Australian Government
Bureau of Meteorology

WATER MONITORING STANDARDISATION TECHNICAL COMMITTEE

National Industry Guidelines for hydrometric monitoring

PART 10: APPLICATION OF POINT ACOUSTIC DOPPLER VELOCITY METERS FOR DETERMINING DISCHARGE IN OPEN CHANNELS

NI GL 100.10–2019
February 2019

Acknowledgements

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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.

2018 review subcommittee members:

Mark Randall (sponsor), Queensland Government, Department of Natural Resources, Mines and Energy

Mark Woodward, Queensland Government, Department of Natural Resources, Mines and Energy

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(Note that at the time of contribution, individuals may have been employed with different organisations and some organisations were known by other names).

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)

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 *(this guideline)*

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

1 Scope and general

1.1 Purpose

The objective of this document is to provide guidelines for recommended practice to ensure that the collected measured streamflow data are:

a) accurate;
b) defendable; and
c) consistent across water monitoring organisations operating under these guidelines.

This is the minimum guideline that shall be followed to allow the collected data to withstand independent validation and data integrity checks. Additional field procedures may vary between organisations and States.

1.2 Scope

This document deals with the use of point acoustic Doppler velocity meters (PVMs) for determining streamflow in open channels. It specifies the required procedures and methods for collecting data by Australian operators, training of operators and the treatment of uncertainty of measurements. It specifies procedures for the collection and processing of surface water velocity data collected by PVMs.

This document does not include or rewrite instrument manufacturers' operating instructions for their individual instruments. Nor does it detail Standard Operating Procedure's (SOPs) of organisations using these instruments. However, it is expected that those SOPs are sufficiently robust to withstand independent scrutiny.

This document contains images and examples sourced from instrument manufacturers or suppliers. Inclusion of these images, with reference to the source, is solely for the purpose of providing examples, additional information and context, and is not to be interpreted as endorsement of any particular proprietary products or services.

1.3 References

1.3.1 Normative reference

The following standard contains provisions which, through reference in this text, constitute provisions of this guideline:

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

1.3.2 Informative references

The following are referenced for information in this guideline:

- International Organization for Standardization/Technical Report 2012, *Hydrometry – Acoustic Doppler profiler – Method and application for measurement of flow in open channels*, ISO/TR 24578:2012.
- International Organization for Standardization/International Electrotechnical Commission 2009, *Uncertainty of measurement – Part 1: Introduction to the expression of uncertainty in measurement*, ISO/IEC Guide 98-1:2009.
- International Organization for Standardization/International Electrotechnical Commission 2008, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement*, ISO/IEC Guide 98-3:2008.
- International Organization for Standardization 2007*, Hydrometric uncertainty guidance (HUG)*, ISO/TS 25377:2007.
- International Organization for Standardization 2005*, Measurement of fluid flow – Procedures for the evaluation of uncertainties*, ISO 5168:2005.
- Mueller, D.S., Wagner, C.R., 2009, *Measuring discharge with acoustic Doppler current profilers from a moving boat*, U.S. Geological Survey Techniques and Methods 3A–22, viewed 2 October 2018, <http://pubs.usgs.gov/tm/3a22/>.

1.4 Bibliography

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

- OTT Hydrometry, 2013, *Acoustic Digital Current (ADC) Meter*, 10.500.001.B.U, OTT Hydromet GmbH, Kempton.
- Sontek/YSI Inc, 2007, *Flow Tracker Handheld ADV Technical manual*, San Diego.
- United States Geological Survey, Office of Surface Water technical memorandum, 2010, *FlowTracker Diagnostic test policy*, viewed 2 October 2018, <http://hydroacoustics.usgs.gov/memos/OSW2010-06.pdf>.
- Wagner, D., 2010, USGS Hydroacoustics Webinar: *Acoustic Digital Current Meter: Description of meter and results of USGS testing*, viewed 2 October 2018, <http://hydroacoustics.usgs.gov/training/webinars.shtml>.

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 Point Velocity Meters

Hand held PVMs are essentially acoustic versions of the traditional mechanical current meter. PVMs use converging beams to measure the velocity of a small sample volume of flow. There are currently two variations of the PVM, the acoustic digital current meter (ADC) and the acoustic Doppler velocimeter (ADV).

The sampling methodology, site selection criteria, and discharge calculation methods applied to undertaking a traditional current meter gauging also apply to the ADC and ADV. These guidelines and operational standards are outlined in ISO 748 for current meter measurements and shall be followed.

The manufacturer's instructions shall also be consulted and applied for specific instrument operational instructions and tolerances.

2.1 Acoustic Digital Current Meter (ADC)

The ADC uses two acoustic transducers which act as both transmitters and receivers; this provides the ADC with two sampling volumes located 10 cm in front of the transducers. The ADC measures velocity in the following manner:

1. An ultrasonic burst is sent into the water from beam 1 and beam 2 in unison.
2. The particles in the measurement path reflect a small amount of the ultrasonic signal.
3. The multitude of the reflected signals result in the generation of a reflection pattern which is then saved to the digital signal processor (DSP).
4. After a certain amount of time a second burst is sent into the water.
5. A second reflection pattern is generated. This pattern is distorted due to slightly different reflections. This is because some particles have been turning around and have another reflection or some particles are no longer in the measurement range.
6. The DSP checks both received reflection patterns for similarities using the cross-correlation method.
7. All existing signal differences are rejected so that two similar but offset signal patterns are left for velocity evaluation via a calculation of time shift.

2.2 Acoustic Doppler Velocimeter (ADV)

The ADV is a bistatic Doppler and operates along traditional Doppler principles. An acoustic ping is emitted from a centrally mounted transducer, acoustic receiver transducers mounted on arms are focused on a sample point located 10 cm to the side of the mount. The transmitter generates a ping at a known frequency which is scattered as it passes through the sampling point. The receivers sample the reflected signal (backscatter) and the change in frequency for each receiver is then measured.

The Doppler shift along the bistatic axis of the receiver and transmitter is proportional to the velocity of the water. As the unit knows the orientation of the axis it is able to calculate velocity.

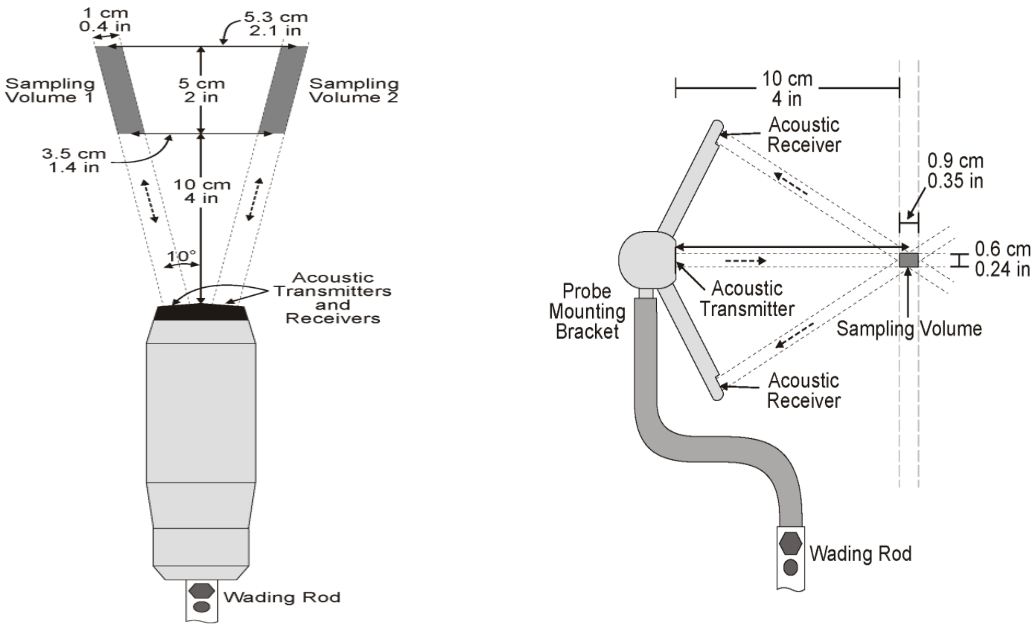

Figure 1. An illustration of the ADC (left), and ADV (right) point velocity meters
(Source: USGS, Wagner, D., 2010)

2.3 Hand held point velocity meter QA/QC

The ADV and ADC both have inbuilt QA/QC diagnostic programs that check that the transducers are operating within the manufacturer's specifications which are based on ISO operating standards. The following system checks shall be undertaken and recorded in the instrument management file:

1. The quality assigned to a PVM measurement should be assigned on the same basis and criteria as a conventional current meter wading measurement.
2. A unit failing any internal QA check shall be returned to the manufacturer for repair and not used for discharge measurements.

3 Instrument management

Each organisation should have its own office ADCP management record that contains instrument specific records containing details of:

1. The person making the entry with details of the work carried out. In the case of manufacturer servicing the details of work done, and a copy of the maintenance report from the service provider.

2. Time and date of the entry.
3. All calibration and operational checks carried out.
4. Installed software/firmware and/or relevant programs/modes that control the operation of the instrument.

Organisations may also choose to record other relevant information.

3.1 Instrument maintenance

Each organisation should have a maintenance schedule set in place and recorded in the PVM management record. These maintenance procedures should be in accordance with the PVM manufacturer's guidelines.

PVM units shall be inspected before each field deployment with more detailed checks carried out on an annual basis for data quality control purposes. Any PVM demonstrating maintenance issues that could compromise data integrity shall not be used to record streamflow data.

Each organisation shall have instrument maintenance and servicing requirements identified in their SOPs based on manufacturers' specifications and recommendations.

3.2 Instrument tests

PVMs should be periodically tested to ensure the validity of the data recorded by the following methods:

1. Operating the instrument at a site with a stable and verifiable velocity structure such as a control weir, or tow tank (if available).
2. Each of the following shall apply when in the field:
   a) Compare the PVM reported water depth from the pressure sensor (if fitted), with actual measured depth from a calibrated pressure transducer or wading rod.
   b) Compare the temperature reported by the PVM thermistor with a measured stream temperature. The PVM measured temperature should be within 2°C of an independent calibrated measuring device. The temperature difference shall be recorded in the measurement quality documentation. A 5°C difference in temperature results in a 2% bias error in the measured discharge (*Mueller et al, 2009*). If the ADCP temperature is less than the independently measured temperature, the bias introduced will be negative. Conversely, if the ADCP temperature is more than the independently measured temperature, the bias introduced will be positive.
   c) Measure electrical conductivity at the transducer face and enter the value (as parts per thousand) within the measurement software when operating in environments where the salinity may differ from that of freshwater. Where the PVM does not support software entry, post processing of the discharge measurement should be undertaken.

      NOTE: A salinity change of 12 parts per thousand (PPT) equates to a 1% bias error in the speed of sound calculation and a 2% error in the velocity calculation. Freshwater is 0 PPT and sea water is 30-35 PPT. If the salinity entered is less than the independently measured salinity, the bias introduced will be negative. Subsequently if the salinity entered is more than the independently measured salinity, the bias introduced will positive.

The PVM uses these three reference measurements to calculate the stage area and speed of sound calculations used to calculate velocity and discharge. Any error in the PVM's ability to accurately measure these variables is transferred to the discharge calculation.

3. Where a PVM possesses an internal diagnostic check, it shall be run in accordance with the manufacturer's guidelines. This diagnostic check verifies that the PVM is functioning correctly and will issue a 'pass' or 'fail' to that unit.

Any PVM that tests outside the operational error specifications as stated by the manufacturer shall not be used for measuring stream velocity. Appropriate defect management processes shall be implemented to resolve the failure.

3.3 Firmware and software upgrades

Software and firmware upgrades shall be installed as recommended by the PVM manufacturer. All firmware upgrades shall be recorded in the PVM instrument records.

4 Operating personnel

The integrity of PVM data is determined by the experience of the operator. Operating personnel should therefore have completed training that covers the deployment of PVM and the principles of gauging measurements. This training should be specific to the brand of PVM unit and the associated software that will be used to process the data. Training should be sought from the PVM manufacturer or an independent training provider.

PVM data shall not be collected without a trained operator present.

Post processed data shall be reviewed by a trained operator before the data is archived.

PVM technology is continually evolving and users should remain up to date on software updates, improvements to the equipment, and changes in recommended operational methodologies.

Refresher training for field deployment, data collection, processing, and quality control should also be made available.

5 Measurement uncertainties

The following information regarding hydrometric and discharge measurement uncertainties has been sourced from ISO/TR 24578:2012 which makes reference to ISO 5168, ISO/TS 25377, ISO/IEC 98-1 and ISO/IEC 98-3. It is the responsibility of the operator to refer to the original documents for future ISO updates on measurement uncertainties.

5.1 Description of measurement uncertainty

All measurements of a physical quantity are subject to uncertainties and therefore the result of a measurement is only an estimate of the true value and only complete when accompanied by a statement of its uncertainty. The discrepancy between the true value and the measured value is the measurement error which is a combination of component errors that arise during the performance of the various elementary operations of the measurement process.

When a measurement depends on several component qualities then the total measurement error is a combination of all the component errors. Therefore, the determination of a measurement's uncertainty is a combination of all the identified component measurement errors, quantification of their corresponding uncertainties and then a combination of those component uncertainties.

The component uncertainties are combined in a manner that accounts for both systematic and random errors and are termed standard uncertainties which correspond to one standard deviation of the probability distribution of measurement errors. One standard deviation equates to a confidence level of 68%. The uncertainty at two standard deviations is twice the standard uncertainty which if estimated can be multiplied by two to obtain the uncertainty at two standard deviations, or 95% confidence level. The multiplication factor is termed as the coverage factor therefore if the uncertainty is expressed at three standard deviations the coverage factor would be three and represent a confidence level of 99%.

When stating uncertainties in the confidence level or the coverage factor i.e. the number of standard deviations shall be stated.

NOTE: For example, if a discharge measurement of 50 cumecs had an uncertainty of 9% at the 95% confidence level the statement of uncertainty should be documented as follows:

Discharge = 50 m^3s^{-1} with an uncertainty of 9% at the 95% confidence level based on a coverage factor of k=2.

5.2 Estimating the uncertainty in a PVM discharge determination

PVMs calculate streamflow by measuring velocity and area. Therefore, the accuracy of a PVM is dependent on how it is set up and how it is operated. PVM manufacturers provide potential values of error within their technical specifications for the PVM sensors. These error values are for the measured velocity of the reflective particles in the sampled section of the water column not for the accuracy of the streamflow measurement. Further points of introduced error occur from:

1. Depth measurement – Depth is an important factor within the streamflow calculation therefore the accuracy and sensitivity of the depth measurement is very important.
2. Thermistor – The speed of sound calculations required to calculate velocities are greatly affected by changes in temperature.
3. Salinity – As with temperature, salinity can affect the speed of sound calculations.
4. Determination of the cross-sectional area.

The key to minimising uncertainty in PVM measurements is to ensure that the operating staff have the required level of training and experience to ensure that the correct operational procedures are adhered to and that the data is accurately processed to quantify all introduced sources of uncertainty. Field procedures should be implemented according to the environmental conditions encountered at the measurement site. All equipment shall be checked regularly to identify any potential sources of error that could be introduced to a measurement. These checks shall be documented to demonstrate due diligence. Refer to Appendix A for an example of a PVM measurement review.

Appendix A PVM measurement review

The information in this appendix is an interpretation of ISO 748 with respect to PVM application, provided by Mark Randall and Mark Woodward, Queensland Government Department of Natural Resources, Mines and Energy. It is included as an example of PVM quality assurance procedures.

Quality assurance

General

- Staff shall ensure that wading discharge measurements are consistent with this method.
- All discharge measurements are to be accompanied by a completed form. Metadata from this is entered directly into the Water Accounting System and hardcopies are kept in a gauging's book for validation and auditing purposes.

Accuracy and quality of measurements

Many conditions can affect the accuracy of a gauging and therefore downgrade the quality of that gauging. It is important that staff accurately quality code all measurements.

The following bullet points describe a number of examples where gauging accuracy can be compromised. Figures 2, 3 and 4 show examples of 'good', 'fair' and 'poor' gaugings.

- Gauging section selection - Finding an ideal gauging section may be near impossible in some locations. The quality of the gauging would be downgraded if:
    - all or part of the flow is at an angle >10° to the gauging section (even if an angle correction is applied)
    - eddies, vortices, reverse flow, funnelling, contraction, and/or turbulence are present
    - horizontal velocity distribution is erratic
    - stream beds and banks are rocky, irregular or mobile.
- Number of verticals and percent discharge per interval – an ideal gauging would have at least 20 intervals and less than 5% discharge in each interval (and definitely less than 10%). Doppler velocimeters will often display the percent discharge per interval. The operator should check this before they close the measurement and add intervals if necessary to bring the percent discharge to less than 10%.
- Where discharge in any interval is above 10% – the quality should be downgraded.
- Operator input and/or errors – the operator may be forced to make decisions on how the gauging is undertaken and may unintentionally allow errors to enter the gauging. Common errors, omissions or decisions that will downgrade the measurement include:
    - using the one point method instead of two point – grass or weeds on the bed may preclude the use of the two point method
    - change in velocity observation time – an operator may choose (sometimes accidently) to observe the velocity for a shorter period (30 seconds) if stage is changing rapidly.

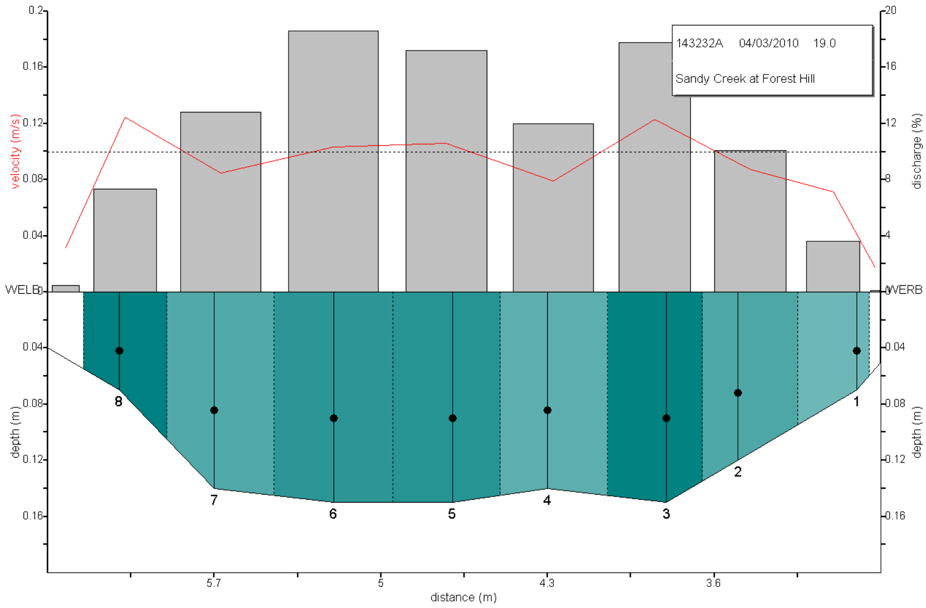

Figure 2. Example of a poor quality PVM gauging. The measurement contains very few verticals resulting in most intervals containing >10% discharge

(Credit: Mark Woodward, Queensland Government Department of Natural Resources, Mines & Energy)

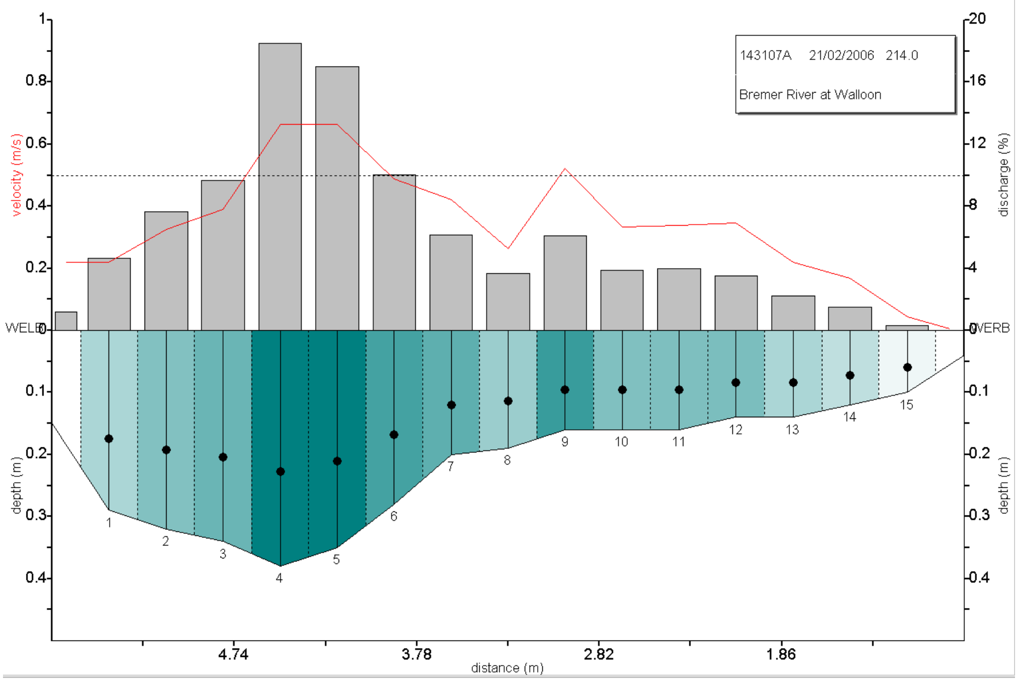

Figure 3. Example of a fair quality PVM gauging – the velocity distribution is slightly irregular, and a number of intervals are over 10%

(Credit: Mark Woodward, Queensland Government Department of Natural Resources, Mines & Energy)

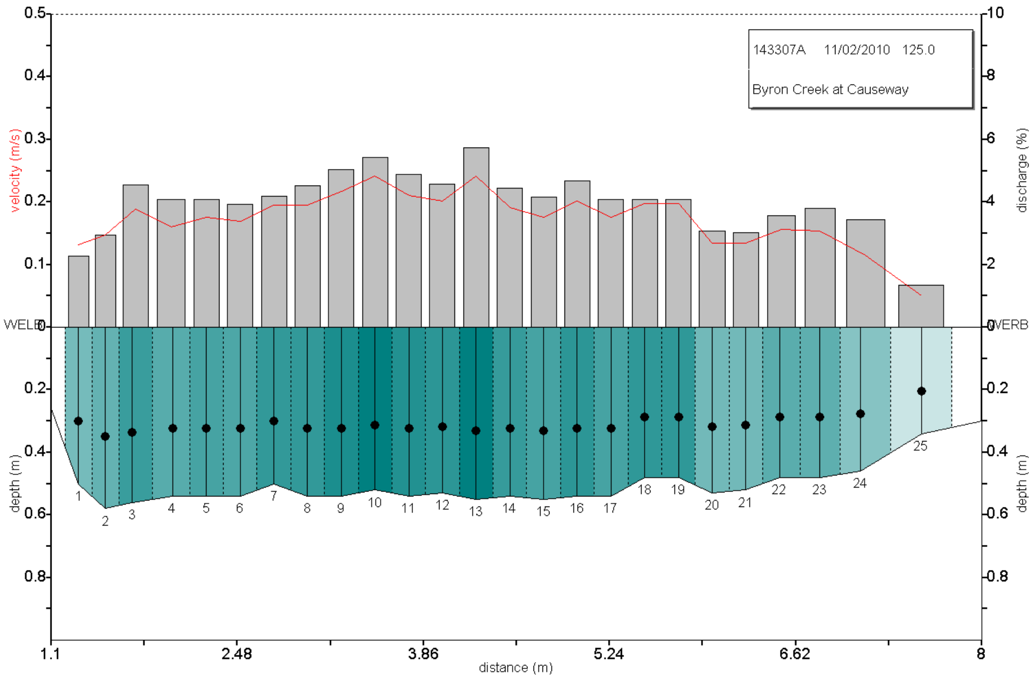

Figure 4. Example of a good quality gauging – there is a fairly uniform velocity distribution, regular bed and bank shape, and most subsection discharges are less than 5%
(Credit: Mark Woodward Queensland Government Department of Natural Resources, Mines & Energy)

Appendix B Training

B.1 Training session outline

LEARNING ELEMENTS	RESOURCES	DESCRIPTION	
Identify and understand the 1.1 Purpose and 1.2 Scope of this guideline	Copies of all guidelines and definitions documents. Access to all reference material.	Explain the purpose of the procedural guideline for point acoustic Doppler velocity meters. Outline its scope.	Face to face delivery
2 Point Velocity Meters	Copies of all guidelines and definitions documents. Access to all reference material.	i) Identify two kinds of PVM: ADC and ADV. ii) Identify standards for their use.	Face to face delivery
2.1 Acoustic Digital Current Meter	Copies of all guidelines and definitions documents. Access to all reference	Explain how an ADC measures water velocity.	Face to face delivery
2.2 Acoustic Doppler Velocimeter (ADV)	Copies of all guidelines and definitions documents. Access to all reference material.	Explain how an ADV measures water velocity.	Face to face delivery
2.3 Hand held point velocity meter QA/QC	Copies of all guidelines and definitions documents. Access to all reference	Discuss the internal quality checks built into hand held ADC's and ADV's.	Face to face delivery
3 Instrument management	Copies of all guidelines and definitions documents. Access to all reference material.	Address instrument management records.	Face to face delivery
3.1 Instrument maintenance	Copies of all guidelines and definitions documents. Access to all reference material.	Address instrument maintenance and effect on data integrity.	Face to face delivery
3.2 Instrument tests	Copies of all guidelines and definitions documents. Access to all reference material.	Explain instrument testing by checking against a known velocity structure, depth and temperature.	Face to face delivery

LEARNING ELEMENTS	RESOURCES	DESCRIPTION	
3.3 Firmware and software upgrades	Copies of all guidelines and definitions documents. Access to all reference material.	Discuss firmware and software upgrades and records.	Face to face delivery
4 Operating personnel	Copies of all guidelines and definitions documents. Access to all reference material.	Discuss training of PVM operating personnel, data processing and technology evolution.	Face to face delivery
5 Measurement uncertainties	Copies of all guidelines and definitions documents. Access to all reference material.	Identify international standards for hydrometric discharge measurement uncertainty.	Face to face delivery
5.1 Description of measurement uncertainty	Copies of all guidelines and definitions documents. Access to all reference material.	Explain the uncertainty of measurement of physical quantities and the level of confidence in recorded and calculated values.	Face to face delivery
5.2 Estimating the uncertainty in a PVM discharge determination	Copies of all guidelines and definitions documents. Access to all reference material.	Give examples of sources of uncertainty in estimating ADVM discharge determination. Discuss use and maintenance for error minimisation.	Face to face delivery
Appendix A PVM measurement review	Copies of all guidelines and definitions documents. Access to all reference material.	Discuss PVM quality assurance procedures.	Face to face delivery

B.2 Training learning resources

B.2.1 Introduction

Welcome to the learner resource for National Industry Guidelines for hydrometric monitoring, Part 10: *Application of Point Acoustic Doppler Velocity Meters for Determining Discharge in Open Channels*, NI GL 100.10–2019. The purpose of this resource is to develop your knowledge and skills and improve your competency in this guideline.

B.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
2 Point Velocity Meters	2 Point Velocity Meters 2.1 Acoustic Digital Current Meter 2.2 Acoustic Doppler Velocimeter (ADV) 2.3 Hand held point velocity meter QA/QC
3 Instrument management	3.1 Instrument maintenance 3.2 Instrument tests 3.3 Firmware and software upgrades
4 Operating personnel	4 Operating personnel
5 Measurement uncertainties	5 Measurement uncertainties 5.1 Description of measurement uncertainty 5.2 Estimating the uncertainty in a PVM discharge determination
Appendix A PVM measurement review	Appendix A PVM measurement review

B.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 10: *Application of Point Acoustic Doppler Velocity Meters for Determining Discharge in Open Channels*, NI GL 100.10–2019.

B.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

- understand procedural standards for using acoustic instruments to gather water data
- use and understand related internal procedures and work instructions.

B.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.

B.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 river banks
- prevent unnecessary disturbance of the river system
- 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.

B.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
- Manufacturer's instruction manuals
- Organisation's procedures and work instructions
- Herschy, Reginald W. (1985), *Stream flow Measurement*, Elsevier Applied Science Publishers, New York, NY, USA
- Australian Standards

World Meteorological Organization (WMO)

- 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>
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- World Meteorological Organization 2010b, *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>