transverse flow: Flow perpendicular to the main direction of flow which is parallel to the axis of the channel. Sometimes referred to as secondary flow, to differentiate it from the main or primary flow. Transverse flow occurs in all channels, both straight and curved in plan, although it is more evident in curved channels, causing super-elevation of the water surface on the outside of a bend.

3.7 node; nodal point: Point in the plan of a sinuous channel at which the amplitude of the sinuous path is a minimum. It is located in the transition, or crossover, in the channel. In a dynamically stable channel which meanders, the node migrates downstream with the meander loops, but may be prevented from migrating by natural or artificial obstruction, thus creating a static stretch of river downstream.

3.8 specific discharge: This term has two meanings depending on local usage.

a) Discharge per unit area of catchment. Often used to compare the magnitude of flow in different rivers (maximum, mean or minimum).

b) Discharge corresponding to a specific stage or gauge height. Often used to illustrate changes in the conveyance capacity of a channel caused by changes in sediment load and bed level during a particular period (flood, annual flow, flow between years, etc.). Sometimes used to detect accreting or degrading channels over a period of years.

4 Site selection in stable and straight reaches of meandering rivers

Subclause 6.2.1 a) of ISO 748:1979 indicates that the channel at the measuring site shall be straight and of uniform cross-section and slope, as far as possible, in order to avoid an abnormal velocity distribution. Subclause 6.2 b) of ISO 748:1979 further states that the accuracy of the determination of discharge by the velocity-area method is increased if the velocities at all points are parallel to one another and at right angles to the meandering cross-section.

At a measuring site, even if properly located to satisfy these requirements during flood season, the flow direction can change appreciably during low water season. As far as possible, the basic stream gauging section should not be changed. However, when the flow directions during flood and low water seasons are very different, it is permissible to suitably adjust the orientation of gauging section during low water season, taking into account the requirements in subclauses 6.2.1 a) and 6.2 b) of ISO 748:1979.

5 Site selection in rivers with relatively stable meanders

In alluvial rivers, the course over long reaches is sometimes comprised of one meander followed by another. Finding a sufficiently long straight reach then becomes difficult. Under these conditions the gauging site shall be located either in the reach of two bends or at the transition between successive bends.

In a bend, transverse flow develops, and the resultant direction and velocity of flow are composed of the net effect of normal and transverse flows. The distribution of velocities and depths across the section also becomes extremely heterogeneous.

On the other hand, in the transition between successive meanders, the river course is relatively straight over a short reach. The cross-section is more uniform and better defined that in the bend. A transition therefore provides better site conditions for a gauging station. When a straight reach over a sufficiently long distance is not available, the best alternative is therefore to select a site in a transition.

The important factors that affect the accuracy of the discharge measurement in meandering rivers are the scouring and silting and the change in flow direction at the discharge measuring section. In regard to the former, the measuring time should be shortened as much as possible by operating more than one crew simultaneously. In regard to the latter, the velocity measured at each point shall be corrected for angle using a direction-measuring current meter.

6 Site selection in rivers with unstable meanders

In alluvial rivers, meanders are often unstable. If the bend curvature is small, the meander tends to progress downstream by continued erosion along the concave bank and filling along the convex bank. In this process, the river course changes its position. If the bend curvature is great, continued erosion and filling result in formation of a hairpin bend, ultimately forming a cut-off across the bottleneck. In this process, the meander changes its shape.

Thus depending on the bend curvature, bank recession and changes in meander position and/or shape occur, rendering the river course unstable. Requirements of site stability cannot be satisfied in such rivers.

Local strata of stiff clay or rock are sometimes encountered along the meandering course of alluvial rivers. This natural constraint obstructs free passage of the meandering train. The meanders accumulate upstream of such constraints. On the downstream side after some distance, the river course again forms meanders. However, within and immediately downstream of the constraint, the river profile does not change appreciably. These locations are termed "nodal points" and, in view of the stability of the river at these points, they are ideally suited for locating gauging sites on rivers which have an otherwise unstable course.

When natural constraints do not occur, sometimes artificial constraints in the form of a bridge with a constricted waterway may exist. The effect of such an artificial constraint is to produce nodal points. The river reach immediately downstream of such structures, where the river course remains locally stable, can therefore be utilized for locating gauging sites.

7 Discharge measurement in braided rivers

One difficulty experienced in discharge measurement in braided rivers with sandy beds carrying sustained heavy floods is the instability of the river. Different bed forms, such as ripples, mega-ripples, dunes and sand waves, can occur simultaneously in different portions of the cross-section. Their size can be relatively large (for example, a wave height up to 0,3 m, 1,5 m, 7,6 m and 15,2 m, with corresponding wave lengths up to 1,5 m, 152 m, 488 m and 914 m respectively). These bed forms can also exhibit a significant rate of downstream movement (as much as 3 m/day, 122 m/day, 167 m/day and 204 m/day respectively have been observed). The bed form controls bed rugosity, and hence different parts of a cross-section can have different rugosities and depths merely due to different bed forms. Movement of bed forms in a single day causes continual variation in local rugosity coefficients and also in depths. All these factors can bring about appreciable variation in water level, even with the same discharge. Under these conditions, in addition to the mean stage-discharge curve, curves at extremes of depth must be established. For instance, upper levels and freeboards of engineering structures have to be designed with respect to upper stage curves, whereas foundation levels have to be designed with respect to the depth of flow according to the lower stage envelope curves.

Another cause of instability in braided rivers is the downstream movement of islands separating channels. These islands are eroded at their upstream end and built up at their downstream end, resulting in migration of the islands. The rate of such movement is, however, slow and the accuracy of daily observation of discharge at the gauging site therefore may not be affected. Segmentation may however need to be suitably changed when daily or periodic observations are made during the flood season.

When several major channels are required to be gauged along the measuring line, it may become necessary to employ two or more survey boats and crews to work simultaneously in order to complete one discharge measurement at a single time. Whenever possible, it is however preferable to locate the gauging site where the river is narrow and has fewer active channels due to natural or artificial constraints.

Braided rivers in submountainous regions often experience flash floods wherein the stage changes rapidly. Discharge measurements therefore shall be made as quickly as possible to keep the change in stage to a minimum. This can be achieved by using a single-point method for measurement of velocity instead of the two- or multiple-point method, by reducing the number of observation verticals. In such reduction, the resulting error shall be less than the error caused by a rapid change in stage during the period of a single discharge measurement.

As an illustration, a typical rapid discharge measurement can be made using the following procedure:

a) use the 0,6 depth method instead of the 0,2 to 0,8 depth or multipoint method;

b) use the 0,2 depth or a subsurface method, if the 0,6 method creates a vertical angle requiring time-consuming correction or if the vertical angle increases because of drift, thus increasing the sounding time;

c) reduce time of velocity observation to about 20 s to 30 s;

d) reduce the number of observation verticals to about 15 to 18.

This procedure reduces the time for discharge measurement to 15 min to 20 min.

Braided rivers in submountainous regions are often subject to sedimentation, with a tendency to shifting channels. This instability affects not only the scheme of segmentation but also the rating curve. Specific discharge-gauging curves are useful in such cases to keep track of the sedimentation rate.

8 Discharge measurement from a bridge

In wide flood plains, rivers of both meandering and braided types often spill copiously during high floods. Spill depths are often substantial and the overbank area subject to extensive inundation.

On the overbank area, numerous obstructions to flow can exist, such as buildings, crops, trees, bushes and weeds. Negotiating such obstructions during discharge measurement using a boat is difficult. This difficulty is not encountered if discharge measurements are made from a bridge. The discharge of the river channel and spills may be spread over an extensive area, but it converges and passes through the relatively narrow and well-defined bridge structure. Discharge measurements from a bridge then are more practical.

In making depth and velocity observations from a bridge, the choice of the upstream or downstream side of the bridge for the observation cross-section should be guided by comparative merit. For instance, when the upstream side is chosen, the hydraulic conditions are normally found to be superior and approaching flotsam can be seen and more easily avoided. On the other hand, if the measurement is made from the downstream side, the vertical angles are more easily observed, the flow is straighter due to the guiding effect of the bridge and damage to the current-meter due to possible collision with the piers is avoided. The physical conditions at the bridge, such as location of walkways, traffic hazards and accumulation of debris against the piers, also need to be considered.

When making observations from a bridge, it must be noted that the discharge distribution along the measurement line is affected by the obstruction caused by the bridge piers. The effect is local and is restricted to a limited width on either side of the piers. Within this width, measurement of velocity and depth is difficult and risky, with increased uncertainty. The greater the number of piers, the greater the uncertainty in the measurement of the total discharge. In such cases, estimation of discharge flowing through the cross-sectional width adjoining the piers is preferred to direct measurement. The estimation is made by first determining the discharge intensity q_m over the vertical at the end of the affected zone on either side of each of the piers. Next, it is assumed that, in the absence of the pier, this discharge intensity would have been operative over the entire width b_m between the vertical at the end of the affected zone and the centreline of the pier. The discharge flowing through the affected zone adjoining each pier is then estimated as $q_m b_m$.

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