Australian Government
Bureau of Meteorology

WATER MONITORING
STANDARDISATION
TECHNICAL COMMITTEE

National Industry Guidelines for hydrometric monitoring

PART 4: GAUGING (STATIONARY VELOCITY-AREA METHOD)

NI GL 100.04–2019
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In 2017 and 2018 the Water Monitoring Standardisation Technical Committee (WaMSTeC) led a periodic review of the National Industry Guidelines for hydrometric monitoring. WaMSTeC subcommittees conducted the review process and coordinated extensive industry consultation.

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Foreword

This guideline is part of a series of eleven National Industry Guidelines for hydrometric monitoring. It has been developed in the context of the Bureau of Meteorology's role under the *Water Act 2007* (Cwlth) to enhance understanding of Australia's water resources.

The Bureau of Meteorology first published these guidelines in 2013 as part of a collaborative effort amongst hydrometric monitoring practitioners to establish standardised practice. They cover activities relating to surface water level, discharge and water quality monitoring, groundwater level and water quality monitoring and rainfall monitoring. They contain high level guidance and targets and present non-mandatory Australian industry recommended practice.

The initial versions of these guidelines were endorsed by the Water Information Standards Business Forum (the Forum), a nationally representative committee coordinating and fostering water information standardisation. In 2014, the functions and activities of the Forum transitioned to the Water Monitoring Standardisation Technical Committee (WaMSTeC).

In 2017, as part of the ongoing governance of the guidelines, WaMSTeC initiated a 5-yearly review process to ensure the guidelines remain fit-for-purpose.

These revised guidelines are the result of that review. They now include additional guidance for groundwater monitoring, and other updates which improve the guidelines' currency and relevance. WaMSTeC endorsed these revised guidelines in December 2018.

Industry consultation has been a strong theme throughout development and review of the eleven guidelines. The process has been sponsored by industry leaders and has featured active involvement and support from the Australian Hydrographers Association, which is considered the peak industry representative body in hydrometric monitoring.

These guidelines should be used by all organisations involved in the collection, analysis and reporting of hydrometric information. The application of these guidelines to the development and maintenance of hydrometric programs should help organisations mitigate program under-performance and reduce their exposure to risk.

Organisations that implement these guidelines will need to maintain work practices and procedures that align with guideline requirements. Within the guidelines, the term “shall” indicates a requirement that must be met, and the term “should” indicates a recommendation.

The National Industry Guidelines can be considered living documents. They will continue to be subject to periodic WaMSTeC review at intervals of no greater than five years. In the review phase, WaMSTeC will consider any issues or requests for changes raised by the industry. Ongoing reviews will ensure the guidelines remain technically sound and up to date with technological advancements.

National Industry Guidelines for hydrometric monitoring

This document is one part of the National Industry Guidelines for hydrometric monitoring series, which can be found at http://www.bom.gov.au/water/standards/niGuidelinesHyd.shtml.

The series contains the following parts:

Part 0: Glossary

Part 1: Primary Measured Data

Part 2: Site Establishment and Operations

Part 3: Instrument and Measurement Systems Management

Part 4: Gauging (stationary velocity-area method) *(this guideline)*

Part 5: Data Editing, Estimation and Management

Part 6: Stream Discharge Relationship Development and Maintenance

Part 7: Training

Part 8: Application of Acoustic Doppler Current Profilers to Measure Discharge in Open Channels

Part 9: Application of in-situ Point Acoustic Doppler Velocity Meters for Determining Velocity in Open Channels

Part 10: Application of Point Acoustic Doppler Velocity Meters for Determining Discharge in Open Channels

Part 11: Application of Surface Velocity Methods for Velocity and Open Channel Discharge Measurements

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National Industry Guidelines for hydrometric monitoring Part 4: Gauging (stationary velocity-area method)

1 Scope and general

1.1 Purpose

The purpose of this document is to provide guidelines for recommended practice for the measurement of discharge in open flow channels using current meters.

1.2 Scope

This guideline covers measurement of discharge in open flow channels using current meters.

1.3 Application

This guideline is applicable to non-tidal areas. It can be applied to the following:

a) current meter technologies
   i. rotating element current meters
   ii. acoustic Doppler velocity meters
   iii. electromagnetic velocity meters
   iv. acoustic Doppler current profilers deployed in stationary mode only; and

b) volumetric techniques.

1.4 References

1.4.1 Normative references

The following guidelines contain provisions which, through reference in this text, constitute provisions of this guideline:

1. Bureau of Meteorology 2019, National Industry Guidelines for hydrometric monitoring, *Application of Acoustic Doppler Current Profilers to Measure Discharge in Open Channels*, NI GL100.08–2019.
2. Bureau of Meteorology 2019, National Industry Guidelines for hydrometric monitoring, *Application of in-situ Point Acoustic Doppler Velocity Meters for Determining Velocity in Open Channels*, NI GL100.09–2019.

3. Bureau of Meteorology 2019, National Industry Guidelines for hydrometric monitoring, *Application of Point Acoustic Doppler Velocity Meters for Determining Discharge in Open Channels*, NI GL100.10–2019.

4. International Organization for Standardization, *Hydrometry — Measurement of liquid flow in open channels using current meters or floats*, ISO 748:2007.

5. Standards Australia, *Measurement of water flow in open channels – Measuring devices, instruments and equipment—Rotating element current-meters*, AS 3778.6.1—1992 (same as ISO 2537:1988).

6. Standards Australia, *Measurement of water flow in open channels – Measuring devices, instruments and equipment—Position fixing equipment for hydrometric boats*, AS 3778.6.8—1992 (R2009) (same as ISO 6420:1984).

7. World Meteorological Organization 2008, *Guide to Hydrological Practices*, Volume I: Hydrology – From Measurement to Hydrological Information. WMO-No. 168. Sixth edition, 2008. ISBN 978-92-63-10168-6, viewed 2 October 2018, <http://www.whycos.org/hwrp/guide/index.php>.

8. World Meteorological Organization 2009, *Guide to Hydrological Practices*, Volume II: Management of Water Resources and Application of Hydrological Practices, WMO-No. 168, Sixth edition, 2009, viewed 2 October 2018, <http://www.whycos.org/hwrp/guide/index.php>.

9. World Meteorological Organization 2010, *Manual on Stream Gauging*, Volume I: Fieldwork. WMO-No. 1044, 2010. ISBN 978-92-63-11044-2, viewed 2 October 2018, <http://www.wmo.int/pages/prog/hwrp/manuals.php>.

10. World Meteorological Organization 2010, *Manual on Stream Gauging*, Volume II: Computation of Discharge. WMO-No. 1044, 2010. ISBN 978-92-63-11044-2, viewed 2 October 2018, <http://www.wmo.int/pages/prog/hwrp/manuals.php>.

1.4.2 Bibliography

Cognisance of the following was taken in the preparation of this guideline:

1. Herschy, R. W., 1985, *Streamflow Measurement,* Elsevier Applied Science Publishers, New York, NY, USA.

2. United States Geological Survey 2009, *Flow Meter Quality-Assurance Check – SonTek/YSI FlowTracker Acoustic Doppler Velocimeter*, USA: USGS, USGS OSWTM 2010.02. viewed on 2 October 2018, <http://hydroacoustics.usgs.gov/memos/OSW2010-02.pdf>.

1.5 Definitions

For the purpose of this guideline, the definitions given in National Industry Guidelines for hydrometric monitoring, Part 0: *Glossary,* NI GL 100.00–2019 apply.

2 Safety requirements

All work undertaken for hydrometric projects shall be in accordance with the relevant government work health and safety legislation.

3 Quality assurance

Multiple sources of error exist in any monitoring system and these errors contribute to the overall measurement uncertainty. Continuous improvement efforts should be employed to reduce or eliminate as many sources of error as is realistic. If the overall measurement uncertainty exceeds customer requirements, further investigations shall be undertaken to identify and eliminate sources of error.

4 Overview (generic)

A gauging is a physical measurement of flow in a channel. Discharge is the volume of liquid flowing through a cross section in a unit of time.

Using the velocity area method, discharge equals the cross sectional (wet) area multiplied by mean velocity within the section.

$$Q = A\,\bar{u}$$

where
Q is the discharge
A is the cross sectional (wet) area
$\bar{u}$ is the mean flow velocity.

Gaugings are undertaken over a period of time and across all flow ranges where practicable to define the stage-discharge relationship (rating) at a site. This enables conversion of continuous river level data to continuous flow rate for the site. Sufficient gaugings must be undertaken to adequately define the discharge rating, and to maintain currency.

5 Selecting the site and flow conditions

5.1 Gauging location (generic)

The following site conditions should be considered when selecting a suitable gauging location:

- site safety and risks
- access to site (e.g., rocky, overgrown)
- depth and distance across at the section (e.g., sufficient depth for meter, too deep, too wide)
- proximity to monitoring site (e.g., consideration of inflow and outflow at the gauge pool).

5.2 Selecting the flow conditions (generic)

Site selection shall comply with Clause 5.1 of ISO 748:2007 *Hydrometry — Measurement of liquid flow in open channels using current meters or floats*.

Where possible, measurements shall be taken under ideal flow conditions. Ideal flow conditions have a steady unchanging level (depth of flow) during the gauging period, and with no wave activity. Sites where the following is occurring should be avoided:

1. Water surface wave action – sites with standing waves or moving waves (e.g. rapids) on the water surface, should be avoided, and a better location chosen if possible.
2. The water level (depth) changes during the gauging period – flow conditions with rapidly changing levels should be avoided, because the final calculated discharge cannot be readily assigned to a known level.

Where flow conditions are not ideal, the following applies:

> Where measurements of the depths are made separately from the velocity measurements and the water level is not steady, the water level shall be observed at the time of each measurement of the depth. When this is not possible, the water level shall be observed at sufficient intervals for the value of the level at the time of each determination of depth to be obtained by interpolation.
>
> *[Source: ISO 748:2007]* [1]

Comments relating to site conditions shall be recorded with the data.

6 Gauging by area/velocity method

Gauging is completed by measuring the depth and water velocity of the stream at multiple points across the stream at the gauging location.

6.1 Depth

Measurements of water depth (soundings) are taken at chosen positions (verticals) across the stream to allow the determination of the cross-sectional area of the stream.

Clause 6.3.1 of ISO 748:2007 *Hydrometry — Measurement of liquid flow in open channels using current meters or floats* applies:

> Measurement of depth shall be made at intervals close enough to define the cross-sectional profile accurately. The number of points at which depth shall be measured should be the same as the number of points at which velocity is measured.[2]

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[1] Source: ISO 748:2007 Clause 6.3.4. © Standards Australia Limited. Copied by the Australian Government Bureau of Meteorology with the permission of Standards Australia and Standards New Zealand under Licence 1901-c052.

[2] Source: ISO 748:2007 Clause 6.3.1. © Standards Australia Limited. Copied by the Australian Government Bureau of Meteorology with the permission of Standards Australia and Standards New Zealand under Licence 1901-c052.

6.2 Velocity

6.2.1 Determination of mean velocity in a vertical

The choice of method for determining the mean velocity in a vertical is based on the methods described in Clause 7.1.5 of ISO 748:2007 *Hydrometry — Measurement of liquid flow in open channels using current meters or floats*. These methods are classified as follows:

a) velocity distribution method (see 7.1.5.2);

b) reduced point methods (see 7.1.5.3); and

c) integration method (see 7.1.5.4).

The organisation shall undertake actions to ensure that the choice of method for determining the mean velocity in a vertical is in accordance with the customer's requirements and required confidence limits of derived flow.

Reduced point methods, whilst less strict than methods exploring the entire field of velocity, are used frequently because they require less time than the velocity-distribution method. They are based, however, on theoretical velocity profiles.

Clause 7.1.5.3.1 of ISO 748:2007 *Hydrometry — Measurement of liquid flow in open channels using current meters or floats* recommends:

> …for a new gauging section the accuracy of the selected method be assessed by comparing the results of preliminary gaugings with those obtained from the velocity distribution method.[3]

For reduced point methods, the mean velocity in a vertical is based on the point velocity measurement performed within the vertical. The mean velocity is determined from the established methods as described in ISO 748:2007 *Hydrometry — Measurement of liquid flow in open channels using current meters or floats* and the calculation is based on the formula summarised in Table 1.

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3 Source: ISO 748:2007 Clause 7.1.5.3.1. © Standards Australia Limited. Copied by the Australian Government Bureau of Meteorology with the permission of Standards Australia and Standards New Zealand under Licence 1901-c052.

Table 1 – Mean velocity determination

Reduced point method	Mean velocity
Two point	$v_{mean} = \frac{V_{0.2d} + V_{0.8d}}{2}$
Six-tenths depth	$v_{mean} = V_{0.6d}$
Two-tenths depth	$v_{mean} = 0.87V_{0.2d}$
Three point	$v_{mean} = \frac{V_{0.2d} + 2V_{0.6d} + V_{0.8d}}{4}$ When more weight to the 0.2 and 0.8 depth observations is desired:- $v_{mean} = \frac{V_{0.2d} + V_{0.6d} + V_{0.8d}}{3}$
Five point	$v_{mean} = \frac{V_{surface} + 2V_{0.2d} + 3V_{0.6d} + 3V_{0.8d} + V_{bottom}}{10}$
Six point	$v_{mean} = \frac{V_{surface} + 2V_{0.2d} + 2V_{0.4d} + 2V_{0.6d} + 2V_{0.8d} + V_{bottom}}{10}$

In using the reduced point methods, the recommended option is the two point method.

Extensive field studies and mathematical analysis indicate that the two point method gives the most accurate and consistent results from all the methods, except the velocity distribution method as documented in Clause 5.4.2 of WMO-No. 1044, Volume I (2010).

The following limitations of the two point method should be considered:

1. Depth of water:
    - Rotating element meters require a minimum depth > 0.75m to avoid interference from the water surface and streambed. No part of the meter shall break the surface of the water.
    - Point acoustic Doppler velocity meters (PVMs) will have stated minimum depth limits and should be used with caution at shallow depths. Solid boundaries, such as submerged rocks, included within or near the sampling volume will cause the velocity to be biased low.

    The one point method (0.6 depth) should be used in shallower streams.
2. Distortion of vertical velocity distribution caused by overhanging vegetation and/or submerged objects. Where these conditions are present, an additional velocity observation (0.6 depth) should be made.
3. Time constraint due to rapidly changing stage or other factors. The one point method (0.6 depth) should be used in this case.

4. Ice/debris at the surface, which may make the shallower depth measurements associated with the two point method difficult to obtain. The one point method (0.6 depth) should be used in this case.

6.2.1.1 Oblique flow

The gauging section should be aligned perpendicular to the flow direction. Oblique flows should be avoided as much as practical, as outlined in Clause 7.1.4 of ISO 748:2007 *Hydrometry — Measurement of liquid flow in open channels using current meters or floats*.

Some propeller type and acoustic Doppler velocity meters compensate for oblique flows while others will require the manual vector calculation (cos) of the velocity. These characteristics of each meter should be understood by field operators.

6.2.2 Number of verticals

The selection of the number of verticals required within a cross section is based on the criteria described in Clause 7.1.3 of ISO 748:2007 *Hydrometry — Measurement of liquid flow in open channels using current meters or floats* that states:

> In judging the specific number *n* of verticals that are to be defined for the purpose of gauging stream flow at a particular location, the following criteria shall be applied. These criteria shall be the minimum requirement and only practical constraints of time, costs, or on site conditions should result in a reduction of these numbers.

Channel width < 0.5 m	***n* = 5 to 6**
Channel width > 0.5 m and < 1 m	***n* = 6 to 7**
Channel width > 1 m and < 3 m	***n* = 7 to 12**
Channel width > 3 m and < 5 m	***n* = 13 to 16**
Channel width > 5 m	***n* ≥ 22**

> For channel widths > 5 m, the number of verticals shall be chosen so that the discharge in each segment is less than 5% of the total, insofar as possible, and that in no case should exceed 10%.[4]

Any reduction of verticals will reduce the veracity and quality of results.

6.2.3 Exposure time

The velocity at each selected point shall be observed by exposing a current meter for a minimum of 30 seconds.

This is also the minimum exposure time stipulated in ISO 748:2007 *Hydrometry — Measurement of liquid flow in open channels using current meters or floats.*

In most organisations exposure times of 40, 50 or 60 seconds are normally used for a point velocity measurement. Field experience has shown that increasing the exposure

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4 Source: ISO 748:2007 Clause 7.1.3. © Standards Australia Limited. Copied by the Australian Government Bureau of Meteorology with the permission of Standards Australia and Standards New Zealand under Licence 1901-c052.

time and overall measurement time will reduce anomalies caused by system and local site interferences.

6.2.4 Errors and limitations

The possible causes of gauging errors are outlined in Clause 7.1.6 of ISO 748:2007 *Hydrometry — Measurement of liquid flow in open channels using current meters or floats.*

6.3 Computation of discharge

The organisation shall determine the discharge computation method to be used. The various methods are detailed in Section 8 of ISO 748:2007 *Hydrometry — Measurement of liquid flow in open channels using current meters or floats.*

6.4 Discharge result uncertainty

The key to minimising uncertainty in discharge measurements is to ensure that operating staff have the required level of training and experience to adhere to correct operational procedures and accurately process data, quantifying all introduced sources of measurement uncertainty.

The organisation should calculate the uncertainty in discharge measurement, as detailed in Section 9 of ISO 748:2007 *Hydrometry — Measurement of liquid flow in open channels using current meters or floats.*

6.5 Discharge result validity

Additional stream discharge measurements during gauging processes at a site provide greater statistical confidence in the actual discharge measured at that point of time and hence greater confidence in subsequent discharge relationship development or review processes.

Taking an additional discharge measurement may not always be practical at the time due to time limitations, safety, customer requirements, etc.

Undertaking additional stream discharge measurements may be triggered by:

- initial discharge result outside expected deviations from rating;
- stream flow conditions not ideal for measurement as defined in the various parts of AS 3778 and ISO 748 listed in 1.4.1 Normative References, or elsewhere in these guidelines;
- change in stream flow conditions at the site (e.g., changing stage, external influences); and
- customer defined requirements.

In some instances, conducting additional gaugings concurrently may provide benefits through immediate validation of stream discharge results as long as the concurrent gauging does not interfere or create disturbance with stream flow lines in the section being used by the other stream gauging. Ideally, an additional gauging should be made at a different section, using different equipment and operators.

An organisation shall prepare a procedure describing the conditions where additional stream discharge measurements are required. These may be further defined on a site specific basis, streamflow specific basis or any other variable specification e.g., establishing missing segments of a stage-discharge relationship, establishing new stage-discharge relationship, deviations from expected results, and similar.

6.6 Calibration of velocity meters

Current meters and velocity meters used for undertaking velocity area method gaugings shall be calibrated in accordance with AS 3778.6.1—1992.

Validation of acoustic point velocity meters shall be carried out in accordance with National Industry Guidelines for hydrometric monitoring, Part 9: *Application of in-situ Point Acoustic Doppler Velocity Meters for Determining Velocity in Open Channels*, NI GL 100.09–2019, section 3.2.

Organisations shall maintain calibration and spot check records as part of their procedures.

Appendix A Training

A.1 Training session outline

LEARNING ELEMENTS	RESOURCES	DESCRIPTION	
Identify and understand the 1.1 Purpose, 1.2 Scope and 1.3 Application of this guideline	Copies of all guidelines documents. Access to all reference material.	Discussion with reference to the guidelines document	Face to face delivery
2 Safety requirements	Copies of all guidelines documents. Access to all reference material.	Discussion with reference to the guidelines document	Face to face delivery
3 Quality assurance	Copies of all guidelines documents. Access to all reference material.	Discussion with reference to the guidelines document	Face to face delivery
4 Overview (generic)	Copies of all guidelines documents. Access to all reference material.	Using the text from the guideline explain the terms: gauging discharge relationship.	Face to face delivery
5 Selecting the site and flow conditions 5.1 Gauging location (generic) 5.2 Selecting the flow conditions (generic)	Copies of all guidelines documents. Access to all reference material.	Using the text from the guideline provide an explanation considerations when selecting a gauging location.	Face to face delivery
6 Gauging by area/velocity method 6.1 Depth	Copies of all guidelines documents. Access to all reference material.	Provide an explanation of depth measurement.	Face to face delivery

LEARNING ELEMENTS	RESOURCES	DESCRIPTION	
6.2 Velocity 6.2.1 Determination of mean velocity in a vertical 6.2.2 Number of verticals 6.2.3 Exposure time 6.2.4 Errors and limitations	Copies of all guidelines documents. Access to all reference material.	Provide an explanation of “soundings” and “verticals”. Explain the methods for determining mean velocity, and the number of verticals that are to be measured. Discuss limitations of the two point method. Explain the location of the verticals. Explain how position a current meter in relation to flow. Number of gaugings with respect to deviation. Documentation of flow conditions etc.	Face to face delivery
6.3 Computation of discharge	Copies of all guidelines documents. Access to all reference material.	Discuss the discharge computation methods in ISO 748:2007.	Face to face delivery
6.4 Discharge result uncertainty	Copies of all guidelines documents. Access to all reference material.	Discuss the methods of calculating uncertainty in discharge measurements in ISO 748:2007.	Face to face delivery
6.5 Discharge result validity	Copies of all guidelines documents. Access to all reference material.	Explain the requirement to develop procedures and work instructions for additional gaugings.	Face to face delivery
6.6 Calibration of velocity meters	Copies of all guidelines documents. Access to all reference material.	Describe calibration recording. Provide reference information for each piece of equipment used.	Face to face delivery
1.4.1 Normative references	Copies of all guidelines documents.	Trainers to ensure the learner’s ability to source and use reference material.	Face to face delivery

A.2 Training learning resources

A.2.1 Introduction

Welcome to the learner resource for National Industry Guidelines for hydrometric monitoring, Part 4: *Gauging (stationary velocity−area method)*, NI GL 100.04–2019. The purpose of this resource is to develop your knowledge and skills and improve your competency in this guideline.

A.2.2 Section references

The table below shows elements of the guideline that are covered in this Learner Resource. This may help the learner to map their progress as they work their way through this resource.

Section	Unit element
1 Scope and general	1.1 Purpose 1.2 Scope 1.3 Application 1.5 Definitions
2 Safety requirements	
3 Quality assurance	
4 Overview (generic)	
5 Selecting the site and flow conditions	Provide an overview of the reasons for gaugings and the location of gauging sites. 5.1 Gauging location (generic) 5.2 Selecting the flow conditions (generic)
6 Gauging by area/velocity method	6.1 Depth 6.2 Velocity 6.3 Computation of discharge 6.4 Discharge result uncertainty 6.5 Discharge result validity 6.6 Calibration of velocity meters
1.4.1 Normative references	

A.2.3 Who needs this competency?

This learning material covers the skills and knowledge required for a person to use and understand National Industry Guidelines for hydrometric monitoring, Part 4: *Gauging (stationary velocity–area method)*, NI GL 100.04–2019.

A.2.4 Learning outcomes

At the completion of this learner resource you will be competent in the following:

- use the guideline document for reference
- use the guideline in day to day operations

- access the material referenced in the guideline document
- use and understand related internal procedures and work instructions.

A.2.5 Health and safety considerations

Health and safety legislation shall always be considered when implementing National Industry Guidelines, workplace procedures and work instructions.

Employees carrying out work related to the National Industry Guidelines should be adequately trained in all relevant health and safety matters.

A.2.6 Environmental considerations

Compliance with this guideline may involve working in the environment. As such care should be taken to:

- prevent unnecessary damage to the site environment
- prevent unnecessary disturbance of the natural environment
- carefully construct any infrastructure to minimise impacts on the environment and river flow conditions
- plan access roads to sites to minimise impacts during all seasonal conditions.

A.2.7 What resources will I need?

- Workplace policies and procedures
- Manufacturer manuals, requirements and specifications
- Codes of practice
- Workplace equipment, tools and instruments
- Workplace reports
- Workplace maps, plans and instructions
- Permits and access to locations and worksites

Other useful resources

- Relevant Health and Safety Act
- Safe Work Australia Model Codes of Practice
- Organisations procedures and work instructions
- Australian Standards