INTERNATIONAL STANDARD

ISO 748

Fifth edition 2021-11

《国际标准》
IS0748
第五版 （2021年11月发布）

Hydrometry - Measurement of liquid flow in open channels - Velocity area methods using point velocity measurements

Hydrométrie - Mesurage du débit des écoulements à surface libre - Méthodes d'exploration du champ des vitesses utilisant le mesurage de la vitesse par point

水文测量
明渠中液体流量的测量
使用点流速测量的速度面积法

2023年5月1日第一版翻译稿，仅用于非商业目的

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Reference number
ISO 748:2021(E)

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Published in Switzerland

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Foreword 前言

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

用于制定本标准的程序和打算进一步维护本标准的程序在《ISO/IEC指引》第1部分中有所描述。值得注意的是，不同类型的ISO文件需要不同的批准标准。本标准是根据《ISO/IEC指引》第2部分的编辑规则起草的（详见www.iso.org/directives）。

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

关于标准的自愿性质的解释，与合格评定有关的ISO特定术语和表达方式的含义，以及关于ISO在技术性贸易壁垒（TBT）中遵守世界贸易组织（WTO）原则的信息，详见www.iso.org/iso/foreword.html。

This document was prepared by Technical Committee ISO/TC 113, *Hydrometry*, Subcommittee SC 1, *Velocity area methods*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 318, Hydrometry, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

本标准由ISO/TC 113水力学技术委员会SC 1小组速度面积法委员会与欧洲标准化委员会（CEN）技术委员会CEN/TC 318水力学技术委员会合作，根据ISO与CEN之间的技术合作协议（《维也纳协议》）编写。

This fifth edition cancels and replaces the fourth edition (ISO 748:2007), which has been technically revised. The main changes compared with the previous edition are as follows:
第五版取消并取代了第四版（ISO 748:2007），并对其进行了技术修订。与前一版相比，主要变化如下：

— the document has been updated to take account of technological developments
为响应技术发展，文中涉及的相应文件已更新;

— *Clause 7* has been revised to reduce uncertainties in measurements
对*第7条*进行了修订，以减少测量的不确定因素;

— ISO 9196 regarding measurement under ice conditions has been incorporated
纳入了关于冰面条件下测量的ISO 9196.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at *www.iso.org/members.html*.
关于本标准的任何反馈或问题应直接向用户的国家标准机构提出。这些机构的完整名单可在*www.iso.org/members.html*查阅。

Hydrometry - Measurement of liquid flow in open channels - Velocity area methods using point velocity measurements

水文测量-明渠中液体流量的测量-使用点流速测量的速度面积法

1 Scope 适用范围

This document specifies methods for determining the velocity and cross-sectional area of water flowing in open channels and for calculating the discharge employing point velocity measurement devices.

本标准规定了确定明渠水流速度和过流断面面积，以及使用点流速仪计算流量的方法。

It is applicable to methods using rotating-element current meters, acoustic doppler velocimeters (ADVs), acoustic doppler current profiler (ADCP) stationary method, surface velocity measurement including floats and other surface velocity systems.

本标准适用于使用转子式流速仪、声学多普勒流速仪（ADVs）、声学多普勒剖面流速仪（ADCP）静止法、包括浮标和其他水面流速测量系统的水面流速测量方法。

Although some general procedures are discussed, this document does not describe in detail how to use or deploy these systems.

虽然本标准讨论了一些通用程序，但并未详细描述如何使用或部署这些系统。

NOTE 注：

For detailed procedures, refer to guidelines from instrument manufacturers and the appropriate public agencies.

关于详细操作程序，请参考仪器制造商和相应的公共机构的使用指南。

2 Normative references 规范性参考文献

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

有以下文件在文中被提及，其部分或全部内容构成本标准的要求。对于注明日期的参考文献，仅适用于所引用的版本，而对于未注明日期的参考文件，适用于所参考文件的最新版本（包括任何修订版）。

ISO 772, *Hydrometry — Vocabulary and symbols 水文测量学 - 词汇和符号*

ISO 25377:2020, *Hydrometric uncertainty guidance (HUG) 水文测量不确定性指南(HUG)*

3 Terms and definitions 术语与定义

For the purposes of this document, the terms and definitions given in ISO 772 apply.
本标准使用ISO 772中的术语和定义。

ISO and IEC maintain terminological databases for use in standardization at the following addresses:
国际标准化组织和国际电工委员会在以下地址维护用于标准化的术语数据库：

— ISO Online browsing platform 国际标准化组织在线浏览平台: available at https://www.iso.org/obp
— IEC Electropedia 电子百科: available at https://www.electropedia.org/

4 Principle of the methods of measurements 测量方法的原理

The principle depends upon determining velocity and cross-sectional area.
其原理取决于待确定的速度和过流断面面积。
This is characterized as shown by *Formula (1)*:
其特点如*公式（1）*所示

$$Q = \bar{V}A \tag{1}$$

Where 其中

Q is the flow (m^3/s); Q 是流量 (单位：m^3/s)

$\bar{V}$ is the mean velocity (m/s) (averaged over the cross-section);
是平均流速（m/s）（过流断面的平均值）；

5 Site Selection 场地选择

5.1 Selection of site 场地的选择

It may, under certain conditions of river flow or level, prove necessary to carry out measurements on sections upstream or downstream of the original chosen location. This is quite acceptable if there are no substantial unmeasured losses or gains to the river in the intervening reach and so long as all flow measurements can be related to any stage value recorded at the principal reference section.
在某些河流流量或水位条件下，可能需要在最初选择的地点的上游或下游部分进行测量。如果在中间的河段没有大量未测量的出流或入流，则可入选作为检测点，而且只要所有的流量测量都能与主要参考断面记录的任何阶段值相关。

NOTE 注意：
Ideal measurement conditions can be found when all requirements are satisfied. If ideal conditions are not available, it is still possible to make a measurement, but uncertainty will be increased.
当所有要求都得到满足时，则认为找到了理想的测量条件。若没有找到理想条件，依旧可以进行测量，但不确定因素会增加。

5.2 Demarcation of site 场地的划定

5.2.1 A permanent station, or one likely to be used frequently for future measurement, shall be provided with means for demarcation of the cross-section and for determination of stage.
一个永久性站点，或一个可能经常用于流量测量的站点应由划定过流断面和确定阶段的方法确定。

5.2.2 The position of each cross-section, normal to the mean direction of flow, shall be defined on the two banks by clearly visible and readily identifiable markers. Where a site is subject to considerable snow cover, the section line-markers may be referenced to other natural objects and, if possible, the position noted using a global navigation satellite system (GNSS).
每一过流断面的位置，在平均流向的法线上，应在两岸以清晰可见和易于识别的标记来界定。如果现场有大量积雪，断面线标记可参照其他自然物体，如果可能的话，可使用全球导航卫星系统（GNSS）记录位置。

5.2.3 The stage shall be read from a gauge at the start and end of the measurement period. If the water level changes rapidly, a level measurement is recommended to be taken at least every 30 min.
在测量期间的开始和结束时，应从仪表上读出其处于哪一阶段。如果水位变化迅速，建议至少每30分钟测量一次水位。

5.2.4 An auxiliary gauge on the opposite bank shall be installed where there is likelihood of a difference in the level of water surface between the two banks. The mean of the measurements taken from the two gauges shall be used as the mean level of the water surface and as a base for the cross- sectional profile of the stream.
在两岸水面可能存在差异的情况下，应在对岸安装一个辅助水尺。两个水位计测量的平均值应作为水面的平均水平，并作为河流过流断面剖面的基础。

6 Measurement of cross-sectional area 过流断面面积的测量

6.1 General 概述

The cross-sectional profile of the open channel at the gauging-site shall be determined at a sufficient number of points to establish the shape of the bed and to minimize the uncertainty in the calculation of the cross-sectional area.
测量点的明渠过流断面测定应在足够多的点上进行，如此方可确定渠底的形状，并尽量减少过流断面面积计算的不确定因素。

6.2 Measurement of width 宽度的测量

Measurement of the width of the channel and the width of the individual segments shall be obtained by measuring the horizontal distance from or to a fixed reference point which shall be in the same vertical plane as the cross-section at the measuring site.
渠道宽度和各段宽度的测量应通过测量与固定参考点的水平距离获得，该参考点应与测量地点的过流断面处于同一垂直面。

6.3 Measurement of depth 深度的测量

Measurement of depth shall be made at intervals close enough to define the cross-sectional profile accurately. The number of points at which depth is to be measured shall be at each vertical where velocity is measured.
深度的测量应以足够近的间隔进行，以准确界定过流断面的轮廓。测量深度的点的数量应在测量速度的每个垂直点上进行。

The number of sampling verticals depends on the variability of the water depth in the cross-section. This number is adequate when the number of points does not significantly change the value of the cross-section obtained.

取样垂直度的数量取决于过流断面中水深的变化情况。当点的数量不会引起所获得的过流断面的数值的明显改变时，说明点数已经足量。

Where it is impracticable to take more than one reading of the depth, the uncertainty in measurement may be increased (see *Clause 9*).
如果不能对深度进行一次以上的深度操作，测量的不确定性可能会增加（详见*第9条*）。

When measuring depths with a wire not normal to the surface, see *Annex F*.
当使用不垂直于水面的金属丝测量深度时，请参见*附录F*。

7 Measurement of mean velocity 平均流速的测量

7.1 Determination of mean velocity using point velocity measurements 使用点速度测量法确定平均流速

7.1.1 General 概述

A range of instruments are available to measure point velocity. These are described in *Annex A* .
可用于测量点速度的仪器众多，详细仪器应用的描述可见于*附录A*。

7.1.2 Measurement procedure 测量程序

Velocity observations are normally made at the same time as measurements of the depth. Where, however, the two measurements are made at different times, such as at a pre-surveyed station, the velocity observations shall be taken at a sufficient number of places, and the horizontal distance between observations shall be measured as described in *6.2* and *6.3*.
速度观测通常与深度测量同时进行。然而，如果这两个测量是在不同的时间进行的，例如在一个预先勘测的站点，速度观测应在足够数量的地方进行，观测之间的水平距离应按*6.2*和*6.3*所述进行测量。

For all measurements, the best professional judgement of an experienced hydrographer should be used, and detailed notes regarding the measurement and assumptions made should be included in the record.
所有测量应使用有经验的水文地理学家的最佳专业判断执行，并在记录中包括有关测量和假设的详细说明。

In judging the recommended minimum number of verticals in small channels that are to be defined for the purpose of determining flow at a particular location, the following criteria shall be applied.
在判断为确定某一特定地点的流量而确定的小河道的建议最小垂直度数时，应使用以下标准。

— Channel width 渠道宽度< 0.5 m $n \geq 15$

— Channel width 渠道宽度> 0.5 m且< 5m $n \geq 20$

— Channel width 渠道宽度> 5 m $n \geq 22$

As far as possible, verticals should be chosen so that the discharge of each segment is less than 5 % of the total and shall not exceed 10 % of the total.
纵向的选择应尽可能使每段的流量小于总量的5%，且不得超过总量的10%。

For very small channels, practical considerations do not always allow the recommended minimum number of verticals.
非常小的通道实际上并不一定能达到建议的最小垂直数。

The distance between two verticals shall be greater than the width of the sensor and should not be less than the minimum recommendations of the specific instrument used.
两条垂直线之间的距离应大于传感器的宽度，并且不应小于所使用的具体仪器的最小建议值。

In all instances, measurements of depth made at the water’s edge are additional to the above. The first and last verticals shall be as close as practically possible to the water’s edge.

在所有情况下，在水边进行的深度测量是对上述规定的补充。第一个和最后一个垂直点应尽可能地靠近水边。

The device used for point velocity measurement shall be held in position for a minimum of 30s to obtain a good representation of mean velocity. It shall be held so movement of the instrument is minimized during the measurement period.
用于点速度测量的仪器应至少保持30秒的间距，才能最好地监测到平均流速。在测量过程中，应尽量减少仪器的移动。

In channels where the flow is unsteady, it is possible to correct for the variations in the total discharge during the period of the measurement not only by observing the change in stage, but also by continuously measuring the velocity at some conveniently chosen point in the main current.
在流量不稳定的渠道中，不仅可以通过观察阶段的变化来校正测量期间总流量的变化，还可以通过连续测量主要水流中某个方便选择的点的速度来校正。

For continuity with previous versions of this document, the following criteria can be used but the level of uncertainty of the overall measurement will be much greater.
为了与本标准以前的版本保持一致，可以使用以下标准，但整个测量的不确定性水平将大大增加。

— Channel width 渠道宽度< 0.5 m — n = 5至6
— Channel width 渠道宽度> 0.5 m and < 1 m — n = 6至7
— Channel width 渠道宽度> 1 m and < 3 m — n = 7至12
— Channel width 渠道宽度> 3 m and < 5 m — n = 13至16
— Channel width 渠道宽度> 5 m — $n \geq 22$

See *Table D.6* for guidance on percentage uncertainty in measurement of mean velocity due to a limited number of verticals.
由于垂直方向的数量有限，可参考*表D6*确定关于平均速度测量的不确定性百分比。

7.1.3 Oblique flow 斜向水流

If oblique flow is unavoidable, either the velocity component perpendicular to the cross-section should be measured directly or the velocity magnitude measured and corrected based upon the angle from perpendicular. Special instruments have been developed for measuring the angle and velocity at a point simultaneously. Where, however, these are not available and there is insignificant wind, the angle of flow throughout the vertical can be assumed to be the same as that observed on the surface. This angle can be measured with appropriate equipment provided that the operator is located above the measurement vertical. If the channel is very deep, subjected to tides or the local bed profile is changing rapidly, this assumption shall not be accepted without confirmation.
如果斜向水流无法避免，应直接测量垂直于横截面的速度分量，或测量速度大小，并根据与垂直方向的角度进行校正。目前已有专门用于同时测量某一点的角度和速度的仪器。但在无法获得这些专业仪器、且没有明显的风的条件下，可以假设整个垂直方向的流动角度与水面上观察到的角度相同。这个角度可以用适当的设备来测量，只要操作者位于测量垂直线之上。如果河道很深，受到潮汐的影响，或者当地的渠底轮廓变化很快，在未经确认的情况下，这种假设不得接受。

If the measured angle between the flow direction and the perpendicular to the cross-section is θ, the velocity used for the computation of flow discharge shall be as shown by *Formula (2)*:
如果测量的流向与过流断面垂直的角度为θ，用于计算流量的速度应如*公式（2）*所示：

$$v_c = v_m \times \cos\theta \qquad (2)$$

Where 其中

v_c is the velocity corrected 校正后的速度

v_m is the velocity measured 测量的流速

NOTE 注：
Some current meters are equipped to measure the normal component of velocity directly when held perpendicular to the measurement cross-section in oblique flow. This correction is not applied in such cases.
某些流速仪被配备为在斜向水流中垂直于测量截面时直接测量速度的垂向分量。这种校正不适用于这种情况。

7.1.4 Determination of the mean velocity in a vertical 测定垂直方向的平均流速

7.1.4.1 Choice and classification 选择和分类

The choice of the method for determining mean velocity depends on certain factors.These are safety, time available, width and depth of the channel, bed conditions in the measuring section and the upstream reach, rate of change of stage, degree of accuracy desired and equipment used.
确定平均流速的方法的选择取决于某些因素。这些因素包括安全、可用的时间、河道的宽度和深度、测量段和上游河段的渠底条件、阶段的变化率，所需的精确程度和使用的设备。

These methods are classified as follows: 这些方法分类如下：

a) velocity distribution method (see *7.1.4.2*) 速度分布法（详见*7.1.4.2*）;
b) reduced point methods (see *7.1.4.3*)减点法（详见*7.1.4.3*）;
c) integration method (see *7.1.5*)流速积测法（详见*7.1.5*）.

7.1.4.2 Velocity distribution method 速度分布法

Using this method, the values of the velocity are obtained from observations at a number of points in each vertical between the surface of the water and the bed of the channel. The number and spacing of the points shall be so chosen as to define accurately the velocity distribution in each vertical with a difference in readings between two adjacent points of not more than 20% with respect to the higher value. The location of the top and the bottom readings shall be chosen, taking into account the specification under *7.1.2* and *7.1.3*.
使用这种方法，速度值是通过在水面和渠底之间的每个垂直方向上的一些点的观测得到的。点的数量和间距的选择应能准确定义每个垂直方向的速度分布，相邻两点之间的读数与较高的值相差不超过20％。在选择顶部和底部读数的位置时，应将*7.1.2*和*7.1.3*的规定纳入考虑条件。

This subclause deals primarily with the determination of mean velocity in the vertical. It can be necessary to apply the same principle to the determination of mean velocity close to the vertical side or wall of a channel. The velocity curve can be extrapolated from the last measuring point to the bed or vertical side of the channel by calculating v_x from *Formula (3)*:
本小节主要涉及垂直方向上的平均流速的确定。在确定接近垂直面的平均流速时，可能需要应用同样的原则或通道壁的平均流速。流速曲线可以从最后一个测量点推算到河道的渠底或垂直面，从*公式（3）*中计算出v_x：

$$v_x = v_a \left(\frac{x}{a} \right)^{\frac{1}{m}} \tag{3}$$

Where 其中

- v_x is the open point velocity in the extrapolated zone at a distance x from the bed or vertical side 是推断区中距离渠底或垂直面x处的开放点流速;
- v_α is the velocity at the last measuring point at a distance α from the bed or vertical side 是最后一个测量点的流速，距离渠底或垂直面的距离为α;
- m is an exponent 是一个指数.

The mean velocity, ṽ, between the bottom (or a vertical side) of the channel and the nearest point of measurement (where the measured velocity is v_a) can be calculated directly from Formula (4):
通道底部（或垂直面）和最近的测量点（测量流速为v_a）之间的平均流速ṽ,可由公式（4）直接得出：

$$\bar{v} = \left(\frac{m}{m+1} \right) v_a \quad (4)$$

Generally, *m* lies between 5 and 7 but it can vary over a wider range depending on the hydraulic resistance. The value *m*=4 applies to coarse beds or coarse vertical sides while *m*=10 is characteristic of smooth beds or smooth vertical sides
一般来说，m在5和7之间取值，但它可以在更大的范围内变化，这是其取值应取决于水力阻力。m=4的值适用于粗糙的渠底或粗糙的垂直面，而m=10是光滑的渠底或光滑的垂直面的特征。

m is obtained as shown by Formula (5):

*m*可由以下公式（5）得出：

$$m = \frac{C_{ver}}{\sqrt{g}} \left(\frac{2\sqrt{g}}{\sqrt{g} + C_{ver}} + 0{,}3 \right) \quad (5)$$

其中

g is the acceleration due to gravity (m/s²) 重力加速度

C_{ver} is Chezy's coefficient on a vertical ($m^{0,5}$/s) Chezy在垂直方向的系数

NOTE 注：

An alternative method of obtaining the velocity in the region below the last measuring point is based on the assumption that the velocity for some distance up from the bed of the channel is proportional to the logarithm of the distance *X* from that boundary. If the observed velocities at points approaching the bed are plotted against log *X*, then the best-fitting straight line through these points can be extended to the boundary. The velocities close to the boundary can then be read from the graph.
另一种获得最后一个测量点以下区域速度的方法是基于这样的假设：从河道渠底向上一定距离的流速与距离该边界的对数X成正比。如果将接近渠底的各点的观测速度与对数X作图，那么通过这些点的最佳拟合直线就可以延伸到边界。然后可以从图中读出靠近边界的流速。

7.1.4.2.1 ADCP stationary method ADCP静止法

In the ADCP stationary method, the ADCP is held in a specific location for a specified time and then averaging the data at that vertical to obtain a mean velocity profile or a depth-integrated mean velocity at that location.
在ADCP静止法中，ADCP在一个特定的位置保持一定的时间，然后对该垂直位置的数据进行平均，得到该位置的平均流速曲线或深度积分平均流速。

It should be noted that ADCP instrumentation cannot measure velocity near the ADCP transducers, above the transducers or near the bed. Current manufacturer software allows extrapolation in these areas based upon the measured velocities to compute a mean velocity for the vertical.
值得我们注意的是，ADCP流量计不能测量ADCP换能器附近、换能器上方或渠底附近的流速。-目前制造商的软件可以根据测量的流速在这些区域进行外推，计算出垂直方向的平均流速。

7.1.4.3 Reduced point methods 减点法

7.1.4.3.1 General 概述

These methods, less strict than methods exploring the entire field of velocity, are used frequently because they require less time than the velocity-distribution method (see 7.1.4.2).
这些方法不如探索整个速度场的方法严格，但经常被使用，因为它们比速度分布法用时更短（详见7.1.4.2）。

It is recommended that for a new gauging section the accuracy of the selected method be assessed by the velocity distribution method.
建议对于一个新的测井段，用速度分布法来评估所选方法的准确性。

7.1.4.3.2 One-point method 单点法

Velocity observations shall be made on each vertical by exposing the current meter at 0,6 of the depth below the surface. The value observed shall be taken as the mean velocity in the vertical.
应在每个垂直方向上进行流速观测，将流速仪暴露在水面下0.6的深度。观察到的数值应作为该垂直面的平均流速。

7.1.4.3.3 Two-point method 两点法

Velocity observations shall be made on each vertical by exposing the current meter at 0,2 and 0,8 of the depth below the surface. The average of the two values shall be taken as the mean velocity in the vertical. See Formula (6):
应在每个垂直方向上进行流速观测，在水面下0.2和0.8的深度暴露流速仪。这两个值的平均值应作为该垂直面的平均流速，详见公式(6)：

$$\bar{v} = 0,5\left(v_{0,2} + v_{0,8}\right) \tag{6}$$

An alternative method of determining the mean velocity of a vertical is the Kreps method which uses velocity observations at the surface and at 0,62 of the depth below the surface.
确定垂直方向平均流速的另一种方法是Kreps法，它使用在水面和水面以下0.62深度的流速观测。

When using the Kreps method, velocity observations shall be made as near as possible to the surface and 0,62 of the depth below the surface. See Formula (7):
当使用Kreps方法时，流速观测应尽可能靠近水面和水面下0.62的深度，详见公式（7）：

$$\bar{v} = 0{,}31 \times v_0 + 0{,}634 \times v_{0{,}62} \tag{7}$$

NOTE 注：
The Kreps method, which was developed by the Austrian hydrologist Harald Kreps, is also a two-point method[21].
Kreps 方法是由奥地利水文学家 Harald Kreps 开发的，也是属于两点法[21]的一种

7.1.4.3.4 Three-point method 三点法

Velocity observations shall be made on each vertical by exposing the current meter at 0,2, 0,6 and 0,8 of the depth below the surface. The 0,6 measurement may be weighted and the mean velocity v obtained from *Formula (8)*:
应在每个垂直方向上进行流速观测，在水面下0.2、0.6和0.8的深度暴露流速仪。0.6m的测量值可以加权，并从*公式（8）*中得到平均流速v：

$$\bar{v} = 0{,}25\left(v_{0{,}2} + 2v_{0{,}6} + v_{0{,}8}\right) \tag{8}$$

7.1.4.3.5 Five-point method 五点法

Velocity measurements are made by exposing the current meter on each vertical at 0,2, 0,6 and 0,8 of the depth below the surface and as near as possible to the surface and the bed. The mean velocity v is obtained from *Formula (9)*:
流速测量是通过在水面下0.2、0.6和0.8深度的每个垂直点上暴露流速仪，并尽可能靠近水面和渠底来进行。平均流速$\tilde{v}$由*公式（9）*得到：

$$\bar{v} = 0{,}1\left(v_0 + 3v_{0{,}2} + 3v_{0{,}6} + 2v_{0{,}8} + v_{\text{bed}}\right) \tag{9}$$

7.1.4.3.6 Six-point method 六点法

Velocity observations are made by exposing the current meter on each vertical at 0,2, 0,4, 0,6 and 0,8 of the depth below the surface and as near as possible to the surface and the bed. The mean velocity v can be found from *Formula (10)*:
流速观测是在水面下0,2、0,4、0,6和0,8深度的每个垂直点上暴露流速仪，并尽可能靠近水面和渠底。平均流速$\tilde{v}$可由*公式（10）*算得：

$$\bar{v} = 0{,}1\left(v_0 + 2v_{0{,}2} 2v_{0{,}4} + 2v_{0{,}6} + 2v_{0{,}8} + v_{\text{bed}}\right) \tag{10}$$

7.1.4.3.7 Alternate sampling methods 替代采样方法

Alternative sampling methods for determining the mean velocity in the vertical may be utilized under exceptional circumstances, e.g. high velocity, rapidly changing stage or floating debris, provided the method applied can be demonstrated by experiment to give results of a similar accuracy to those listed above.
在特殊情况下，如高速、快速变化的阶段或漂浮物，可使用替代的采样方法来确定垂直方向的平均流速，但所使用的方法必须通过实验证明其结果与上述方法具有相近的精度。

7.1.5 Integration method 流速积测法

In the integration method, the velocity throughout each vertical is measured by raising and lowering a current meter through the entire depth on each vertical at a uniform rate. The speed at which the meter is lowered or raised should not be more than 5 % of the mean water velocity and should not in any event exceed 0,04 m/s. Two complete cycles should be made on each vertical and, if the results differ by more than 10 %, the operation (two complete cycles) should be repeated until results within this limit are obtained.
在积测法中，每个垂直面的流速是通过在每个垂直面的整个深度上以均匀的流速升高和降低流速仪来测量的。流速仪下降或上升的流速不应超过平均流速的5%，在任何情况下都不应超过0.04米/秒。在每个垂直方向上应进行两个完整的循环，如果结果相差超过10%，则应重复操作（两个完整的循环），直到获得这个限度内的结果。

The integration method gives good results if the time of measurement allowed is sufficiently long (60 s to 100 s). The technique can be, but is not normally, used in depths of less than 1 m.
如果允许的测量时间足够长（60秒至100秒），积测法可以得到优秀的结果。该技术可用于深度小于1米的地方，但这种使用深度一般不太常见。

The average number of revolutions is the total number of revolutions divided by the total time taken for the measurement in that vertical. The average velocity can then be read from the instrument calibration corresponding to the average number of revolutions. Uncertainties introduced by using meters with more than one calibration equation should be avoided.
平均转数是总转数除以在该垂直方向测量所需的总时间。然后可以从与平均转数相对应的仪器校准中读取平均流速。应避免使用具有一个以上校准方程的仪表所带来的不确定性。

7.1.6 Errors and limitations 误差和局限性

Estimates of the possible errors that can occur when using the various methods detailed in 7.2 are given in Clause 9. It should be noted that these estimates are of possible random errors which can occur even when all the precautions noted earlier and below are observed. If the measurement is not made under these best conditions, additional uncertainty shall be included when estimating the overall uncertainty of the measurement.
第9条给出了使用7.2中所述的各种方法时可能发生的误差的估计值。需要注意的点是，这些估计是对可能发生的随机误差的估计，即使遵守了前面和下面提到的所有预防措施也会发生。如果测量不是在这些最佳条件下进行的，在估计测量的总体不确定度时，应将额外不确定因素纳入考虑。

Errors can arise: 可能会出现的误差

a) if the flow is unsteady; 若流量不稳定

b) if material in suspension interferes with the performance of the current meter;
若悬浮物造成了流速仪性能干扰

c) if oblique flow occurs, and the appropriate correction factors are not known accurately;
若出现了斜向水流，且没有适当修正系数

d) if the instrument used for measurement of velocity is outside the range established by the calibration;
若用于测量流速的仪器超出了校准所确定的范围

e) if the set-up for measurement (such as rods or cables suspending the current meter, the boat, etc.) is different from that used during the calibration of the instrument, in which case it is possible that a systematic error is introduced;
测量的装置（如悬挂流速仪的杆子或缆绳、船等）与仪器校准时使用的装置不同，在这种情况下，有可能导致系统误差

f) if there is significant disturbance of the water surface by wind; 若水面受到风的严重干扰

g) if the device is not held steadily in the correct place during the measurement or when an oscillating movement occurs; in the latter case, the resultant of the flow velocity and the transverse velocities gives rise to serious positive errors.
如果在测量过程中，设备没有稳定在正确的位置上，或发生振荡运动；在后一种情况下，流速和横向流速的结果会引起严重的正误差。

7.2 Determination of mean velocity from surface velocity 根据水面流速确定平均流速

7.2.1 General 概述

Traditionally, determination of mean velocity from surface velocity was not encouraged as uncertainties are high. As technologies have developed, there are a greater range of techniques and instruments that are able to calculate mean velocity more accurately using measurements from the water surface. 一般情况下不鼓励以水面流速确定平均流速，因为其不确定性很高。随着技术的发展，有更多的技术和仪器能够利用水面的测量结果更准确地计算出平均流速。

Instruments that are designed to measure discharge by measuring surface velocity only shall conform to the relevant parts of this document.
只通过测量水面流速来测量流量的仪器应符合本标准的相关部分要求。

7.2.2 Non-contact systems 非接触式测量系统

A range of instruments are available to measure surface velocity. Some are described in *Annex C*. Particular attention shall be paid to *Clause 5*.
可用于测量水面流速的仪器众多。部分仪器的使用描述可见于*附录C*，应特别注意*第5条*。

Measurement of the cross-sectional area shall be in accordance with *Clause 6*.
过流断面面积的测量应符合*第6条*的规定。

The velocity coefficient at a site shall be derived using a proven technique. If the site is to be used regularly, an index rating shall be calculated. This shall be applied to the surface velocity measured to ensure the mean velocity is used in the calculation of the discharge.
场地的流速系数应使用已经验证的技术得出。如果该地点要经常使用，应计算出一个指数等级。这应适用于测量的水面流速，以确保在计算流量时使用平均流速。

Calculation of uncertainties shall be with reference to *9.3* and ISO 25377:2020.
不确定性的计算应参照*9.3*和ISO 25377:2020。

7.2.3 Surface one-point method by current meter 用流速计测量水面单点法

The depth of submergence of the current meter shall be uniform over all the verticals; care shall be taken to ensure that the current meter observations are not affected by random surface-waves and wind. This “surface” velocity may be converted to the mean velocity in the vertical by multiplying it by a predetermined coefficient specific to the section and to the discharge.
测流仪的浸没深度应在所有垂直方向上保持一致；应注意确保测流仪的观测值不受随机的水面波和风的影响。这个 "水面 "流速可以通过乘以一个针对该断面和流量的预先确定的系数来转换为垂直方向的平均流速。

The coefficient shall be computed for all stages by correlating the velocity at the surface with the velocity at 0,6 of the depth or, where greater accuracy is desired, with the mean velocity obtained by one of the other methods described previously.
所有阶段的系数都应通过将水面的流速与深度的0.6处的流速相关联来计算，或者在需要更精确的情况下，与通过前面描述的其他方法之一获得的平均流速相关联。

7.2.4 Measurement of velocity using floats 用浮标测量流速

A full description of this method is described in *Annex B*.
对该方法的完整描述见*附件B*。

This method shall only be used when it is impossible to employ other point measurement devices, however, it is a useful technique in cases of reconnaissance or because of access difficulties, excessive velocities and depths or the presence of material in suspension.
只有在无法使用其他点测量设备时，才应使用这种方法，然而，在侦察或由于进入困难、流速和深度过大或存在悬浮物的情况下，这种方法可以使用。

7.2.5 Exceptions 例外情况

Where it is not possible to check the coefficient directly, it may be assumed for guidance that, in general, the coefficient of the surface velocity varies between 0,84 and 0,90 depending on the shape and velocity profile of the channel.
在无法直接检查系数的情况下，可以假设：一般来说，水面流速的系数由渠道的形状和流速曲线决定，取值与0.84和0.90之间。

7.2.6 Main sources of error 误差的主要来源

Errors that can occur during the measurement of surface velocity are listed below. They shall be taken into consideration when estimating the overall error as given in *Clause 9*.

下面列出了在测量水面流速时可能出现的误差。在估计*第9条*规定的总误差时，应考虑到这些误差。

Errors can arise: 误差可能会由以下因素引发

a) if the coefficient from which the mean velocity is obtained from the surface velocity is not known accurately; 若从水面流速得到的平均流速的系数不准确

b) if the cross-section has been measured incorrectly; 若过流断面的测量不正确

c) if the cross-section is unstable, i.e. has a moving bed; 若过流断面不稳定，即渠底移动频繁

c) if the measured velocity does not reflect the true velocity due to unstable flow or oblique currents; 测量的流速由于不稳定的水流或斜向水流而不能反映真实的流速

e) if floats are used and their motion is biased relative to the water surface motion due to wind. 如果使用了浮标，并且由于风的作用，浮标的运动相对于水面运动有偏差

8 Computation of discharge 流量的计算

8.1 Arithmetic methods 算法

8.1.1 General 概述

The methods shown below can be enhanced by adding additional bathymetric verticals with no velocity. This is especially useful for surface velocity gaugings and for varying discharge conditions, but also to improve the efficiency of routine measurements.
下面所示的方法可以通过增加无速度的测深垂直线来加强。这对水面流速测量和不同的流量条件特别有用，也可以提高常规测量的效率。

Where the bed is uneven, and if time and cost allow, determining the depth at points midway between the annotated verticals as shown in Figure 2 can provide a more accurate determination of the area of each panel.
在渠底不平坦的地方，如果时间和成本允许，如图2所示，在注释的垂直线之间的中间点确定深度，可以更准确地确定每个板块的面积。

8.1.2 Mean-section method 平均断面法

The cross-section is regarded as being made up of a number of segments, *n*, each bounded by two adjacent verticals (see Figure 1).
过流断面被认为是由数段，也即是n，组成的，每个段以两个相邻的垂直线为界（详见图1）。

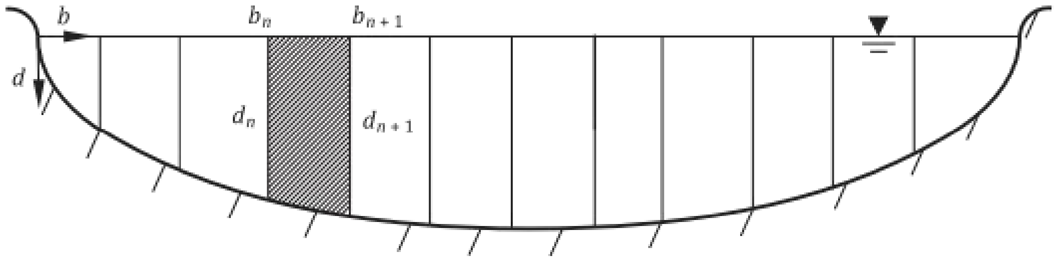


Figure 1 — Diagram illustrating the mean section method

图1 平均截面法示意图

The flow in the shaded panel is calculated as shown by Formula (11):
阴影部分的流量计算如公式（11）所示：

$$q=(b_{n+1}-b_n)\left(\frac{d_{n+1}+d_n}{2}\right)\left(\frac{\bar{v}_{n+1}+\bar{v}_n}{2}\right) \quad (11)$$

where v is the average velocity in each vertical. 其中$\bar{v}$是每个垂直方向的平均流速。

The additional discharge in the segments between the bank and the first vertical, and between the last vertical and the other bank, can be estimated from Formula (11), on the assumption that the velocity at the banks is zero. If, however, this discharge is a significant proportion of the total flow, then Formula (4) may be used to obtain the mean velocity in the region of the bank.
假设岸边的流速为零，岸边与第一个垂直线之间以及最后一个垂直线与另一个岸边之间的段的额外流量可以从公式（11）中估算。然而，如果这种流量在总流量中占很大比例，那么可以用公式（4）来获得岸边区域的平均流速。

The total flow is equal to the sum of the discharge in each panel, thus, as shown by *Formula (12)*:
总流量等于每个板块的流量之和，因此，如*公式（12）*所示：

$$Q=\sum_{n=1}^{m}(b_{n+1}-b_n)\left(\frac{d_{n+1}+d_n}{2}\right)\left(\frac{\bar{v}_{n+1}+\bar{v}_n}{2}\right) \tag{12}$$

8.1.3 Mid-section method 中断面法

The cross-section is regarded as being made up of a number of segments, each containing a vertical (see *Figure 2)*.
过流断面被认为是由若干段组成的，每段包含一个垂直面（详见*图 2*）。

The discharge in each segment shall be computed by multiplying $\bar{v}\cdot n$ by the corresponding depth and width as measured along the water-surface line. This width shall be taken to be the sum of half the width from the adjacent vertical to the vertical for which $\bar{v}\cdot n$ has been calculated plus half the width from this vertical to the corresponding adjacent vertical on the other side. The value for $\bar{v}\cdot n$ in the two half-widths next to the banks may be taken as zero.

每段的流量应通过将 $\bar{v}\cdot n$ 乘以沿水面线测量的相应深度和宽度计算得出。其中宽度应视为从相邻垂直线到计算 $\bar{v}\cdot n$ n 的垂直线的一半宽度加上从该垂直线到另一侧相邻垂直线的一半宽度之和。岸边的两个半宽 $\bar{v}\cdot n$ $v\cdot$ n值可被视为零。

For this reason, the first and last verticals of a measurement should be as close to the banks as possible if the mid-section method of calculation is used.
因此，若使用中断面法，测量的第一个和最后一个垂直点应尽可能地接近岸边。

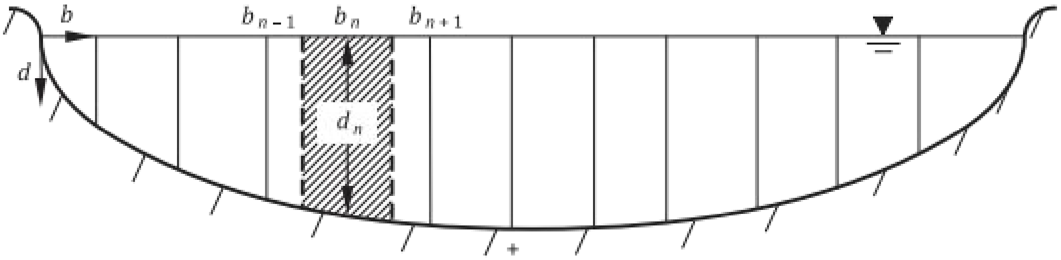


Figure 2 — Diagram illustrating the mid-section method

图2 中断面法说明示意图

For this method, the flow in each panel is calculated as shown by *Formula (13)*:
在这种方法中，每个板块的流量计算如*公式（13）*所示：

$$q = \bar{v}_n d_n \left(\frac{b_{n+1} - b_{n-1}}{2} \right) \tag{13}$$

where $\bar{v}$ the average velocity in the vertical.

其中$\bar{v}$ 是垂直方向上的平均流速。

The computation is carried out at each vertical and the total discharge through the section is obtained by summing these partial discharges, as shown by *Formula (14)*:
如*公式（14）*所示，在每个垂直方向上进行计算，通过这些部分流量的总和得到通过该部分的总流量：

$$Q = \sum_{n=1}^{m} \bar{v}_n d_n \left(\frac{b_{n+1} - b_{n-1}}{2} \right) \tag{14}$$

8.1.4 Bathymetric verticals 测深垂直法

Adding additional verticals to define the channel bathymetry but with no velocity measurements is a very useful procedure, especially for surface velocity gaugings and for varying discharge conditions, but also to improve the efficiency of routine measurements.
增加额外的垂直线来定义航道水深，但不测量流速的方法非常有用，特别是对于水面流速测量和不同的流量条件，但这也是为了提高常规测量的效率。

Bathymetric verticals can be inserted anywhere between the normal verticals (one or several, and not necessarily “midway”). There are two computation options, both acceptable:

测深垂直线可以插入正常垂直线之间的任何地方（一个或几个，不一定是中间段）。有两个计算选项都是可行的：

a) correct the wetted area of each panel using the bathymetric verticals, and no change to estimated panel velocities;
用测深垂直线校正每个板块的湿润面积，对估计的板块速度没有变化；

b) estimate the missing velocities at bathymetric verticals: instead of a simple linear interpolation, interpolate linearly the $\frac{V}{H}$ ratios (proportional to the local Froude or Chezy numbers).
估计测深垂直线上缺失的速度：不是简单的线性内插，而是线性内插 $\frac{V}{H}$ 比率（与局部Froude或Chezy数成正比）。

The advantage of b) is to account for the measured depth in the estimation of the mean velocities over the panels. This option is not recommended when there is no velocity vertical between the edge and a bathymetric vertical.
b）的优点是在估计各板块的平均流速时，考虑了测量的深度。当边缘和测深垂直线之间没有速度垂直线时，不建议使用这种方法。

8.2 Independent vertical method 独立垂直法

This method is useful for measuring streams with rapidly changing discharge. Several verticals are chosen and their distances measured from a fixed reference point (see *Figure 3*). For each gauging, measurements of velocity and depth are made using one of the methods described above. The water level is measured at the beginning and end of the series of measurements on each vertical. For each segment, a separate stage discharge relation is prepared. Subsequently, the discharge of the river at a given stage can be determined by combining the discharges for each segment when corrected for the change in water level between the moment of measurement and the moment of calculation of the total discharge.
这种方法对于测量流量迅速变化的河流很有用。选择几个垂直点，从一个固定的参考点测量它们的距离（见*图3*）。对于每个测量点，使用上述方法之一进行速度和深度的测量。水位是在每个垂直线上一系列测量的开始和结束时测量的。对于每一个区段，都要准备一个单独的阶段流量关系。随后，通过结合各段的流量，并对测量时刻和总流量计算时刻之间的水位变化进行修正，可以确定河流在特定阶段的流量。

Over time and across a large range of flow, it is possible to derive a relationship between stage and unit- width discharge for each vertical. A family of curves can then be constructed. Each curve represents an independent stage discharge relationship for the corresponding segment of channel width (see Figure 4). This assumes that the channel geometry remains constant and that no change occurs in the position of a vertical relative to the reference point.

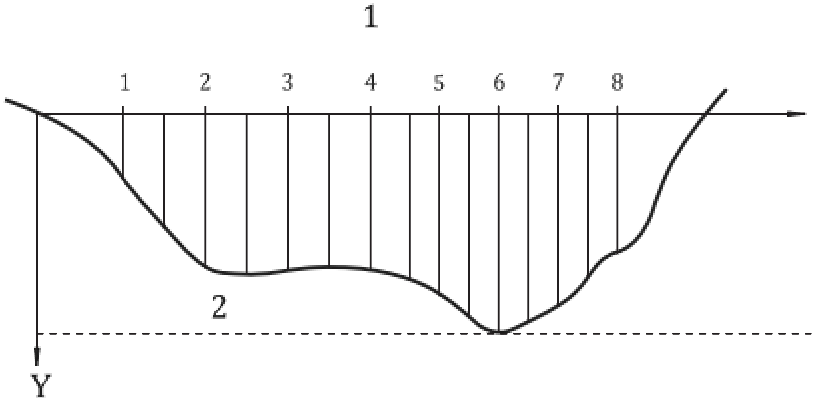
随着时间的推移，在很大的流量范围内，有可能推导出每个垂直方向的阶段和单位宽度流量之间的关系。然后可以构建一个曲线系列。每条曲线都代表了相应河道宽度段的独立阶段流量关系（见图4）。这样做的前提是，渠道的几何形状保持不变，垂直线相对于参考点的位置没有变化。

For a given value of stage, total flow in the cross-section is obtained by using a mathematical method by summation of all segment discharges (see Figure 5), or with a graphical method (see Figure 6) by plotting the unit-width discharge for all verticals and determining the area under this curve.

对于一个给定的阶段值，过流断面的总流量可以通过数学方法得到，即所有段的流量相加（见图5），或者用图形方法（见图6），绘制所有垂直线的单位宽度流量，确定该曲线下的面积。

Total flow in the cross-section for any given value of stage can be obtained by either of these methods.

任何给定的阶段值的过流断面的总流量可以通过这些方法中的任何一种获得。



Key 关键词

X channel width通道宽度 (m)

Y stage阶段 (m)

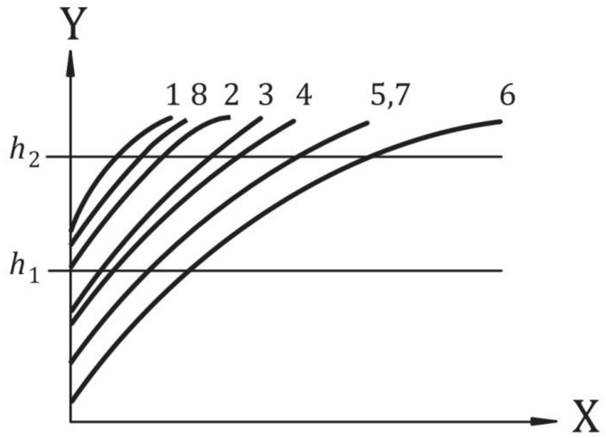
1 verticals 垂直线

2 channel bed 渠道渠底

3 stage datum阶段基准点

Figure 3 Verticals in cross-section

图3 横截面中的垂直方向

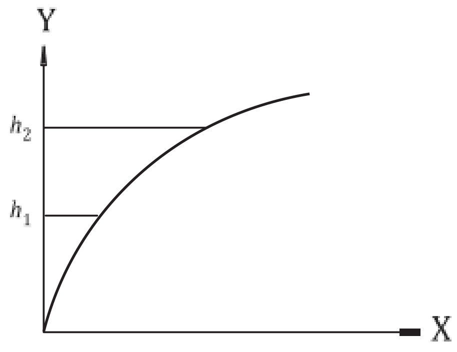


Key 关键词

X discharge per unit单位流量 (m^3/s)

Y stage 阶段 (m)

Figure 4 Stage/discharge curves for individual verticals
图4 各个垂直方向的阶段/流量曲线

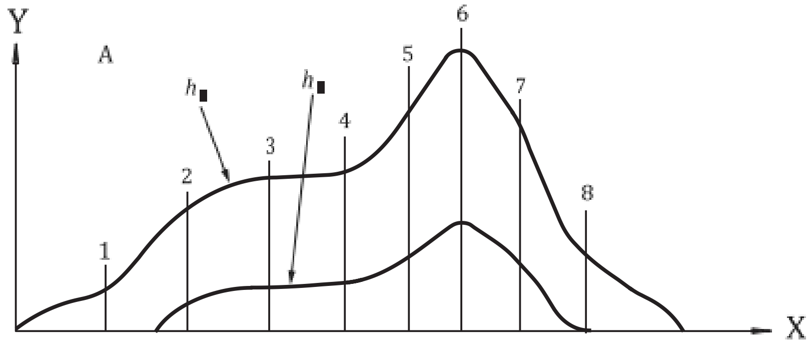


Key

X total discharge总流量 (m³/s)

Y stage 阶段(m)

Figure 5 Total discharge (mathematical method)
图5 总流量（数学方法）



Key

X distance距离 (m)

Y discharge per unit width单位宽度的流量 (m³/s)

A distribution of q for h_1 or h_2 h_1或h_2的q的分布情况

Figure 6 Computation of discharge from current meter measurement — Independent vertical method
图6 从流速仪测量计算流量--独立垂直法

8.3 Mean-section method — Horizontal planes 平均断面法-水平面

Instead of determining the mean velocity in each vertical, the mean velocities for a number of horizontal planes can be determined by a corresponding procedure to that given in 7.1.4.2. A similar method to that given in *8.1.2* can then be used to determine the discharge. The use of horizontal and vertical-plane computation is particularly suited to measurements in regular-shaped channels, as it enables a check to be made on the accuracy of the computation. 可以用*7.1.4.2*中的相应程序来确定若干水平面的平均流速，而非确定每个垂直面的平均流速。然后可以用与*8.1.2*中给出的类似方法来确定流量。使用水平面和垂直面的计算方法特别适合于在规则形状的渠道中进行测量，因为它可以对计算的准确性进行检查。

9 Uncertainties in flow measurement 流量测量中的不确定因素

9.1 General 概述

The uncertainty of discharge is discussed in ISO 25377. A reference should be made to ISO 25377. *Annex D* examines the individual components of the uncertainty and provides examples. It should not be assumed, however, that these are generally applicable, and it should be stressed that the observations on which they are based do not include all kinds and sizes of rivers, see ISO 1088.

流量的不确定性在ISO 25377中讨论过，因此，应参考ISO 25377。*附录D*研究了不确定因素的各个组成部分，并提供了一些例子。然而，不应假定这些是普遍适用的，而应该强调的它们所依据的观察结果并不包括所有种类和规模的河流，详见ISO 1088。

9.2 Method of calculating the uncertainty in discharge by measurement of velocity by current meter 用流速仪测量速度计算流量的不确定性的方法

9.2.1 General 概述

The measurement method, briefly, consists of dividing the channel cross-section under consideration into segments by m verticals and measuring the width, depth and mean velocity (denoted by b_i, d_i and v_i, respectively) associated with each vertical i. The mean velocity v_i at each vertical is computed from point velocity measurements made at each of several depths on the vertical. The flow is computed as shown by *Formula (15)*:

简言之，测量方法包括将所考虑的河道过流断面按*m*个垂直方向划分为若干段，并测量与每个垂直方向i相关的宽度、深度和平均速度（分别用b_i、d_i和v_i表示）。每个垂直面上的平均流速v_i是由垂直面上几个深度的点速度测量值计算出来的。流量的计算如*公式（15）*所示：

$$Q = F \sum b_i d_i v_i \tag{15}$$

Where 其中

Q is the flow (in cubic metres per second)

Q是流量（单位：m³/s）；

F is a factor, assumed to be unity, that relates the discrete sum over the finite number of verticals to the integral of the continuous function over the cross-section.

F 是一个系数，假定是统一的，它将有限的垂直数上的离散和与横截面上的连续函数的积分联系起来。

9.2.2 Contributory uncertainties 可能致使的不确定因素

The relative (percentage) combined standard uncertainty in the measurement is shown by *Formula (16)*:

测量的相对（百分比）综合标准不确定度用*公式（16）*表示

$$u(Q)^2 = u_m^2 + u_s^2 + \frac{\sum_{i=1}^{m} (b_i d_i \bar{v}_i)^2 \left(u_{\mathrm{b},i}^2 + u_{\mathrm{d},i}^2 + u_{\bar{v},i}^2\right)}{\left(\sum_{i=1}^{m} (b_i d_i \bar{v}_i)\right)^2} \tag{16}$$

Where 其中

$u(Q)$ is the relative (percentage) combined standard uncertainty in discharge; 是流量的相对（百分比）综合标准不确定度

$u_{\mathrm{b},i}$, $u_{\mathrm{d},i}$, $u_{\bar{v},i}$ are the relative (percentage) standard uncertainties in the width, depth and mean velocity measured at vertical *i*; 是垂直i处测量的宽度、深度和平均流速的相对（百分比）标准不确定度；

u_s is the uncertainty due to variable responsiveness of the current meter (u_{cm}), width measurement instrument (u_{bm}) and depth sounding instrument (u_{ds}): 是由于测流仪（u_{cm}）、宽度测量仪器（u_{bm}）和深度探测仪器（u_{ds}）的反应能力不同而导致的不确定度：

$$u_s = \sqrt{u_{\mathrm{cm}}^2 + u_{\mathrm{bm}}^2 + u_{\mathrm{ds}}^2} \tag{17}$$

An estimated practical value of 1 % may be taken for this expression.
对于这个表达式，可以取一个估计的实际值，即1%。

u_m is the uncertainty due to the limited number of verticals; 是由于垂直线数量有限而产生的不确定性。

m is the number of verticals. 是垂直线的数量。

The mean velocity v_i at vertical i is an estimate of the average of point measurements of velocity made at one or more depths in the vertical (see, for example, 7.1.5). The uncertainty in v_i is computed as shown by Formula (18):
垂直方向i处的平均流速vi 是对垂直方向上一个或多个深度的流速点测量值的平均估计（例如，见7.1.5）。v_i 的不确定性如公式(18)所示进行计算：

$$u(\bar{v}_i)^2 = u_{\mathrm{p},i}^2 + \left(\frac{1}{n_i}\right)\left(u_{\mathrm{c},i}^2 + u_{\mathrm{e},i}^2\right) \quad (18)$$

Where 其中

$u_{p,i}^2$ is the uncertainty in mean velocity v_i due to the limited number of depths at which velocity measurements are made at vertical i; $u_{p,i}^2$是因在垂直i处进行流速测量的深度有限条件下，平流流速v_i的不确定度；

n_i is the number of depths in the vertical i at which velocity measurements are made 是垂直方向i上进行速度测量的深度数;

$u_{c,i}$ is the uncertainty in the velocity at a particular measuring point in vertical i due to lack of repeatability of the current meter;是由于流速仪缺乏重复性而造成的垂直i中某一测量点的速度的不确定度；

$u_{e,i}$ is the uncertainty in point velocity at a particular depth in vertical i due to velocity fluctuations (pulsations) in the stream during the exposure time of the current meter.
是由于流速仪曝光时间内水流的速度波动（搏动）造成的垂直方向i中某一特定深度的点速度的不确定度。

Combining Formulae (16) and (18) results in Formula (19):
将公式（16）和（18）结合起来，可得公式（19）：

$$u(Q)^2 = u_m^2 + u_s^2 + \frac{\sum_{i=1}^{m}(b_i d_i \bar{v}_i)^2 \left(u_{b,i}^2 + u_{d,i}^2 + u_{p,i}^2 + \left(\frac{1}{n_i}\right)\left(u_{c,i}^2 + u_{e,i}^2\right)\right)}{\left(\sum_{i=1}^{m}(b_i d_i \bar{v}_i)\right)^2} \tag{19}$$

If the measurement verticals are placed so that the segment discharges $(b_i\ d_i\ \bar{v}_i)$ approximately equal and if the component uncertainties are equal from vertical to vertical, then Formula (19) simplifies to Formula (20):
如果测量的垂直点被放置，使各段流量 $(b_i\ d_i\ \bar{v}_i)$大致相等，如果各组成部分的不确定性在垂直点之间相等，那么公式（19）简化为公式（20）：

$$u(Q) = \left[u_m^2 + u_s^2 + \left(\frac{1}{m}\right)\left(u_b^2 + u_d^2 + u_p^2 + \left(\frac{1}{n}\right)\left(u_c^2 + u_e^2\right)\right)\right]^{\frac{1}{2}} \tag{20}$$

EXAMPLE 例：

It is required to estimate the uncertainty in a current meter gauging from the following particulars:

需要根据以下细节来估计流速仪测量的不确定度：

Number of verticals used in the gauging:测量中使用的垂直线数量	20
Number of points taken in the vertical (0,2 and 0,8):在垂直方向上的取点数量	2
Average velocity in measuring section:测量部分的平均速度:	高于 0.3 m/s
Exposure time of current meter：流速仪的曝光时间	3分钟
Rating of current meter:流速仪的等级	单独的等级

Component uncertainties (percentages) can be obtained from information given in Annex D, which presents the results of investigations carried out since the publication of the first edition of this document in 1968.
成分的不确定度（百分比）可以从附录D中给出的信息中获得，该附录介绍了自1968年本标准第一版出版以来所进行的调查的结果。

u_m = 2,5 (详见see Table D.6)

u_s = 1,0 (详见以上see above)

u_b = 0,5 (详见表D.2第一行 see D.2, line 1)

u_d = 0,5 (详见表D.3第二行see D.3, line 2)

u_p = 3,5 (详见表D.4 see Table D.4)

u_c = 1,0 (详见表D.5 see Table D.5)

u_e = 3,0 (at 0,2 depth) (详见表D.3 see Table D.3)

= 3,0 (at 0,8 depth) (详见表D.3 see Table D.3)

Therefore:
因此

$$u_e = \sqrt{3^2 + 3^2} = 4,2$$

Using Formula (20): 使用公式（20）计算：

$$u(Q) = \left[u_m^2 + u_s^2 + \left(\frac{1}{m}\right)\left(u_b^2 + u_d^2 + u_p^2 + \left(\frac{1}{n}\right)\left(u_c^2 + u_e^2\right) \right) \right]^{\frac{1}{2}}$$

$$u(Q) = \left[2,5^2 + 1,0^2 + \left(\frac{1}{20}\right)\left(0,5^2 + 0,5^2 + 3,5^2 + \left(\frac{1}{2}\right)\left(1,0^2 + 4,2^2\right) \right) \right]^{\frac{1}{2}}$$

results in: 可得：

$u(Q) = 2,89$ %

The expanded uncertainty at the 95 % confidence level, U_{95}, is obtained by applying a coverage factor of $k = 2$.
通过应用k=2的覆盖系数，可以得到95%置信度下的扩展不确定度U_{95}。

Thus: 因此：

$U_{95}(Q) = k \times u(Q)$

$= 2 \times 2,89$

$= 5,78$ %

Therefore: 可得：

$U_{95}(Q) = 6$ %

If the measured flow is Q m³/s, the result of the measurement is expressed as: 如果测量的流量为Q m3/s，测量结果表示为：

Q $m^3/s \pm 6$ %

where the expanded uncertainty, coverage factor is $k = 2$, and the approximate level of confidence = 95 %.
其中扩大的不确定性，覆盖系数为k=2，近似的置信度=95％。

9.3 Method of calculating the uncertainty in discharge by measurement of velocity using floats 用浮标测量速度计算流量的不确定性因素的方法

9.3.1 General 概述

While there have been considerable investigations carried out into the uncertainties in current meter gauging, little work has been performed into the uncertainties in float gauging. As a result, there is little guidance in the literature and little research reported to allow reliable recommendations to be made. The analysis in this subclause is therefore given as guidance until more information is available.

目前针对流速仪测量的不确定度的调查众多，但对浮标测量的不确定度的研究却少之又少。因此，现行文献中很少有参考意见，也很少有研究报告，进而无法提出可靠的建议。所以，在获得更多信息之前，本小节中的分析仅可作为指导参考。

9.3.2 Contributory uncertainties 可能致使的不确定因素

Calculate the discharge as shown by *Formula (21)* (see *Clause B.5*): 如公式（21）所示，计算流量（详见B.5）：

$$Q = F \sum_{i=1}^{n} K_f \bar{v}_i \left(\frac{A_i' + A_i}{2} \right) \tag{21}$$

where 其中

Q is the discharge (cubic metres per second);
是流量（m^3/s）

F is a factor, assumed to be unity, that relates the discrete sum over the finite number of verticals to the integral of the continuous function over the cross-section; 是一个系数，假定是统一的，它将有限的垂直数上的离散和与横截面上的连续函数的积分联系起来；

n is the number of segments; 是分段的数量；

K_f is the coefficient of velocity for the float; 是浮标的速度系数；

v_i is the mean float velocity in the ith segment; 是第i段的平均浮标速度；

Ai and Ai′ are the ith segment areas of upstream and downstream cross-sections, respectively. 分别为上游和下游断面的第i段面积。

The overall uncertainty in discharge is composed of: 流量的总体不确定度由以下几个方面组成：

a) uncertainties in width: $u_{b,i}$ in estimating cross-section areas; 宽度的不确定性：估计过流断面面积时的$u_{b,i}$

b) uncertainties in depth: $u_{d,i}$ in estimating cross-section areas (allowing for scour and fill, if any); 深度的不确定性：$u_{d,i}$，用于估算过流断面面积（考虑到冲刷和填充，如有）；

c) uncertainties in determination of surface float velocities: $u\bar{v}_i$ composed of: 确定水面浮标速度的不确定性：$u\bar{v}_i$，由以下部分组成：

— the uncertainty in the coefficient of velocity for the float, $u_{k,f}$;
浮标速度系数的不确定性，$u_{k,f}$；

— the uncertainty of the length of travel path, $u_{L,i}$;
行进路径长度的不确定性，$u_{L,i}$；

— the uncertainty of the time taken for the passage of the float, $u_{t,i}$, see Formula (22):
浮标通过时间的不确定性，$u_{t,i}$，详见公式（22）：

$$u_{v,i}^2 = u_{k,f}^2 + u_{L,i}^2 + u_{t,i}^2 \tag{22}$$

d) uncertainty due to the limited number of segments used, u_m.
由于使用的段数有限，不确定度，u_m

9.3.3 Combined uncertainty in discharge 流量的综合不确定因素

The method of calculation is similar to that given in 9.3.2, see Formula (23):
计算方法与9.3.2中给出的方法类似，详见公式（23）：

$$u_Q = \sqrt{u_m^2 + \frac{1}{m}\left(u_b^2 + u_d^2 + u_v^2\right)} \tag{23}$$

EXAMPLE 例：

Float gauging with five paths using surface floats: 使用水面浮标的五条路径的浮标测量：

u_m = 7,5 % (see Table D.6). This may be reduced provided the areas are determined from a detailed cross-section and the velocities are determined from a smoothed velocity distribution. (详见表D.6)。如果面积是由详细的过流断面确定的，而速度是由平滑的速度分布确定的，则可以减少这种情况。

$u_{k,f}$ = 15 % (see Table D.4 详见表D.4)

u_L = 5 % (estimated 预估值)

u_t = 5 % (estimated 预估值)

$$u_v = \sqrt{u_{k,f}^2 + u_L^2 + u_t^2}$$

$$= \sqrt{15^2 + 5^2 + 5^2}$$

= 16,5 % (or taken from Table D.4 alone = 15 % 或仅取自表D.4=15 %)

u_b = 1 % (estimated 预估值)

u_d = 1 % (estimated 预估值)

Therefore:
因此

$$u(Q)=\sqrt{7{,}5^2+\frac{1}{5}\left(1+1+16{,}5^2\right)}$$

$u(Q) = 10.5\ \%$

The expanded uncertainty at a level of confidence of approximately 95 %, U_{95}, is obtained by applying a coverage factor of k = 2.
通过应用k=2的覆盖系数，可以得到置信度约为95%的扩大不确定度，即U_{95}。

Then: 此后：

$U_{95}(Q) = k \cdot u(Q)$

$= 2 \times 10.5$

$= 21\ \%$

Therefore: 可得：

$U_{95}(Q) = 21\ \%$

If the measured flow is Q m^3/s, the result of the measurement is expressed as:
如果测量的流量是Q m^3/s，测量结果表示为：

Q m^3/s ± 21 % (expanded uncertainty, coverage k = 2, approximate level of confidence = 95 %
扩大的不确定度，覆盖率k = 2，近似的置信度 = 95 %.

9.4 Limitations 局限因素

For ideal conditions and procedure, the computed uncertainty usually lies between 5% and 7%. However, for many measurements done in non-ideal conditions, the uncertainty values obtained have some limitations.
对于理想的条件和程序，计算出的不确定度通常在5％和7％之间。然而，对于在非理想条件下进行的许多测量，获得的不确定度值有一些不足。

The following limitations have been identified. 已知本文有以下的局限性。

a) The informative values given in *Annex D* for uncertainty components are derived from empirical studies, they are specific to an instrument type and to some measurement conditions.
*附录D*中给出的不确定度成分的信息值是从经验研究中得出的，它们是特定于一种仪器类型和一些测量条件的。

b) Top, bottom and edge velocity extrapolations are not taken into account in the uncertainty analysis, though their contribution is not necessarily negligible.
在不确定度分析中不考虑顶部、底部和边缘的速度外推，尽管它们的影响不一定可以忽略不计。

c) When vertical integration of velocity is performed directly (velocity distribution method), a negligible default value (0,5 %) is attributed to the u_p component. For non-ideal measurements with not enough velocity points and often significant top/bottom extrapolations, the value of u_p should be taken higher than 0,5 %.
当直接进行速度的垂直整合时（速度分布法），一个可忽略的默认值（0.5%）被归入u_p分量。对于非理想的测量，由于没有足够的速度点，而且往往有明显的顶部/底部外推，u_p分量的值应高于0.5 %。

d) Most of the computed uncertainty usually stems from the term u_m, which is an empirical function of the number of verticals m, with no consideration of the spatial distribution of verticals, compared to the transversal variation in bed geometry and flow distribution.

本文中大部分计算出的不确定度通常来自于术语u_m，它是垂直数m的经验函数，较之渠底几何形状和流量分布的横向变化，它没有考虑垂直数的空间分布。

e) Time-integration error in the case of varying discharge during the measurement is not estimated.

在测量过程中排量变化的情况下，不估计时间积分误差。

NOTE 注：

This effect is different from hysteresis, i.e. the discharge deviation to the steady conditions due to transient flow effects.

这种效应与滞后效应不同，即由于瞬时流动效应导致的流量偏离稳定条件。

f) Some uncertainty components are missing from the equation. In particular, a term accounting for systematic errors due to the vertical velocity integration method should be added (this is obvious for surface velocity gaugings, but also for other techniques). Other missing error sources include: position, inclination and orientation of the instruments (current meters, rod, sounding, etc.) resulting in velocity projection errors and position and depth errors; and bed changes when bathymetry is not measured simultaneously with velocities.

方程中缺少一些不确定性成分。 特别是应增加一个考虑垂直速度积分法引起的系统误差的项（这对水面速度测量很明显，但也适用于其他技术）。其他缺失的误差源包括：仪器的位置、倾角和方向（流速仪、杆、测深等），导致速度投影误差和位置及深度误差；当测深没有与速度同时测量时，渠底就会发生变化。

9.5 Interpolated variance estimator (IVE) 插值方差估计（IVE）

The IVE[15] quantifies uncertainty in mid-section velocity-area measurements, whatever the instrumentation. The method is as given in 9.2 but rather than using laboratory or empirical results to estimate uncertainty in the depth and velocity, it instead relies on information contained in the many verticals collected during the measurement. For width uncertainty and for systematic uncertainties caused by meter fabrication errors, the values suggested by this document are employed. IVE does not address consistent field user biases such as persistent meter tilt or flow angularity. Testing has shown that the IVE method provides more sensitivity to measurement conditions than the standard ISO method. Recent comparisons of IVE with other methods for computing measurement uncertainty[19] indicate that IVE provides a more realistic estimate relative to other methods tested. IVE should only be applied when 10 or more verticals are used.

IVE[15]量化了中段速度面积测量的不确定性，无论使用何种仪器。其方法如 9.2 所述，但不是使用实验室或经验结果来估计深度和流速的不确定性，而是依靠测量过程中收集的许多垂直数据中包含的信息。对于宽度不确定度和由仪表制造误差引起的系统不确定度，使用本标准建议的数值。IVE不能解决一致的现场用户偏差，如持续的仪表倾斜或流量角度。测试表明，IVE方法比标准ISO方法对测量条件更加敏感。最近IVE与其他计算测量不确定度的方法的比较[19]表明，相对于其他测试方法，IVE提供了一个更现实的估计。IVE只应在使用10个或更多垂直面时应用。

9.6 Q+

Similar to the IVE and Flaure methods, the Q+ method[18] is a variant of this document’s method for computing the uncertainty of velocity-area discharge measurements, which aims at improving the estimation of the uncertainties due to the spatial integration of velocities and depths throughout the cross-section. An alternative computation of the vertical velocity integration uncertainty (u_p) is proposed when the velocity distribution method is applied. The lateral flow integration uncertainty (u_m) is also estimated directly from the velocity and depth measurements instead of the look-up table values of this document. The lateral depth integration uncertainty and the lateral velocity integration uncertainty are estimated separately in the form of two distinct uncertainty components, u_m(D) and u_m(V), which may be combined to compute u_m. Thus, the improved sampling of the cross- sectional geometry using bathymetric verticals can be assessed. Both u_m(D) and u_m(V) uncertainty components are computed based on an angle (or slope) reflecting the maximum possible errors in the bed profile, i.e. in the wetted areas of the panels. This angle can be user-defined or estimated from the data[19].

与 IVE 和 Flaure 方法相近的是, Q+方法[18] 是本文计算速度面积流量不确定度的变体, 其目的是改进对整个断面的流速和深度的空间整合所引起的不确定度的估计。在使用速度分布法时，提出了垂直速度积分不确定度（u_p）的替代计算方法。横向流量积分不确定度（u_m）也是直接从速度和深度测量值中估算出来的，而不是本文的查找表值。横向深度集成不确定度和横向速度集成不确定度是以两个不同的不确定度分量u_m(D)和u_m(V)的形式分别估计的，它们可以结合起来计算u_m。 因此，可以评估使用测深垂直线对过流断面几何形状的改进采样。u_m(D)和u_m(V)的不确定性成分都是根据反映渠底轮廓的最大可能误差的角度（或斜率）来计算的，即在面板的湿润区域。这个角度可以由用户定义或从数据中估计[19]。

9.7 Flaure

The Flaure method (for “FLow Analogue UnceRtainty Estimation”)[19] estimates the uncertainty component relating to the limited number of verticals. High-resolution reference gaugings (with 31 and more verticals) are used to assess the uncertainty component through a statistical analysis. Instead of subsampling purely randomly the verticals of these reference stream-gaugings, a subsampling method is developed in a way that mimics the behaviour of a hydrometric technician. A sampling quality index (SQI) is suggested and appears to be a more explanatory variable than the number of verticals. This index takes into account the spacing between verticals and the variation of unit flow between two verticals.

Flaure方法（用于 "水流模拟不确定性估计"）[19]估计与有限的垂直面数量有关的不确定性成分。高分辨率的参考测量仪（有31个或更多的垂直面）被用来通过统计分析来评估不确定

性成分。不对这些参考河道测量的垂直方向进行纯粹的随机取样，而是以模仿水文测量技术员的行为的方式开发一种取样方法。提出了一个采样质量指数（SQI），它似乎是一个比垂直线数量更具解释力的变量。该指数考虑了垂直线之间的间距和两个垂直线之间单位流量的变化。

This new method was applied to 3185 stream-gaugings with various flow conditions and compared with the other methods (this document, IVE, Q+ with a simple automated parametrization). Results show that Flaure is overall consistent with the Q+ method but not with this document and IVE methods, which produce clearly overestimated uncertainties for discharge measurements with less than 15 verticals.

这种新方法被应用于3185个不同流量条件的溪流测量，并与其他方法（本文、IVE、Q+与简单的自动参数化）进行比较。结果表明，Flaure与Q+方法总体上是一致的，但与本标准和IVE方法不一致，后者对少于15个垂直方向的排放测量产生明显的高估不确定性。

Annex A
(informative)
附录A
（资料性文件）

Use of point velocity current meters

点流速仪的使用

A.1 General概述

As far as possible, the type of measuring equipment should be selected to minimize the depth of the unmeasured zones.

应尽可能地选择测量设备的类型，以尽量减少未测量区的深度。

A.2 Rotating-element current meters 转子式流速仪

A.2.1 General 概述

Rotating-element current meters shall be manufactured, calibrated and maintained in accordance with ISO 2537 and ISO 3455. They should be used only within their calibrated range and fitted on suspension equipment similar to that used during calibration.

转子式流速仪应按照ISO 2537和ISO 3455的规定制造、校准和维护。它们只能在其校准范围内使用，并安装在与校准时使用的类似的悬挂设备上。

In the vicinity of the minimum speed of response, the uncertainty in determining the velocity is high. Care should be exercised when measuring velocities near the minimum speed of response.

在最小响应速度附近，确定速度的不确定性很高。在测量最小响应速度附近的速度时，应谨慎使用。

For high velocities, the propeller, in the case of propeller-type current meters, or the reduction ratio where available, shall be chosen in order that the maximum speed of rotation can be correctly measured by the revolution counter.

在高速度情境下使用转子式流速仪，应选择螺旋桨，或在有减速比的情况下，以使最大旋转速度能被旋转计数器正确测量。

No rotating-element current meter shall be selected for use where the depth at the point of measurement is less than four times the diameter of the impeller that is to be used, or of the body of the meter itself, whichever is the greater. No part of the meter shall break the surface of the water. An exception to this is cases where the cross-section is very shallow at one side but is the best available.

如果测量点的深度小于所使用的叶轮直径或表体本身直径的四倍（以较大者为准），则不得选择使用转子式流速仪。水表的任何部分都不得突破水面。如果横截面在一侧非常浅，则是例外，此时使用转子式流速仪效果是最好的。

A spin test, where appropriate, should be performed before and after each discharge measurement to ensure the mechanism of the current meter operates freely, see ISO 2537. 在

适当的情况下，在每次流量测量前后都应进行旋转测试，以确保测流仪的机制运作自如，详见ISO 2537。

A.2.2 Integration method using current meter 使用流速仪的综合法

The speed at which the current meter is lowered or raised shall not be more than 5 % of the mean water velocity and shall not in any event exceed 0,04 m/s. Two complete cycles shall be made on each vertical. If the results differ by more than 10 %, the operation (two complete cycles) shall be repeated until results within this limit are obtained.

流速仪下降或上升的速度不得超过平均流速的5%，并且在任何情况下不得超过0.04米/秒。在每个垂直方向上应进行两个完整的循环。如果结果相差超过10%，则应重复操作（两个完整的周期），直到获得这一限度内的结果。

When a sounding rod or weight is used, it will not be possible to measure the velocity throughout the entire vertical; a zone may, for example, remain unmeasured near the channel bed. An estimate of the unit width discharge of this zone can be obtained using *Formula (A.1)*:

当使用探杆或砝码时，不可能测量整个垂直方向的速度；例如，在渠道床附近可能有一个区域没有测量。使用*公式（A.1）*可以得到这个区域的单位宽度排放的估计：

$$q_\mathrm{u} = \frac{2v_\mathrm{m}h_\mathrm{f}}{3} \quad \text{(A.1)}$$

Where 其中

q_u is the unit width discharge below the measured zone;
是被测区下面的单位宽度流量

v_m is the mean velocity for the measured part of the vertical
是垂直测量部分的平均流速;

h_f is the depth of the unmeasured zone
是未测量区的深度.

Similarly, the unit width discharge for any unmeasured zone near the surface is obtained using *Formula (A.2)*:
同样地，用*公式（A.2）*可以得到水面附近任何未测量区域的单位宽度排放：

$$q_s = \frac{v_m h_s}{0,9} \tag{A.2}$$

Where 其中

q_s is the unit width discharge above the measured zone
是被测区上方的单位宽度流量;

v_m is the mean velocity for the measured part of the vertical
是垂直测量部分的平均流速;

h_s is the depth of the unmeasured zone
是未测量区的深度.

A.3 Acoustic doppler velocimeters (ADVs) 声学多普勒流速仪

Hand-held ADVs are acoustic point-velocity current meters. They use two or three transducers to transmit sound pulses into the water and a receiving transducer to sample the reflected signal and compute the velocity in the sample volume. They provide velocity measurements at a single point and typically come with software and/or hardware interfaces for computing discharge with various methods previously discussed.
手持式多普勒流速仪是声学点流速仪。 它们使用两个或三个换能器向水中发射声音脉冲，一个接收换能器对反射信号进行采样，并计算采样体积内的速度。它们提供单点的速度测量，通常带有软件和/或硬件接口，用于用前面讨论的各种方法计算流量。

ADVs determine water velocity by measuring the change in acoustic frequency (or Doppler shift) in reflections from moving particles or scatters (such as suspended sediment) in the flow, which are assumed to be moving at the same velocity as the water.
ADVs通过测量水流中移动的颗粒或散射物（如悬浮泥沙）反射的声学频率变化（或多普勒频移）来确定流速，这些颗粒或散射物被假定为以与水相同的速度移动。

The sampling methodology, site selection criteria, and discharge calculation methods applied to undertaking a traditional current meter gauging also apply to the ADVs. ADV current meters are capable of operation in low velocities and shallow depths of water.
用于进行传统流速仪测量的采样方法、选址标准和流量计算方法也适用于ADVs。ADV流速仪能够在低速和浅水中运行。

A.4 Acoustic echo correlation velocimeters (AECVs)声学回波互相关测速仪

Hand-held AECVs are point-velocity current meters that measure the full velocity profile. Velocities are measured from the bottom to the surface simultaneously and seamlessly. Positioning at different sampling depths is not required.
手持式AECVs是测量全速度剖面的测速仪，可测量整个流速曲线。从底部到水面的流速可以同时无缝测量。不需要在不同的采样深度进行定位。

Acoustic reflectors such as sediment particles and air bubbles that are present in the water are scanned with ultrasonic pulses and the reflected received signals are stored as echo patterns. Further ultrasonic scans are performed every few milliseconds and consecutive echo patterns are compared to determine the particulate movements, and thus water velocity, within the measurement window. A full water depth velocity profile is determined by analysing these measurements in up to 16 vertical slices or layers.

用超声波脉冲扫描水中的沉积物颗粒和气泡等声学反射体，并将反射的接收信号存储为回波模式。每隔几毫秒进行一次进一步的超声波扫描，并对连续的回声模式进行比较，以确定颗粒的运动，从而确定测量窗口内的流速。通过分析这些测量结果，在多达16个垂直切片或层中确定完整的水深速度曲线。

The sampling methodology, site selection criteria and discharge calculation methods applied to undertaking a traditional current meter gauging also apply to the AECVs. AECV current meters are capable of operation in low velocities and shallow depths of water.

采样方法、选址标准和流量计算方法适用于进行传统的流速仪测量，也适用于AECVs。AECV测流仪能够在低速和浅水深度下运行。

A.5 Acoustic doppler current profiler (ADCP) stationary method 声学多普勒流速仪（ADCP）固定法

The stationary method utilizes the ADCP to measure discharge on a vertical by vertical basis, similar to a standard current meter.

固定法是利用ADCP在垂直方向上测量流量，类似于标准的流速仪。

The ADCP sensors can be used suspended from a bridge, cableway or by wading, as traditionally with other current meter types. It is also capable of holding position by means of manned and remote-control boats. It is important that the instrument is held stationary as it is sensitive to flow angles.

ADCP传感器可以悬挂在桥上、索道上或通过涉水使用，就像传统上其他类型的流速仪一样。它也能够通过载人船和遥控船来保持位置。重要的是，该仪器必须保持静止，因为它对水流角度很敏感。

NOTE 注

Location of the verticals for the measurement can, with good conditions, be eased by the use of GNSS systems coupled to the ADCPs.

在良好的条件下，通过使用与ADCPs耦合的GNSS系统，可以缓解测量的垂直位置。

The ADCP sensors send multiple acoustic pulses into the water to measure the full velocity profile within the vertical (with extrapolation for near bed and near surface boundaries). From this, the calculation of the mean velocity of the water and the depth of the channel for each measured vertical is made. Calculation of discharge by mid-section or mean-section methods are then made conforming to *Clause 7*. They also conform to the IVE[15].

ADCP传感器向水中发送多个声学脉冲，以测量垂直范围内的全部速度曲线（对近床和近水面边界进行外推）。由此，可以计算出每个测量垂直面的平均流速和河道深度。然后按照*第7条*的规定，用中段或平均段的方法来计算排放。它们也符合 IVE[15]的规定。

A.6 Electromagnetic current meters 电磁式测流仪

Electromagnetic current meters are acceptable for making measurements of point velocity. They shall be calibrated throughout the range of velocity for which they are to be used. They shall meet accuracy requirements similar to rotating-element current meters. They should not be used outside the range of calibration. It is possible that electromagnetic current meters are capable of operation in shallower depths than rotating-element current meters and of detecting and measuring flow reversal.

电磁式测流仪可用于测量点速度。它们应在其使用的速度范围内进行校准。它们应满足近似转子式流速仪精度的要求。它们不应在校准范围之外使用。电磁式流速仪可以在比转子式流速仪更浅的深度工作，并能检测和测量水流的逆转情况。

No electromagnetic current meter should be selected for use where the depth at the point of measurement is less than three times the vertical dimension of the probe, see ISO/TS 15768. An exception to this is the case where the cross-section is very shallow at one side but is the best available.

如果测量点的深度小于探头垂直尺寸的三倍，则不应选择使用电磁式流速仪，详见ISO/TS 15768。这个条件的使用特例是，横截面在一侧非常浅，此时使用效果最佳。

Annex B
(informative)

Surface velocity measurement using floats

附录 B(资料性文件) 使用浮标的水面流速测量

B.1 Measurement of velocity using floats 使用浮标测量速度

B.1.1 General 概述

This method shall only be used when it is impossible to employ a current meter because of access difficulties, excessive velocities and depths, the presence of material in suspension or in cases of reconnaissance.

这种方法只应在由于出入困难、速度和深度过大、存在悬浮物或勘察情况而无法使用流速仪时使用。

B.1.2 Selection of site 选址

Three cross-sections shall be selected along the reach of the channel as described in *Clause 5*, at the beginning, midway and at the end of the reach. The cross-sections shall be far enough apart for the time which the floats take to pass from one cross-section to the next to be measured accurately. The midway cross-section shall be used only for the purpose of checking the velocity measurement between the cross-sections at the beginning and at the end of the reach. A minimum duration of float movement of 20 s is recommended.

如*第5条*所述，应沿河道选择三个过流断面，分别位于河道的起点、中途和终点。过流断面的距离应足够远，以便准确测量浮标从一个过流断面到下一个过流断面的时间。中途过流断面应仅用于检查河段开始和结束时过流断面之间的速度测量。建议浮标移动的最小时间为20秒。

B.1.3 Measuring procedure 测量程序

The float shall be released far enough above the upper cross-section to attain a constant velocity before reaching the first cross-section. The time at which the float passes each of the three cross-sections is then noted. This procedure shall be repeated with the floats at various distances from the bank of the river.

在到达第一个横截面之前，浮标应在上截面上方足够远的地方释放，以达到恒定的速度。然后记下浮标通过三个过流断面中每个过流断面的时间。在浮标与河岸的不同距离上，应重复这一程序。

Increasing the number of floats used to determine the velocity in each segment will improve the accuracy of the measurement.

增加用于确定每段速度的浮标数量将提高测量的准确性。

The width of the channel shall be divided into a certain number of segments of equal width. If, however, the channel is very irregular, each segment shall have approximately the same discharge. The number of segments shall not be less than three, but where possible a minimum of five shall be used, the actual number of segments depending on the time available for these observations at the particular stage of the river.

河道的宽度应划分为一定数量的等宽段。然而，如果河道非常不规则，每段应具有大致相同的排放。分段的数量不应少于三个，但在可能的情况下，应至少使用五个，实际的分段数量取决于在河流的特定阶段可用于这些观察的时间。

B.2 Types of float 浮标的类型

B.2.1 Surface floats 水面浮标

These may be used during floods when velocity measurements are to be made quickly. They shall not be used when their movement is likely to be affected by winds.

当需要快速进行速度测量时，可在洪水期间使用。当其运动可能受到风的影响时，不得使用。

B.2.2 Double floats双层浮标

These may be used for measurements of velocities in deep rivers. The sub-surface body may be positioned at 0,6 of the depth below the surface, or at other depths to obtain direct velocity measurements at these depths.

可用于测量深层河流的速度。次表层体可置于水面下0.6的深度，或其他深度，以获得这些深度的直接速度测量。

B.2.3 Other types of floats 其他类型的浮标

B.2.3.1 General 概述

Other methods of obtaining the mean velocity in each segment may be used if the bed profile is regular over the measuring reach.

如果测量范围内的渠底剖面是规则的，可以使用其他方法来获得各段的平均流速。

B.2.3.2 Sub-surface floats 次表层浮标

These may be used for measurement of velocities in very deep rivers. The length of the sub-surface float, sometimes called the “multiple float”, which consists of separate elements suitably attached together to permit flexibility and supported by a surface float, shall be approximately equal to the water depth, but the float shall in no case touch the bottom.

这些方法可用于测量非常深的河流的流速。次表层浮标，有时称为 "多重浮标"，由独立的元件组成，适当地连接在一起，允许有弹性，并由表层浮标支撑，其长度应与水深大致相等，但浮标在任何情况下都不得触底。

B.3 Determination of velocity 速度的确定

B.3.1 Method 方法

The float velocity shall be determined by dividing the distance between the cross-sections by the time taken by the float to travel this distance. Several measurements of the float velocities shall be taken. The mean of these measurements shall be multiplied by the appropriate coefficient to obtain the mean velocity in the segment. The coefficient derived from current meter measurements at the site at a stage as near as possible to that during the float measurement may be used for converting the float velocity to mean velocity.

浮标的速度应通过将过流断面之间的距离除以浮标走完这段距离所需的时间来确定。对浮标的速度应进行多次测量。这些测量值的平均值应乘以适当的系数，以获得该段的平均速度。在尽可能接近浮标测量时的阶段，从现场的测流仪测量得出的系数可用于将浮标速度转换为平均速度。

B.3.2 Surface floats 水面浮标

Where it is not possible to check the coefficient directly, it may be assumed for guidance that, in general, the coefficient of the surface float varies between 0,84 and 0,90 depending upon the shape of the velocity profile. The higher values are usually obtained when the bed is smooth, but values outside this range can occur under certain circumstances.

在无法直接检查系数的情况下，可以假设为参考情况为：一般来说，根据速度曲线的形状，水面浮标的系数在0.84和0.90之间变化。当渠底光滑时，通常会得到较高的数值，但在某些情况下也会出现超出这个范围的数值。

B.3.3 Double floats 双层浮标

Where it is not possible to check the coefficient directly, it may be accepted for guidance that when the sub-surface body is situated at 0,6 of the depth, the coefficient is approximately equal to 1,0, and at 0,5 of the depth, the coefficient is approximately equal to 0,96.

在无法直接检查系数的情况下，可以接受以下参考：当地下水体位于0.6的深度时，系数大约等于1.0，而在0.5的深度时，系数大约等于0.96。

B.3.4 Other types of floats 其他类型的浮标

Where a direct check on the coefficient is not possible, it may be assumed that the coefficient of the sub- surface floats and velocity rods is in the range of 0,8 to 1,0.

在无法直接检查系数的情况下，可以假定次表层浮标和速度杆的系数在0.8至1.0之间。

B.4 Main sources of error误差的主要来源

Errors can arise: 可能出现误差的情况：

— if the coefficient from which the mean velocity is obtained from the float velocity is not known accurately;

若从浮动速度中获得平均速度的系数不准确

— if too few segments are used for the velocity distribution;

若用于速度分布的段数太少

— if a sub-surface float or velocity-rod is used and the depth of the channel is not uniform throughout the measuring reach;

若使用次表层浮标或速度杆，而整个河道的深度并不均匀

— if the float does not travel in the centre of the panel due to oblique currents;

若由于斜向水流的影响，浮标不能在面板的中心行驶；

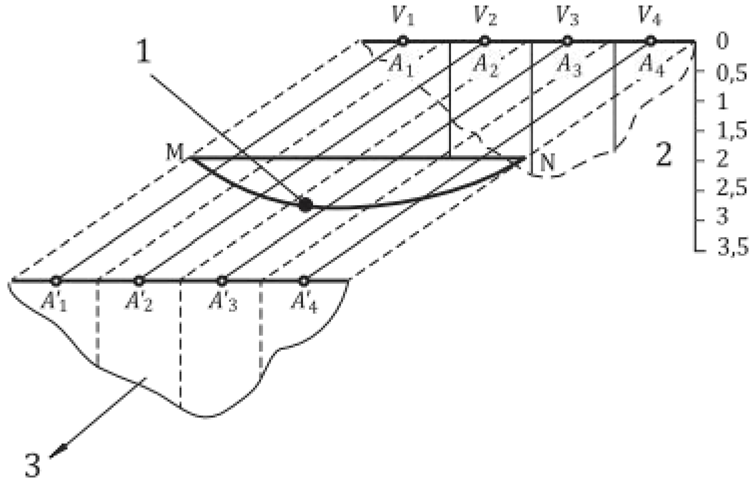
— if there is wind; but it should be noted that this error is generally negligible in comparison with the others listed above, unless a surface float is used.

在有风的情况下；但应注意的是，与上面列出的其他误差相比，除非使用水面浮标，否则该误差通常可以忽略不计。

B.5 Determination of discharge from surface float velocity measurements 根据水面漂浮物的速度测量确定流量

If the upstream and downstream cross-sections are plotted as shown in *Figure B.1* and then divided into a suitable number of segments of equal width, the cross-sectional area of each of these segments can be determined. Halfway between the two cross-section lines, another line MN shall be drawn parallel to the cross-sectional lines. The starting and ending points of each float may then be plotted and joined by firm lines, while the surface-points separating the various panels of the two cross-sections may be joined by dotted lines. Where the firm lines cross the line MN, the corresponding mean velocity (float velocity multiplied by the appropriate coefficient, see NOTE below) shall be plotted normal to MN and the end points of these velocity vectors joined to form a velocity-distribution curve (see *Figure B.2*).

如果将上游和下游的过流断面绘制成*图B.1*所示，然后将其分成适当数量的等宽段，就可以确定每个段的过流断面面积。在两条过流断面线的中间，应绘制另一条与过流断面线平行的MN线。然后可以绘制每个浮动的起点和终点，并以牢固的线条连接，而分隔两个过流断面各板块的水面点可以用虚线连接。在坚固的线与MN线交叉的地方，应绘制相应的平均速度（浮标速度乘以适当的系数，见下面的说明），以MN为法线，并将这些速度矢量的端点连接起来，形成速度分布曲线（详见*图B.2*）。



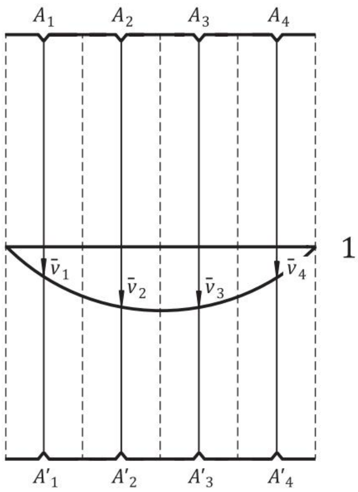
Key

1 surface velocity distribution水面速度分布

2 depth (m) 深度（米）

3 direction of flow流动方向

Figure B.1 — Measurement sections and float paths
图B.1 测量断面和浮动路径



Key

1 velocity (m/s) 速度（米/秒）

Figure B.2 — Mean velocity-distribution curve from float measurements

图B.2 来自浮标测量的平均速度分布曲线

The mean area of corresponding segments of the upper and lower cross-sections, when multiplied by the mean velocity for this panel as shown by the velocity-distribution curve, represents the discharge through that segment. The summation of the discharges for all the segments is equal to the total discharge. The mean velocity in a panel may be determined by measuring, by means of a planimeter, the area under the velocity-distribution curve for the corresponding segment or, alternatively, an approximate value may be adopted equal to the reading of the velocity halfway across the panel. See *Formula (B.1)*:

上部和下部过流断面相应区段的平均面积，乘以速度分布曲线所显示的该板块的平均速度，即为通过该区段的流量。所有区段的流量之和等于总流量。一个板块的平均速度可以通过平面仪测量相应区段的速度分布曲线下的面积来确定，或者也可以使用一个近似值，即等于整个板块一半的速度读数。见*公式（B.1）*：

$$Q = \sum_{i=1}^{m} \bar{v}_i \frac{A_i + A_i'}{2} \tag{B.1}$$

where 其中

v_i is the mean velocity in the segment; 为该段的平均速度；

A_i is the area of upstream segment; 是上游段的面积；

A_i' is the area of downstream segment. 为下游河段的面积。

NOTE

When it is impossible to obtain satisfactory movement of the floats across the whole width of the river, for instance if the floats move towards the centreline of the flow, an unadjusted discharge can be determined by measuring the mean of the surface velocities. This discharge is then multiplied by a coefficient determined from the results of current meter measurements carried out simultaneously with float measurements at the level which approximates to that of the float measurements.

注：当浮标不可能在整个河道宽度上获得满意的运动时，例如，如果浮标向水流中心线移动，可以通过测量水面流速的平均值来确定未经调整的流量。然后将这个流量乘以一个系数，这个系数是根据与浮标测量同时进行的流速仪测量结果确定的，其水位与浮标测量的水位相近。

Annex C
(informative)

Example surface velocity systems

附录 C（资料性文件）水面流速系统示例

C.1 Surface velocity radars 水面测速雷达

C.1.1 General 概述

Velocity radars are used to measure surface velocities and do not penetrate the water surface. The radar's ability to return a surface-water velocity is influenced by:

测速雷达用于测量水面速度，而不穿透水面。雷达流量计反馈水面速度的能力受到以下因素的影响：

a) the quality of disturbances or waveforms on the water surface;

水水面的干扰或波形的质量；

b) the air gap or the distance between the radar unit and the water surface;

雷达流量计与水水面之间的空气间隙或距离；

c) the potential noise imposed by wind drift, eddies, secondary flows and macro turbulence.

风漂移、涡流、次级流和大的湍流带来的潜在噪声。

Accordingly, the following procedures should be followed.

因此，应遵循以下程序。

Typically, the vertical containing the maximum-surface velocity will contain the maximum velocity. Velocities should be measured relative to a known position or geo-reference. At least 20 to 25 surface- water velocities are needed to adequately identify the maximum-surface water velocity and y-axis. The velocity radar can be pointed upstream (preferred) or downstream from a bridge or walkway. It should be oriented parallel to flow lines and tilted (from horizontal) at a nominal 45-degree incidence angle. It should be noted that different radar units operate at different incidence angles. It's important to note when collecting velocity data to avoid wind-dominated reaches, eddies, secondary flows and macro turbulence. 通常情况下，包含最大水面速度的垂直方向将包含最大速度。速度应该是相对于已知的位置或地理参照物测量的。至少需要20至25个水面流速，以充分确定最大水面流速和Y轴。雷达流量计可以指向桥梁或人行道的上游（首选）或下游。它的方向应与流向平行，并以45度的入射角倾斜（从水平方向）。应该注意的是，不同的雷达装置在不同的入射角下工作。在收集速度数据时，要注意避开以风为主的河段、漩涡、次级流和大的湍流。

C.1.2 Guidelines for surface radar installation — Sample quick start guide 水面雷达安装指南--快速入门指南样本

Data should be collected at the cross-section of interest and in the vicinity of the velocity radar footprint:

应在有价值的过流断面和雷达流量计覆盖区域附近收集数据：

— choose straight channels with parallel streamlines;

选用具有平行流向的笔直渠道；

— choose a stream bed free of large rocks, weeds and obstructions that would create turbulence/slack water;

选用没有大石头、杂草和障碍物的渠底，这样会产生湍流/平流；

— use sections that are parabolic, trapezoidal or rectangular;

选用抛物线、梯形或矩形截面；

— use velocities greater than 0,1 m/s to 0,4 m/s and depths greater than 0,3 m;

选用速度大于0.1m/s至0.4m/s，深度大于0.3m的水体；

— avoid variable flow conditions downstream of piers or channel obstructions (highly turbulent conditions should be avoided);

避免在码头或航道障碍物的下游出现多变的水流状况（应避免高度湍流的状况）；

— avoid sections influenced by tributaries or contributing drainage channels.

避开受支流或排水渠道影响的地段。

Collect the following stream flow and channel data at the cross-section of interest:
在有价值的过流断面上收集以下的流量和渠道数据：

— similar to any other point velocity discharge measurement;

与任何其他点的速度流量测量相似；

— at the y-axis, record the surface-water velocity and point velocities, throughout the water column using the six-point method as a minimum (see *7.1.4.3.6*);

在y轴处，至少用六点法记录整个水柱的水面流速和点速度作为最小值（详见*7.1.4.3.6*）；

— confirm the location of the y-axis by repeating this procedure to the left and right of the y-axis;

通过在Y轴的左右两边重复这一程序来确认Y轴的位置；

— water depth at the y-axis;

y轴上的水深

— wind speed and direction.

风速和风向。

To estimate the position of the y-axis, rely on the location of the maximum-surface water velocity; it generally coincides at the same vertical as the maximum velocity.
要估计Y轴的位置，要依靠最大水面流速的位置；一般来说，它与最大流速的垂直方向是一致的。

Develop an index velocity to ascertain mean velocity for the section.
制定一个指数速度来确定该段的平均流速。

Velocity radars can be deployed by hand or fixed on bridges, light cableways or cable stays.
测速雷达可以用手部署，也可以固定在桥梁、轻型索道或缆绳支架上。

C.2 Particle image velocimetry (PIV) 粒子图像测速法

PIV is a technique using images continuously filmed with video or still cameras. Three methods are currently practised:
PIV是一种使用视频或静态摄像机连续拍摄图像的技术。目前有三种使用方法：

— the large-scale particle image velocimeter (LSPIV) determines the velocity vector by matching
water surface patterns between two images obtained at different time points;
大尺度粒子图像测速仪（LSPIV）通过匹配在不同时间点获得的两张图像的水面形态来确定速度矢量；

— the particle track velocimeter (PTV) tracks a tracer;
粒子跟踪测速仪（PTV）跟踪示踪剂；

— the space and time image velocimeter (STIV) monitors the movement of water surface patterns to determine the velocity vector.

空间和时间图像测速仪（STIV）监测水面模式的运动，以确定速度矢量。

Aside from experimental studies, image conversion is sometimes necessary when these techniques are applied to actual flows. For example, in the case of the video images obtained from the river line with few angles of repose and from the aircraft with large angle of repose, images should be converted with the explicit orthorectification method. Additionally, installation and location-survey of ground control points are necessary for accurate orthorectification of the water surface plane. Ideally, the ground control points should be installed at more than six locations distributed in the x, y, and z planes of the channel. Infrared cameras are available for 24 h operation.

除实验研究外，这些技术应用于实际流动时，有时也需要进行图像转换。例如，在从俯仰角较小的河道线上获得的视频图像和从俯仰角较大的飞机上获得的视频图像的情况下，应该用显式正射法转换图像。此外，地面控制点的安装和位置测量对于水面平面的精确正射是必要的。 理想情况下，地面控制点应安装在渠道的X、Y、Z平面上分布的六个以上的位置。红外线相机可以24小时运行。

C.3 Laser 激光器

Laser doppler instruments focus a beam of light from a laser which is mounted above the flow at a specific point. The frequency difference of the transmitted and reflected light gives the velocity at the point of measurement. The laser can be focused at a precise point in the flow field; it can also penetrate the liquid surface. In this way, a single laser can be used to scan both across the flow field horizontally and, to a degree which depends on the clarity of the water, through the depth. This enables the mean fluid velocity to be estimated over a range of flow conditions.

激光多普勒仪器将安装在水流上方的激光器的光束聚焦在一个特定点上。透射光和反射光的频率差给出了测量点的速度。激光可以聚焦在流场中的一个精确点上；它还可以穿透液体水面。这样一来，一个激光器就可以用来水平扫描整个流场，并且在一定程度上取决于水的透明度，扫描深度。这使得平均流体速度可以在一系列的流动条件下被估算出来。

Annex D
(informative)

Uncertainties in the velocity-area measurement

附录 D（资料性文件）流速区域测量的不确定性

D.1 General 概述

It should be noted that the values given in this annex are the result of investigations carried out since the publication of the first edition of this document in 1973. Reference should be made to ISO 25377:2020 and ISO 1088. Nevertheless, it is recommended that each user should determine independently the values of the uncertainties which apply to a specific measurement condition.The values in the tables are relative standard uncertainties (“one standard deviation” values, level of confidence approximately 68 %), expressed as percentages of the measured value.

值得注意的是，本附录中给出的数值为自1973年本标准第一版出版以来进行调查的结果。应参考ISO 25377:2020和ISO1088。但仍建议每个用户应独立确定适用于特定测量条件的不确定度的数值。表中的数值是相对标准不确定度（"一个标准差 "的数值，置信度约为68%），以测量值的百分比表示。

The information given in the tables can also be used to determine the optimum measurement procedure for a desired accuracy.

表中给出的信息也可用于确定所需精度的最佳测量程序。

Error varies by method and by instrument and should be determined case by case. See also *Clause 9*.

误差因方法和仪器而异，应逐案确定。也请参见*第9条*。

D.2 Uncertainties in width (u_b) 宽度的不确定度

The uncertainty in the measurement of width should be no greater than 0,5 %.

宽度测量的不确定度应不大于0.5%。

As an example, the error introduced for a particular range finder having a base distance of 800 mm varies approximately as given in *Table D.1*.

作为一个例子，对于一个基距为800mm的特定测距仪，其引入的误差大约如*表D.1*所示。

Table D.1—Example of uncertainties for a range finder(standard uncertainties,level of confidence approximately 68%)

表D.1一个测距仪的不确定度示例（标准不确定度，置信度约为68%）

Range of width **宽度范围** m	**Absolute error** **绝对误差** **m**	Relative Uncertainty 相对不确定度 %
0至100	0至0.15	0.15
101至150	0.15至 0.25	0.20
151 至250	0.3至 0.6	0.25

D.3 Uncertainties in depth (u_d) 深度的不确定性

For depths up to 0,300 m, the uncertainly should not exceed 1,5 %. For depths over 0,300 m, the uncertainty should not exceed 0,5%.

对于0.300米以下的深度，不确定性不应超过1.5%。对于0.300米以上的深度，不确定性不应超过0.5 %。

As an example, the uncertainty in depth in an alluvial river whose depth varied from 2 m to 7 m and where the velocity varied up to 1,5 m/s was, for these conditions, of the order of 0,05 m measured using a suspension cable.

举例：在一条冲积河中，深度从2米到7米不等，速度变化达1.5米/秒，在这些条件下，用悬索测量的深度不确定度为0.05米左右。

As another example, measurements of depth were taken with a sounding-rod up to a depth of 6 m, and beyond that value by a log line with standard air-line and wet-line corrections. These observations were made within the range of 0,087 m/s to 1,3 m/s, the results are given in *Table D.2*.

另一个例子：用探杆测量深度，深度为6米，超过这个值时，用标准空气线和湿线校正的对数线进行测量。这些观测是在0.087米/秒到1.3米/秒的范围内进行的，结果见*表D.2*。

Table D.2 — Examples of uncertainties in depth measurements (standard uncertainties, level of confidence approximately 68 %)

D.2 - 深度测量中的不确定度实例（标准不确定度，置信度约为68%）

Range of depth 深度范围 m	Absolute Uncertainty 绝对不确定度 m	Relative Uncertainty 相对不确定度 %	Remarks 备注
0.4 to 6 6 to 14	0.02 0.025	0.65 0.25	With sounding rod. 有探测杆 With log-line and air- and wet-line corrections. 有量测线和空气及湿线校正
NOTE Column 3 relative uncertainties were computed from column 2 absolute uncertainties using mid-range depths 3,2 m and 10 m. 注：第3栏的相对不确定度是根据第2栏的绝对不确定度计算出来的，使用的是3.2米和10米的中线深度。			

D.4 Uncertainties in determination of the mean velocity 确定平均速度的不确定度

D.4.1 Times of exposure (u_e) 曝光时间

The percentage uncertainty in point velocity measurement taken at different exposure times and points in the vertical, shown in Table D.3, are given as guidance and should be verified by the user.
表D.3所示的在不同的曝光时间和垂直方向上的点速度测量的不确定性百分比，为指导性数值，应由用户来验证。

Table D. 3 — Percentage uncertainties in point velocity measurement due to limited exposure time (standard uncertainties, level of confidence approximately 68 %)

表D.3 - 由于有限的曝光，点速度测量的百分比不确定度时间（标准不确定度，置信度约为68%）

Velocity 速度 m/s	Point in vertical垂直点							
	0.2*D*, 0.4*D* 或 0.6*D*				0.8*D* 或 0.9*D*			
	Exposure time曝光时间 min							
	0.5	1	2	3	0.5	1	2	3
0.050	25	20	15	10	40	30	25	20
0.100	14	11	8	7	17	14	10	8
0.200	8	6	5	4	9	7	5	4
0.300	5	4	3	3	5	4	3	3
0.400	4	3	3	3	4	3	3	3
0.500	4	3	3	2	4	3	3	2
1.000	4	3	3	2	4	3	3	2
over 1.000	4	3	3	2	4	3	3	2

D.4.2 Number of points in the vertical (u_p) 垂直方向上的点的数量

The uncertainty values shown in *Table D.4* were derived from many samples of irregular vertical velocity curves. They are given as guidance and should be verified by the user.

*表D.4*中显示的不确定度值是从许多不规则垂直速度曲线的样本中得出的。它们是作为指导而给出的，并应由用户进行验证。

Table D.4 — Percentage uncertainties in the measurement of mean velocity at a vertical, due to limited number of points in the vertical (standard uncertainties, level of confidence approximately 68 %)

表D.4 - 垂直方向平均速度测量的不确定度百分比、由于垂直方向上的点的数量有限（标准不确定度，置信程度约68%)

Method of measurement测量方法	Uncertainties 不确定度 %
Velocity distribution 速度分布	0.5
Five points (see 7.1.4.3.5) 五个点	2.5
Two points (0,2*D* and 0,8*D*) (see 7.1.4.3.3) 两个点	3.5
One point (0,6*D*) (see 7.1.4.3.2) 一个点	7.5
Surface (see 7. 3. 3) 水面	15

D.4.3 Rotating-element current meter rating (u_c) 转子式流速仪额定值

The uncertainty values shown in Table D.5 are given as guidance and are based on experiments performed in several of the world's rating tanks. 表D.5中所示的不确定度值为指导性数值，是基于在世界几个计量槽中进行的实验而得出的。

Table D. 5 — Percentage uncertainties in point velocity measurement due to current meter rating error (standard uncertainties, level of confidence approximately 68 %)
表D.5--由于流速仪造成的点速度测量的不确定度百分比额定误差（标准不确定度，置信度约为68%）

Velocity measured 测量的速度 m/s	Uncertainties 不确定度%	
	Individual rating 个人评级	Group or standard rating 团体或标准评级
0.03	10	10
0.10	2.5	5
0.12	1.25	2.5
0.25	1.0	2
0.50	0.5	1.5
大于0.50	0.5	1.0

D.4.4 Number of verticals (u_m) 垂直方向的数量

The uncertainty values in Table D.6 are given as guidance and should be verified by the user.

表D.6中的不确定度值为参考性数值，应该由用户进行核实。

Table D.6 — Percentage uncertainties in the measurement of mean velocity due to the limited
number of verticals (standard uncertainties, level of confidence approximately 68 %)
表D.6--由于有限的垂直度，平均速度测量的不确定度百分比
垂直线数量有限，导致平均速度测量的不确定性百分比（标准不确定度，置信度约为68%）

Number of verticals 垂直方向的数量	Uncertainties 不确定度%
5	7.5
10	4.5
15	3.0
20	2.5
25	2.0
30	1.5
35	1.0
40	1.0
45	1.0

See Reference [20].
详见参考文献20.

Annex E
(informative)

Velocity measurement under ice conditions

附录 E（资料性文件）冰面条件下的流速测量

E.1 Safety practice for measurements from ice cover

在冰面上进行测量的安全做法

Before taking measurements on ice it should be ensured that the personnel performing the measurements have appropriate education and knowledge about working on ice. The safety guidelines given in this annex shall not be seen as a complete set but as an introduction.

在冰面进行测量之前，应确保进行测量的人员具有适当的培训和关于冰面工作的知识。本附件中的安全准则不应视为一套完整的准则，而应视为是一种指南。

As a general rule, the ice shall consist of solid clear ice and not be thinner than 0,1 m. Preferably, the air temperature is no more than a couple of degrees above zero centigrade. Particular precautions shall be taken during spring when the sun can convert solid morning ice to rotten ice within a couple of hours. If the ice is not clear but consists of frozen snow/slush or a combination, the thickness should be at least 0,2 m.

一般来说，冰块应是由固体透明的冰组成，厚度不应小于0.1米，最好是空气温度不超过零摄氏度。在春季应采取特别的预防措施，因为太阳可以在几个小时内将早晨的固体冰转化为腐烂的冰。如果冰不是透明的，而是由冰冻的雪/泥浆或混合物组成，那么厚度至少应该是0.2米。

The whole cross-section shall be checked. This is especially important if the ice is snow covered. Snowdrifts at the banks reduce ice formation and very thin ice or even open water under the snow can be found. If high velocities are part of the cross-section, this section can freeze later than the rest or even stay open. Variation in ice thickness can be huge and if snow covered this cannot be seen. The safe and checked cross-section may be marked if necessary.

应检查整个过流断面。如果冰面被雪覆盖，这一点尤其重要。岸边的雪堆会减少冰的形成，而且可以发现非常薄的冰，甚至是雪下的明水。如果高速度是过流断面的一部分，这个断面可能比其他地方晚结冰，甚至保持开放。冰层厚度的变化可能是巨大的，如果被雪覆盖，这一点是看不到的。如果有必要，可以对安全和检查过的横截面进行标记。

The strength of the ice cover shall continuously be tested using an ice chisel or ice prod when the river is crossed. The speed of a vehicle crossing the ice cover shall be low (especially near the river banks) to prevent wave formation which could increase the pressure on the ice. Stricter precautions shall be taken where water flows above the ice, or when new ice layers are formed, since the ice cover is likely to be thin.

在过河的时候，应不断用冰凿或冰棒测试冰层的强度。穿越冰层的车辆应保持低速行驶（特别是在河岸附近），以防止形成波浪，从而增加冰层的压力。当水在冰面上流动时，或当新的冰层形成时，应采取更严格的预防措施，因为冰层可能很薄。

Operators taking measurements of discharge from the ice cover shall be equipped with appropriate safety equipment such as a life jacket or rescue suit, safety ice nails, a winter lifeline and a hot beverage. An extra set of dry clothes shall be easily available.

测量冰层流量的操作人员应配备适当的安全设备，如救生衣或救援服、安全冰钉、冬季救生绳和热饮。应另外准备一套干衣服以供随时更换。

E.2 Velocity-area method 速度面积法

E.2.1 General 概述

The principle of this method is described in the main part of this document. For channels in which a surface layer of ice exists, the cross-sectional area of water flowing is taken as the area bounded by the bed line (or wetted perimeter) and the lower edge of the ice cover or slush. When flow is between layers of ice, the cross-sectional area also includes the area bounded by the lower ice layer and the lower surface of the ice cover or slush. At times, the ice sheets on the riverbanks are thick enough to reach the riverbeds. Therefore, it is important to use poles for indicating the locations of riverbanks.

这种方法的原理在本标准的主要部分有描述。对于存在水面冰层的渠道，水流的过流断面面积被认为是由渠底线（或湿润周长）和冰面或泥浆的下边缘所限定的面积。当水流在冰层之间时，过流断面面积还包括由下层冰层和冰面或泥浆的下水面所限定的区域。有时，河岸的冰层很厚，足以到达渠底。因此，使用杆子来指示河岸的位置是很重要的。

The instrument used can be mechanical such as current meters or hydroacoustic such as ADCPs or ADVs. When an ADCP is used, the stationary method should be chosen.

使用的仪器可以是机械的，如流速仪或水力声学的，如ADCPs或ADVs。当使用ADCP时，应选择固定的方法。

E.2.2 Selection of site 选址

Discharge measurements under ice conditions are best conducted at sites where the geometry of the cross-sections is well known. The site can be unsuitable for observations if:

冰面条件下的排放测量最好在截面几何形状已知的地点进行。如果出现以下情况，该地点可能不适合进行观测：

a) more than 25% of the cross-section is filled with slush, which is distributed unevenly over the cross-section;

超过25%的过流断面被泥沙填满，泥沙在过流断面上分布不均匀；

b) dead zones occupy more than 10 % of the cross-section; 盲区占过流断面的10%以上；

c) there are large areas with very low stream velocities below the recommended low limit for the instrument; 有大面积的流速非常低，低于仪器推荐的测量下限；

d) it is located in the backwater zone downstream of an ice gorge or ice jam:

位于冰峡或冰塞下游的回水区：

e) it is liable to ice up owing to the freezing of water flowing through cracks on the surface of the ice cover indicating a possible breakup of the ice.

由于流经冰面水面裂缝的水被冻结，表明冰可能破裂，因此容易结冰。

However, in the aforementioned conditions, division of the cross-sectional area and observation of every divided section will increase the accuracy of the discharge measurements.

然而，在上述条件下，划分过流断面面积并观察每一个划分的断面将提高流量测量的准确性。

During the open water period, i.e. the period in which there is no ice cover, sites additional to those normally used for water discharge measurements should be selected and marked on the banks. After the ice cover at the river reach selected for measurements has stabilized, a preliminary survey shall be made to select a longitudinal profile with a length equal to several widths. An appropriate number of holes shall be drilled along the profile to determine the occurrence of slush and its distribution. In channels in which slush is found to be present, and when it is impossible to select another measurement reach, the measurement site shall be located at the centre of a uniform river reach.

在开放水域时期，即没有冰层覆盖的时期，应选择除通常用于流量测量的地点外的其他地点，并在岸边做标记。在选定用于测量的河段的冰面稳定后，应进行初步调查，选择一个长度等于几个宽度的纵向剖面。应沿剖面钻适当数量的孔，以确定泥沙的出现及其分布。在发现有淤泥的河道中，当无法选择另一个测量范围时，测量地点应位于统一河道的中心。

Following the preliminary choice of the site, four or five holes shall be drilled across the river at equal distances to determine whether a regular velocity distribution exists and to establish the slush and ice thickness over the cross-section. Sites in which slush divides the river into separate streams shall be avoided. Braided channels which, in the open water period, are unsuitable for the measurement of discharge owing to the multiplicity of channels, may be suitable under winter conditions since the shallower channels can become blocked by slush or ice, leaving the main channel unblocked and flowing.

在初步选择场地后，应在河面上以相等的距离钻四个或五个孔，以确定是否存在有规律的速度分布，并确定过流断面上的泥泞和冰层厚度。应避免在泥浆将河流分割成独立的溪流的地点。在开放水域时期，由于河道众多，不适合测量流量的辫状河道（多样性通道的河道），在冬季条件下可能适合，因为较浅的河道可能被泥泞或冰堵住，而主河道没有被堵住，并在流动。

E.2.3 Frequency of water discharge measurements 流量测量的频率

The frequency of water discharge measurements during the winter period shall be such as to ensure a reliable estimation of the discharge. If conditions of stable ice cover exist, methods of hydraulic interpolation of winter flow may be used. However, under difficult conditions (such as those of unstable ice cover and incomplete freezing) measurements shall be taken as frequently as possible since, in this case, the discharge is computed by the interpolation of the observed discharges. The time at which the daily discharge measurement shall be made shall be carefully chosen so as to correctly represent the time span for the observation. For example, if daily mean values are observed, the discharge measurement shall be made when the discharge is as close as possible to the daily mean.

冬季期间的流量测量频率应能确保对流量的可靠估计。 如果存在稳定的冰面条件，可以使用冬季流量的水力插值方法。然而，在困难的条件下（如不稳定的冰层和不完全冻结的条件），应尽可能频繁地进行测量，因为在这种情况下，流量是通过观察到的流量的内插法计算出来的。应仔细选择每天测量流量的时间，以正确代表观测的时间跨度。 例如，如果观察到的是日均值，则应在流量尽可能接近日均值时进行流量测量。

E.2.4 Measurements of ice cover thickness 冰层厚度的测量

The ice cover thickness shall be measured using ice-measuring sticks which are lowered into the drilled holes. A zero reading may also be obtained. Using an L-shaped measurement pole enables the measurement of the thicknesses from the top of river ice to the bottom of the ice sheet and from the top of the river ice to the bottom of the slush ice. In this case, averaging the measurements conducted at four points, including the front, back, right and left of a hole, will result in an average ice thickness around the hole.

冰层厚度应使用冰层测量棒进行测量，并将其放入钻孔中。也可以获得一个零的读数。使用L型测量杆可以测量从河冰顶部到冰层底部的厚度，以及从河冰顶部到泥泞冰层底部的厚度。在这种情况下，将在四个点（包括洞口的前、后、右和左）进行的测量结果平均化，就可以得出洞口周围的平均冰厚。

E.2.5 Measurements of slush depth 淤泥深度的测量

For small depths of slush, measurements may be made using an ice-measuring stick. The slush depth is indicated by a change in the resistance to clockwise and anticlockwise rotation of the stick during its rise, i.e. the resistance to rotation increases when the slush layer is reached. For thicker depths of slush, measurements may be made in a similar manner using a special rod with a stop plate or a perforated disc attached to its end. In addition, current meters can be used for slush depth measurements. The current meter is lowered below the slush layers and is then gradually lifted until a zero reading is obtained. It should be borne in mind, however, that the actual slush depth can be somewhat smaller than that obtained by measurement, because a zero reading will also be obtained when the flow velocity decreases to 0,03 m/s to 0,04 m/s. Hydroacoustic instruments are not suited for slush depth measurements.

对于小深度的泥浆，可以使用测冰棒进行测量。泥浆深度通过测量棒在上升过程中顺时针和逆时针旋转的阻力变化来表示，即到达泥浆层时旋转阻力增加。对于更厚的泥浆深度，可以用类似的方式进行测量，使用一个特殊的棒子，在其末端连接一个挡板或一个穿孔盘。此外，测流仪也可用于测量泥浆深度。将流速仪降到泥浆层以下，然后逐渐抬起，直到获得零读数。但应注意的是，实际的泥浆深度可能比测量得到的深度要小一些，因为当流速下降到0.03米/秒至0.04米/秒时，也会得到一个零读数。水声仪器不适合用于测量泥泞深度。

E.2.6 Determination of the effective depth 有效深度的确定

In an ice-covered channel, the effective depth is computed by subtracting the distance between the water surface and the bottom of the ice layer or slush from the total depth. If using a current meter, the total water depth in the channel is measured using a rod or a cable suspended sounding weight which is lowered using a winch; the latter method is similar to the depth measurements made from a boat under open channel conditions. If a hydroacoustic instrument is used, the depth is measured by the instrument itself positioned by the operator at a known distance below the ice or slush.

在冰面覆盖的渠道中，有效深度的计算方法是用总深度减去水面与冰层或泥浆底部之间的距离。如果使用流速仪，则用一根杆子或一根悬挂着探空重物的缆绳来测量航道的总水深，该缆绳用绞盘放下；后一种方法类似于在开放航道条件下从船上进行的深度测量。如果使用水力声学仪器，深度是由操作人员将仪器本身放置在冰面或泥浆下面的已知距离处测量的。

E.2.7 Velocity measurements 速度测量

E.2.7.1 Use of current meters and hydroacoustic instruments under winter conditions 冬季条件下流速仪和水力声学仪器的使用

Velocity measurements using current meters are carried out by lowering them into holes drilled in the ice cover. The current meters can be lowered using a suspension rod, a hand-operated cable (for small depths) or cable suspension equipment (for depths exceeding 3m to 4m). During velocity measurements, the device by which the current meter is held shall be located near the upstream side of the hole and shall be held rigidly at the upper edge of the hole to avoid the influence of vertical stage pulsation.

使用流速仪的速度测量是通过将其放入冰面上的钻孔中进行的。可以使用悬挂杆、手工操作的缆绳（用于小深度）或缆绳悬挂设备（用于超过3m至4m的深度）来下放流速仪。在速度测量过程中，固定流速仪的设备应位于孔的上游附近，并应刚性地固定在孔的上边缘，以避免垂直阶段搏动的影响。

To prevent the current meter from freezing up when it is carried between one measurement vertical and another, it may be placed in a bucket containing heated water or in a hot-air chamber. In measurement verticals with shallow water depth, when the current meter is lowered on a rod without a tailpiece, care shall be taken to ensure the correct position of the current meter with regard to direction of flow in the vertical. In measurement verticals where slush is present, vane current meters may be used in preference to cup-type meters which are liable to become blocked by slush ice.

为了防止流速仪在一个测量垂直面和另一个测量垂直面之间移动时被冻坏，可以将其放在装有加热水的桶中或放在热气室中。在水深较浅的垂直测量中，当流速仪被放在没有尾部的杆子上时，应注意确保流速仪在垂直方向上的正确位置。在有泥浆的垂直测量中，可以优先使用叶片式流速仪，而不建议使用杯式流速仪，因为杯式流速仪很容易被泥浆冰块堵塞。

Before the current meter is lowered, it is advisable to clean a passage in the slush by means of a steel or wooden pole with discs or by using an elliptical (round-shaped) weight suspended on a cable.

在放下流速仪之前，最好用带圆盘的钢杆或木杆或用悬挂在缆绳上的椭圆（圆型）重物在泥泞中清理出一条通道。

Velocity measurements using hydroacoustic instruments are carried out by also positioning them into holes drilled in the ice cover and just below ice cover or slush. When moving the instrument from one vertical to next this should be done quickly. A thin layer of ice on the transducers will thaw fast when put in the water again but thick layers can be more troublesome. The temperature of the batteries can be more crucial and precautions to not let them to get too cold should be made.

使用水力声学仪器进行速度测量时，也要将其定位在冰面上和冰面或泥浆下的钻孔中。当把仪器从一个垂直方向移到下一个垂直方向时，应该迅速完成。当再次放入水中时，传感器上的薄冰层会迅速解冻，但厚冰层会更麻烦。电池的温度可能更关键，应采取预防措施，不能让它们长期处于低温条件中。

E.2.7.2 Selection of verticals for velocity measurements 选择速度测量的垂直点

The principles governing the location of velocity verticals under ice conditions are similar to those governing the location of velocity verticals under open channel conditions. These principles are as follows.

在冰面条件下，管理速度垂直仪位置的原则与管理明渠条件下速度垂直仪位置的原则相似。这些原则如下。

a) The minimum number of velocity verticals shall be as specified in *7.1.2*, to ensure sufficient accuracy in velocity interpolation with respect to the channel width. Sections between successive verticals shall contain substantially equal proportions of the total water discharge.

速度垂直线的最低数量应符合*7.1.2*的规定，以确保速度插值相对于渠道宽度有足够的准确性。连续的垂直线之间的断面应包含总流量的基本相等的比例。

b) The location of the vertical shall be such as to reflect the flow structure and the cross-section of the river bottom in the best possible way.

垂直线的位置应尽可能地反映水流结构和河底的过流断面。

c) When current meters are used, the distance between each vertical shall exceed the propeller diameter of the current meter; therefore, in very small rivers (brooks) there may be a small number of verticals.

当使用流速仪时，每个垂直线之间的距离应超过流速仪的螺旋桨直径；因此，在非常小的河流（小溪）中，可能有少量的垂直线。

The profile of the bottom at the gauging station shall be determined and the location of the verticals shall be selected prior to the formation of ice cover. When this is not feasible, approximately 20 holes shall be drilled along the cross-section at equal distances. (From hydrometric practice it has been found that 20 is the minimum number of holes required to reproduce the channel profile with sufficient accuracy.) Furthermore, the intervals of the measurement holes can be determined depending on the width of the river.

应确定测量站的底部轮廓，并在冰层形成之前选择垂直线的位置。当这不可行时，应沿过流断面以相等的距离钻大约20个孔。 (从水文测量的实践中发现，20个孔是足够准确地再现河道剖面所需的最小数量）。此外，测量孔的间隔可以根据河流的宽度来确定。

Additional holes shall then be drilled to ensure sufficient accuracy of discharge measurements. The location of the edges of the channel cross-section shall be determined after all other necessary holes have been drilled, since it is easy to blunt the tip of the drill during this procedure.

然后应钻更多的孔，以确保流量测量的精度足够准确。渠道横截面的边缘位置应在所有其他必要的孔都钻完后再确定，因为在这个过程中很容易把钻头的尖端弄钝。

E.2.7.3 Velocity measurements on a vertical 垂直方向上的速度测量

Owing to roughness of the lower surface of the ice sheet, the vertical velocity curve for the winter period differs from that under open-channel conditions. At the lower surface of the ice cover, the velocity distribution is very similar to that found in a pipe. The degree of reduction in velocity varies with the roughness of the lower surface of the ice.

由于冰层下水面的粗糙度，冬季的垂直速度曲线与明渠条件下的速度曲线不同。在冰面的下水面，速度分布与管道中的速度非常相似。速度下降的程度随冰层下水面的粗糙度而变化。

When current meters are used and if depth permits, the distance from the current meter axis to the river bed and that from the current meter axis to the lower ice surface should be no less than twice the

当使用流速仪时，如果深度允许，流速仪轴线到渠底的距离和流速仪轴线到下层冰面的距离应不小于叶片螺旋桨直径的两倍。

diameter of the vane propeller. The one-point method can be applied (see *7.1.4.3.2*) where the effective depth is about 0,30 m to 1,0 m; in this case, the current meter is located at 0,6 times the effective depth. To compute the mean velocity, a coefficient of 0,88 to 0,90 shall be applied.

在有效深度约为0.30米至1.0米时，可使用一点法（见*7.1.4.3.2*）；在这种情况下，流速仪位于有效深度的0.6倍处。为了计算平均速度，应使用0.88至0.90的系数。

When the effective depth is equal to or exceeds 1,0 m, other measurement methods can be applied (see *7.1.4.3.1*).

当有效深度等于或超过1,0米时，可使用其他测量方法（见*7.1.4.3.1*）。

When using hydroacoustic instruments, the software should be particularly suited for measurements on ice.

当使用水力声学仪器时，软件应特别适合在冰面测量。

E.2.7.4 Computation of mean velocity on a vertical 垂直线上平均速度的计算

Computation of the mean velocity shall conform to *7.1.4.3.1*.

平均速度的计算应符合*7.1.4.3.1*的规定。

E.2.8 Discharge measurements under partial ice cover conditions 部分冰面条件下的流量测量

If the water is not completely frozen over, discharge measurements in ice covered sections can be carried out by using the methods specified in *E.1.* In an ice-free part of the stream, open channel methods are applied using a gauging footbridge, a cableway or a boat. If current meters or hydroacoustic instruments cannot be used in the open water section of the stream, velocity measurements shall be made using floats; special floats or floating ice can be used to this end. During the period of ice drift on large rivers, the airborne method of velocity measurement is practically the only safe method to use. When drifting ice is distributed evenly over the river, the ice floes may be photographed to determine the flow discharge in the same way that flow discharge measurements are made using floats. Where there is an uneven distribution of ice over the river width, special floats shall be dropped from an aircraft into the open water part of the stream and additional photographs shall be taken to supplement the data.

如果水面没有完全结冰，可以用*E.1*中规定的方法对冰面部分进行流量测量。在溪流的无冰部分，使用明渠法，使用测量天桥、索道或船只。如果在溪流的开放水域部分不能使用流速仪或水力声学仪器，应使用浮标进行速度测量；为此可使用特殊的浮标或浮冰。在大河漂冰期间，空中测速方法实际上是唯一可以使用的安全方法。当漂流的冰块均匀地分布在河面上时，可以对浮冰进行拍照，以确定流量排放，方法与使用浮标进行流量测量相同。当冰块在河道宽度上分布不均时，应从飞机上向河道的开放水域部分投放特殊的浮标，并拍摄额外的照片以补充数据。

E.2.9 Discharge measurements under multi-layered ice conditions 多层冰条件下的流量测量

When there are two or more ice layers at the measurement site, this site shall not be used and another site shall be selected for the discharge measurements. The discharges determined at this alternative site shall be correlated with the water levels at the permanent gauging station. However, at this observation point, the discharge measurements can be conducted when the area into which water flows exists.

当测量点有两个或更多的冰层时，不应使用该测量点，而应选择另一测量点进行流量测量。在这个替代地点确定的流量应与永久测量站的水位相关联。但是，在这个观测点，当水流进入的区域存在时，就可以进行流量测量。

E.2.10 Discharge measurements under conditions of water flow above ice 冰面上水流条件下的流量测量

If water flows over the ice surface as well as below, the discharges above and below the ice cover shall be obtained separately. The discharge below the ice cover shall be determined before water appears above the ice using the method described in *7.1.6*. The cross-sectional area of the water flowing below the ice is determined using the data obtained in the preliminary measurements. However, the distance between the water surface and the upper surface of the submerged ice shall be measured.

如果水既在冰面上流动，也在冰面下流动，则应分别获得冰面上方和下方的流量。在冰面上出现水之前，应使用*7.1.6*所述的方法确定冰面以下的流量。冰层以下水流的过流断面面积是用初步测量得到的数据来确定的。但应测量水面与被淹没的冰层上水面之间的距离。

The flow velocities above the ice shall be measured using procedures similar to those for ice-free channel discharge measurements.

冰面以上的流速应使用与无冰河道流量测量类似的程序进行测量。

If the channel freezes to the bottom in winter and is filled with ice and snow, it is advisable to make, before the start of the spring flood, a ditch in the snow 0,5 m to 1,0 m wide and no less than 20 m long to contain the first stream of water.

如果渠道在冬季冻结到底部，被冰面填满，建议在春汛开始前，在雪地上开一条宽0.5米至1.0米、长不少于20米的沟，以容纳第一股水流。

E.2.11 Discharge computation 流量的计算

The computation of the discharge under ice cover shall be made in accordance with *Clause 8*, the only difference being that the effective rather than the total depth and the effective width of flow rather than river width are used.

冰面下的流量计算应按照*第8条*进行，唯一的区别是使用有效深度而不是总深度，使用有效流宽而不是河宽。

E.3 Representative vertical method 代表性垂直法

E.3.1 Principle of the method 该方法的原理

There is a close relationship between the mean flow velocity in the cross-section and the flow velocity at a given vertical. The discharge Q may thus be obtained from the values of flow velocity measured at a representative vertical in a cross-section using *Formula (E.1)*:

过流断面上的平均流速与某一垂直面上的流速之间有密切的关系。因此，可以用*公式（E.1）*从过流断面中某一代表性垂直方向测得的流速值得到流量Q：

$$Q = CvA \quad \text{(E.1)}$$

Where 其中

A is the cross-sectional area at the given water level;

是给定水位下的过流断面面积

v is the mean or unit velocity at the representative vertical;

是代表垂直方向的平均速度或单位速度

C is a correction coefficient.

是校正系数

E.3.2 Selection of the vertical and determination of the correction coefficient 垂直方向的选择和校正系数的确定

As a general rule, for stable ice cover and in the absence of slush and other ice formations dividing the flow into separate jets, the correlation stated in *E.3.1*, between the mean velocity of flow and the velocity at a representative vertical, is valid.

一般来说，对于稳定的冰层，在没有泥浆和其他冰层将水流分成独立的喷流的情况下，*E.3.1*中所述的平均流速和有代表性的垂直方向的流速之间的相关性是有效的。

To obtain sufficiently accurate results, the choice of the vertical and the establishment of the relationship which is usually linear is made on the basis of 40 or 50 discharge measurements obtained using a multi- point or two-point method. Measurements shall be carried out under stable conditions and shall cover uniformly the total range of levels.

为了获得足够准确的结果，垂直度的选择和通常是线性关系的建立是基于40或50个使用多点或两点方法获得的流量测量。测量应在稳定的条件下进行，并应均匀地覆盖总水平范围。

The measured discharge is plotted versus either the product of the cross-sectional area and the mean velocity of flow v , on the given vertical, or the product of the cross-sectional area and the velocity $v_{0,2}$ at 0,2 of the effective depth where the velocity, according to the field data, is closest to the mean velocity. For practical purposes, the graph which gives the best curve shall be chosen. 测量的流量与过流断面面积和平均流速$\bar{v}$的乘积在给定的垂直线上绘制，或者过流断面面积和有效深度0.2处的流速$v_{0.2}$的乘积，根据现场数据，该处的流速最接近平均流速。出于实际考虑，应选择能提供最佳曲线的图形。

The correction coefficient is obtained as the tangent of the curve as it crosses the origin of coordinates.

校正系数是以曲线越过坐标原点时的切线获得。

E.3.3 Limits of application 适用范围

The location of a representative vertical in the cross-section of a stream shall be stable throughout the year within the total range of stage. The mean square deviation of the relation between the discharge obtained on the basis of the representative vertical method and the discharges actually measured shall not exceed 5% to 10%. The method is not applicable for slush, intermittent backwater and oblique current conditions.

溪流过流断面上有代表性的垂直位置，在整个阶段范围内应全年稳定。根据代表垂直法得到的排量与实际测量的排量之间的均方差不得超过5％至10％。该方法不适用于泥泞、间歇性回水和斜向水流条件。

E.4 Assessment of uncertainties in winter discharge measurements and computations 冬季流量测量和计算的不确定度评估

The assessment of errors in winter flow measurements and the computations of daily discharges shall be carried out in accordance with *Clause 9*.

对冬季流量测量和日流量计算的误差评估应按照*第9条*规定进行。

E.5 A method to continuously compute the flow discharge 连续计算流量排放的方法

A method can be used to continuously compute the flow discharges, which can be derived from *Formula (E.2)*:

可以用一种方法来连续计算流量排放，该方法可从*公式（E.2）*中得出：

$$Q = C\,B_{\mathrm{w}}^{-\frac{1}{4}}\,A_{\mathrm{o}}^{\frac{5}{4}} \tag{E.2}$$

Where 其中

Q is the discharge (m^3/s);

是指流量

C denotes the degree of decrease in roughness caused by melting and smoothing of the river ice bottom by flowing water ($m^{3/4}/s$);

表示流水融化和抚平河底冰层造成的粗糙度下降程度

B_w denotes the river width (m);

表示河道宽度

A_o is the discharge area (m^2).

是指流量面积

Annex F
(informative)

Corrections for wetted length of wire when measuring depths with wire not normal to surface

附录 F (资料性文件) 在测量深度时对导线的湿润长度的修正缆绳不在水面上时的湿润长度的修正

F.1 See Reference [22]. It should be noted that a correction shall also be made for the change between the vertical length and the slant length of the line above the water surface. If the point of suspension of the sounding line is at a vertical distance *X* above the surface and the angle between the sounding line and vertical is *a*, then the air-line correction k_{1a} to be applied is given by Formula (F.1):

F.1 可见参考文献[22]。值得注意的是，还应该对测线在水面上的垂直长度和斜长之间的变化进行修正。如果探空线的悬挂点在水面以上的垂直距离X处，探空线与垂直线之间的角度为a，那么要应用的气线校正k_{1a}由公式（F.1）给出：

$$k_{1a} = (\sec a - 1) X \tag{F.1}$$

The percentage correction $(k_{1a} \cdot 100/X)$ to be deducted from the measured length of the sounding line, for angles up to 30°, is given in Table F.1.

表F.1给出了在角度不超过30°的情况下，从探空线测量长度中扣除的修正百分比$(k_{1a} \cdot 100/X)$

Table F.1 — Air-line correction

表F.1 气线校正

Vertical angle 垂直角	Correction 校正 %	Vertical angle 垂直角	Correction 校正 %
4°	0.24	18°	5.15
6°	0.55	20°	6.42
8°	0.98	22°	7.85
10°	1.54	24°	9.46
12°	2.23	26°	11.26
14°	3.06	28°	13.26
16°	4.03	30°	15.47

The wet-line correction k_{1w} (see Table F.2), also expressed as a percentage to be deducted from the measured length of the sounding line, is estimated on the assumptions that the horizontal drag pressure on the weight in the comparatively still water near the bottom can be neglected, that the velocity distribution in the vertical is normal, and that the sounding wire and the weight are designed to offer little resistance to the water current.

湿线校正 k_{1w}(见表F.2)，也表示为从测得的测线长度中扣除的百分比，是在以下假设的基础上估算的：在接近底部的相对静止的水中，重量上的水平阻力压力可以被忽略，垂直方向上的速度分布是正常的，测线和重量的设计对水流的阻力很小。

The uncertainties in this estimation are such that significant errors can be introduced if the angle of the sounding wire with the vertical is more than 30°.
这种估计的不确定性是，如果探空线与垂直方向的角度超过30°，就会出现重大误差。

Table F.2 — Wet-line correction
表F.2 湿线校正

Vertical angle 垂直角	Correction 校正%	Vertical angle 垂直角	Correction 校正%
4°	0,06	18°	1,64
6°	0,16	20°	2,04
8°	0,32	22°	2,48
10°	0,50	24°	2,96
12°	0,72	26°	3,50
14°	0,98	28°	4,08
16°	1,28	30°	4,72
NOTE The corrections given in this table are percentages of the wet-line depth. 注：本表中给出的校正值是湿线深度的百分比。			

Figure F.1 shows a typical situation where the position of a current meter is affected by the velocity of the water. The required position for the current meter is at point B, a distance *L* from the point of suspension. The velocity of the water will cause the current meter to be pulled downstream so that the angle of suspension is α .
图F.1显示了一个典型的情况，流速仪的位置受到流速的影响。流速仪所需的位置是在B点，与悬挂点的距离为L。水流的速度将导致流速仪被拉向下游，因此悬挂角为α。

$$\cos á = \frac{L}{L_W} \quad (F.2)$$

$$L_W = L + C \quad (F.3)$$

$$\therefore \cos á = \frac{L}{L+C} \quad (F.4)$$

$$L + C = \frac{L}{\cos á} \quad (F.5)$$

$$C = \frac{L}{\cos á} - L \quad (F.6)$$

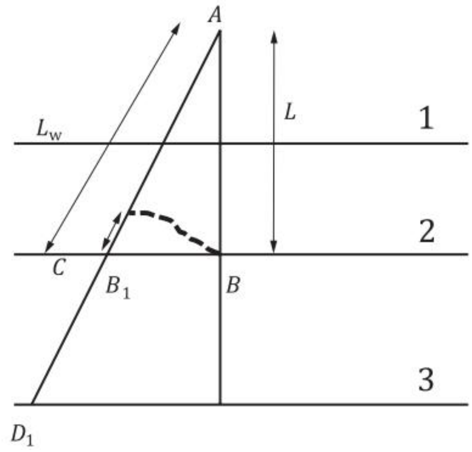


Figure F.1 — Wet-line correction
表F.1 湿线校正

Key

1 water level水位

2 point of suspension 悬浮点

3 bed level 床位

If the cross-section is pre-surveyed then the value of *L* is either known or can be measured on site. The angle *α* can be measured and the correction factor *C* calculated. The process may be iterative as the angle, *α*, can alter as the current meter is lowered into the water.
如果过流断面是预先勘测过的，那么*L*的值是已知的，或者可以在现场测量。可以测量角度*α*，并计算校正系数*C*。这个过程可能是反复进行的，因为角度*α*会随着测流仪的下降而改变。

This method assumes that the bed is horizontal between points D and D1.
这个方法假设D和D1点之间的渠底是水平的。

If the cross-section is not pre-surveyed then the current meter can be lowered to the bed at point D1 and the distance AD1 measured. At the same time, the angle, α, can be measured and thus the distance AD can be calculated.
如果过流断面没有预先测量，那么测流仪可以在D1点下降到渠底，测量距离AD1。同时，可以测量角度α，从而可以计算出距离AD。

$$\cos \acute{a} = \frac{\mathrm{AD}}{\mathrm{AD1}} \tag{F.7}$$

(F.8)

Thus: 可得：

$$\mathrm{AD} = \mathrm{AD1} \cos \acute{a}$$

Having determined distance AD, the procedure used for a pre-surveyed cross-section can be used.
在确定了距离AD之后，就可以使用预先调查的过流断面所使用的程序。

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ICS 17.120.20
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