INTERNATIONAL STANDARD

ISO 25377

First edition
2020-12

Hydrometric uncertainty guidance (HUG)

Lignes directrices relatives à l'incertitude en hydrométrie

Reference number
ISO 25377:2020(E)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The 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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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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.

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

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.

Introduction

The management of a natural environment requires knowledge, by measurement, of what is happening. Only then can effective action be taken and the effectiveness of the action assessed. Much depends on the quality of the knowledge itself.

The quality of measurable knowledge is stated in terms of measurement uncertainty. The internationally agreed method for assessing measurement quality is the guide to the estimation of uncertainty in measurement (GUM). Without this uniformity of measurement standards, equitable sharing of the environment is not possible and international obligations to care for the environment would be weakened.

The essential purpose of the GUM is for a statement of the quality of a measurement result to be presented with all measurements described in technical standards. Without this, no two measurements can be compared, or standards set. Whereas the GUM is a reference document serving the universal requirements of metrology, the Hydrometric uncertainty guidance (HUG) document is specific to hydrometry, i.e. to the measurement of the components of the hydrological cycle. It borrows from the GUM the methods that are the most applicable to hydrometry and applies them to techniques and equipment used in hydrometry.

In the past, error analysis has provided an indication of measurement quality, but such statements cannot properly convey the quality of the result because it presupposes knowledge of a true, error-free, value against which the measured result can be compared. The true value can never be known and uncertainty remains. For this reason, the GUM uses the concept of uncertainty and uses it for all stages and components of the measurement process. This ensures consistency.

The GUM defines standard uncertainty of a result as being equivalent to a standard deviation. This can be the standard deviation of a set of measured values or of probable values. This is broadly similar to the approach used in error analysis that preceded the uncertainty technique. However, the GUM provides additional methods of estimating uncertainty based on probability models. The two approaches are equivalent, but uncertainty requires only a knowledge or estimate of the dispersion of measurement about its mean value, and not the existence of a true value. It is assumed that a careful evaluation of the components of measurement uncertainty brings the mean value close to a probable true value, at least well within its margin of uncertainty.

In more general terms, uncertainty is a parameter that characterizes the dispersion of measurable values that can be attributed to their mean value.

By treating standard deviations and probability models as if they approximated to Gaussian (or normal) distributions, the GUM provides a formal methodology for combining components of uncertainty in measurement systems where several input variables combine to determine the result.

Within this formal framework, the GUM can be consistently applied to a range of applications and, thereby, be used to make meaningful comparisons of results.

The HUG seeks to promote an understanding of the nature of measurement uncertainty and its significance in estimating the ‘quality’ of a measurement or a determination in hydrometry.

Hydrometry is principally concerned with the determination of flow in rivers and man-made channels. This includes:

— environmental hydrometry, i.e. the determination of the flow of natural waters (largely concerned with hydrometric networks, water supply and flood protection);

— industrial hydrometry, i.e. the determination of flows within industrial plants and discharges into the natural environment (largely concerned with environment protection and also irrigation).

Both are the subject of international treaties and undertakings. For this reason, measured data is intended to conform to the GUM to assure that results can be compared.

Hydrometry is also concerned with the determination of rainfall, the movement/diffusion of groundwater and the transport by water flow of sediments and solids. This version of the HUG is concerned with flow determination only.

The results from hydrometry are used by other disciplines to regulate and manage the environment. If knowledge is required of biomass, sedimentary material, toxins, etc., the concentration of these components is determined and their uncertainty estimated. The uncertainty of mass-load can then be determined from the uncertainty of flow determination. The components of this calculation are made compatible through compliance with the GUM.

For practitioners of hydrometry and for engineers, the GUM is not a simple document to refer to. The document has been drafted to provide a legal framework for professional metrologists with a working knowledge of statistical methods and their mathematical representation. A helpful document, see Reference [2], is an abbreviated version of the GUM written to be more accessible to engineers and to specialists in fields other than metrology.

The HUG, although simplifying the concepts, in no way conflicts with the principles and methods of the GUM. Accordingly, the HUG interprets the GUM to apply its requirements to hydrometry in a practical way, and, hopefully, in a way accessible to engineers and those responsible for managing the environment.

In addition, the HUG introduces and develops the Monte Carlo Simulation, a complementary technique, which has benefits for hydrometry, insomuch as complex measurement systems can be represented realistically.

The HUG summarizes basic hydrometric methods defined in various technical standards. The HUG develops uncertainty estimation formulae from the GUM for these basic methods. The basic hydrometric methods described in the HUG might not be identical to those recited in the published technical standards. In such cases, the methods described in these standards are to be taken as authoritative. However, clauses in technical standards that concern uncertainty should be adapted to be in accordance with the HUG.

NOTE 1 There is no unified definition of space coordinates within the hydrometric standards. The textbook conventional axes are adopted in this document when describing open channel flow: the x axis being horizontal and positive in the mean flow direction, the y axis being orthogonal to the x axis in the horizontal plane and the z axis being vertical positive.

NOTE 2 For a complete appreciation of the scope of definitions used in measurement uncertainty, the reader is referred to the GUM[1] or to NIST Technical Note 1297[2].

Hydrometric uncertainty guidance (HUG)

1 Scope

This document provides an understanding of the nature of measurement uncertainty and its significance in estimating the "quality" of a measurement or a determination in hydrometry.

This document is applicable to flow measurements in natural and man-made channels. Rainfall measurements are not covered.

2 Normative references

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.

ISO 772, *Hydrometry — Vocabulary and symbols*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

4 Symbols

Symbols	Explanations	Units
α	coefficient representing the effects of non-uniform energy (velocity) in a channel	b
$\gamma_{xx}, \gamma_{xy}, \gamma_{xz}$	angles between boat axes and the x axis	rad
σ	standard deviation	a
$\Delta' x, \Delta' y$	dispersion of measurement from the mean value of the set of x,y measurements for a symmetric distribution: $\Delta' x = 0{,}5(x_{max} - x_{min})$, etc.	a
$\Delta' x^+, \Delta' x^-$	± dispersion about the mean value, $\bar{x}$, for an asymmetric distribution of measurements where $\Delta' x^+ = (x_{max} - \bar{x})$ and $\Delta' x^- = (\bar{x} - x_{min})$	a
Δ	small difference in a measured quantity $\Delta Q, \Delta h, \Delta T$, etc.	a
$\Delta y, \Delta z$	notional small distances in the y and z directions at a cross-section in the channel	m
Dc_2	in the dilution method, the downstream mixed change ($c_m - c_b$) of concentration of the tracer	mg/l
A, $A(z)$, $A(h)$	cross-section area (in the y, z plane) of the flow	m^2

a Dimensional order depends on its meaning in context.

b Non-dimensional quantity.