Department of Planning and Environment

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In-situ meter accuracy procedures guide

A best practice guide for duly qualified persons performing in-situ accuracy testing on non-urban water meters in NSW

August 2022

Acknowledgement of Country

The Department of Planning and Environment acknowledges that it stands on Aboriginal land. We acknowledge the Traditional Custodians of the land and we show our respect for Elders past, present and emerging through thoughtful and collaborative approaches to our work, seeking to demonstrate our ongoing commitment to providing places in which Aboriginal people are included socially, culturally and economically.

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Preamble

About this guide

A key element of the new metering rules, set out under the Water Management (General) Regulation 2018 (the Regulation), is that meters must be pattern-approved. However, transitional arrangements included in the Regulation acknowledge that water users with non-pattern- approved meters, installed before the rules came into force, should be able to keep these meters if they are still operating accurately.

Ongoing non-urban meter in-situ volumetric accuracy testing is required to meet government maintenance requirements (every five years for closed conduit meters and annually for open channel meters) and potentially for other applications such as compliance testing and following significant meter repairs. Previously installed, non-pattern-approved meters must also be accuracy tested to be certified as compliant, under the transitional arrangements included in the Regulation.

Duly qualified persons (DQPs) certify whether or not the maximum permissible error (+/-5%) of the meter installation is met in the field. DQPs have highlighted and the department recognises the need for more information on how this accuracy testing should be done.

To address this the Water Renewal Taskforce (WRT) commissioned Manly Hydraulics Lab (MHL) to undertake a study to assess in-situ meter testing techniques.

This guide is not intended to be an exhaustive guide to metering, meter accuracy testing, data logging and telemetry requirements and should be read in conjunction with the following:

- NSW Non-Urban Water Metering Policy
- metering-related provisions of the Water Management (General) Regulation 2018
- metering-related provisions of the Water Management Act 2000
- Australian Standard AS 4747, 2013, Meters for non-urban water supply.

How to use this guide

Part A of the guide contains background information on the NSW non-urban water metering framework:

- overview of the non-urban water metering framework
- rollout dates for metering requirements
- transitional arrangements for water users with existing metering equipment — when a meter requires an accuracy test

Part B of the guide contains a report completed by Manly Hydraulics Laboratory for the department describing the in-situ accuracy practice procedures and appendices that contain the links to:

1. Testing technique selection matrix: this document lists the assessed in-situ performance reference techniques. It is to be used in conjunction with the Non-urban meter performance demonstration flowchart in Figure 2.
2. Uncertainty calculators: measurement uncertainty calculation tools to support field in-situ measurements have been developed. These are different depending on whether it is open channel or closed conduit metering equipment being assessed, and the measurement technique. The uncertainty calculators are based on the International Standards Organization, 2008 Guide to the expression of uncertainty in measurement methodology (ISO/GUM). It is also expected as the calculators are used over time that improvements will be made to incorporate better information as it becomes available.

   Uncertainty calculators are available for the following techniques:

   - In-series reference meter
   - Multi beam HVQ
   - Open channel manual gauging
   - Transit time
   - Weir discharge.

These tools must be used in conjunction with the techniques outlined in Part B.

Part A – NSW Non-urban water metering framework

NSW non-urban water metering framework

The NSW Government is delivering a robust new metering framework to measure and meter non-urban water take in NSW under its Water Reform Action Plan (WRAP). The WRAP was released in December 2017 in response to the Independent investigation into NSW water management and compliance, conducted by Ken Matthews AO, and the Murray–Darling Basin Water Compliance Review.

The framework, which is embedded in the *Water Management Act 2000* and the Regulation, began in December 2018 and will be implemented through a staged rollout over five years.

The key objectives of the metering framework, are that:

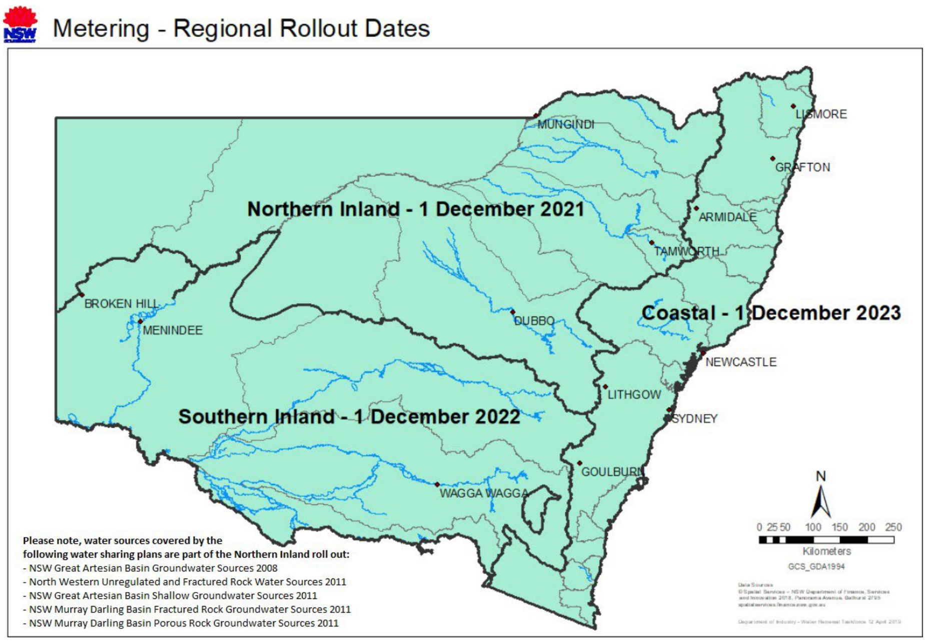
- the vast majority of licensed water take is accurately metered
- meters are accurate, tamper-proof and auditable
- undue costs on smaller water users are minimised
- metering requirements are practical and can be implemented effectively.

Timeline for metering requirements

The metering framework is being rolled out in a staged manner over 5 years.

The first rollout date is 1 December 2020 for all water users who have surface water pumps 500 mm and above. All water users will need to ensure that they have compliant metering equipment by their relevant regional roll-out date, shown in Figure 1.

Figure 1. NSW Non-urban water metering framework rollout dates

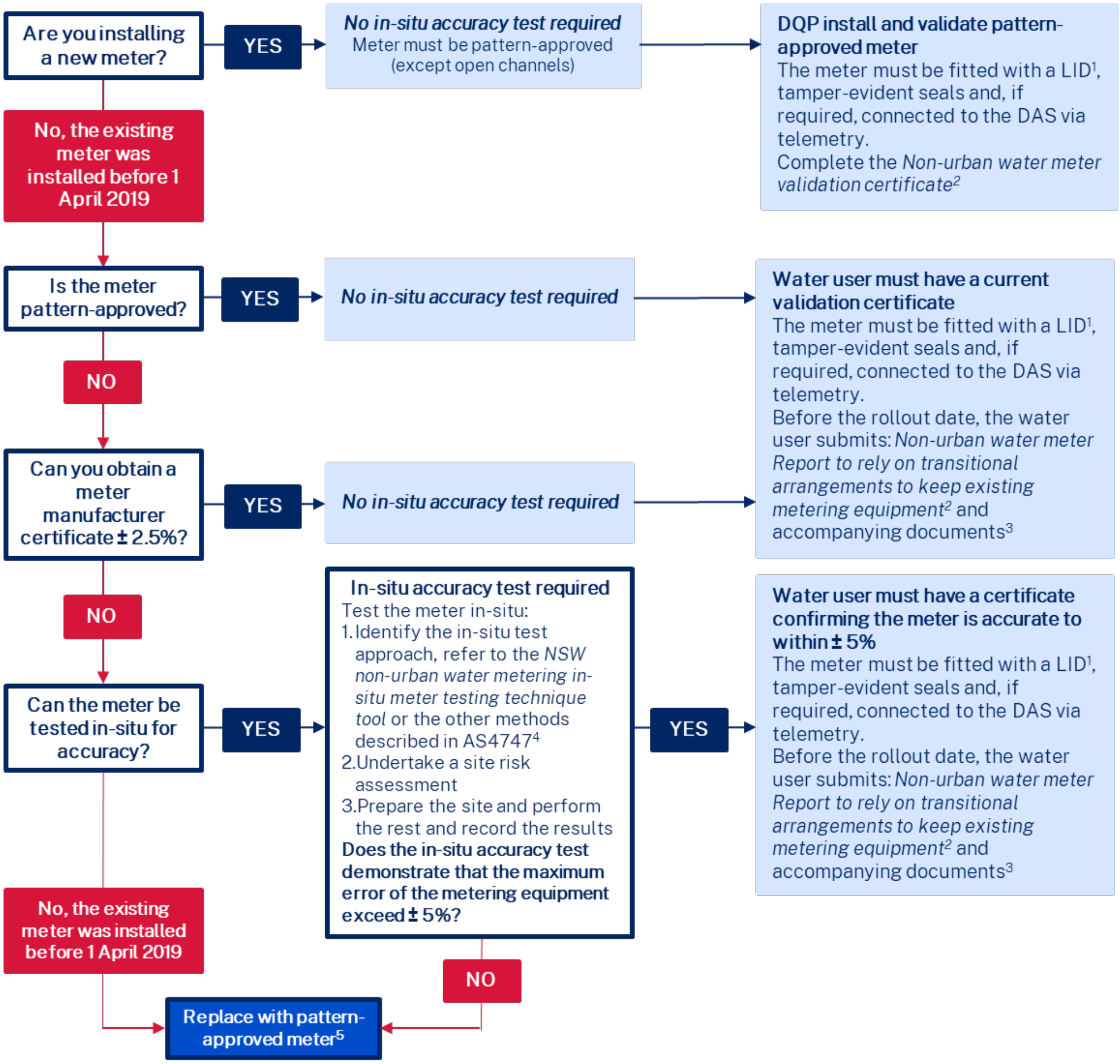


Transitional arrangements for existing metering equipment

Water users with existing meters will be allowed to keep their meters if they meet certain requirements. Users will need to demonstrate, by their rollout date, that the meter is either pattern-approved and validated or is not pattern-approved but accurate. Existing metering equipment means metering equipment that was installed before 1 April 2019.

The in-situ meter accuracy testing flowchart (Figure 2) describes the process that will assist DQPs in understanding the transitional arrangements for existing metering equipment and when metering equipment requires an accuracy test.

Figure 2. In-situ meter accuracy testing flowchart



1. LID – Local intelligence device. A combined data logger and telemetry unit that complies with the Data Logging and Telemetry Specifications 2021. A list of devices that have been tested by Manly Hydraulic Laboratory and published on the department's non-urban metering website.
2. DQPs, via the DQP Portal, can generate or submit certificates, including the validation certificate, and the report to rely on transitional arrangements to keep existing metering equipment on behalf of the water user. The certificate/report will be emailed to the DQP and water user automatically if entered in the DQP Portal. DQPs must submit the certificate/report to the DQP Portal or provide to the water user within 7 days of carrying out the activity.
3. Accompanying documents are:
   - a meter manufacturer's certificate of accuracy confirming the meter was within +/- 2.5% accuracy after manufacture **and** a validation certificate, or
   - a certificate of accuracy for existing meters (non-pattern-approved) from a DQP confirming the meter is accurate to within +/- 5%.
4. AS4747 – Australian Standard AS 4747, 2013, Meters for non-urban water supply
5. DQPs may also discuss other options with water users, such as site modifications or meter replacement to achieve compliance.

Note: an accuracy check by a DQP must be done every 5 years (or every 12 months for open channels), and whenever maintenance affects the metrology of the meter. A new certificate of accuracy completed by a DQP needs to be submitted each time this occurs.

Part B – In-situ flow measurement practice procedures

The following report was prepared by Manly Hydraulics Laboratory (MHL) for the Department of Planning, Industry and Environment in June 2020. Minor editorial changes have been made to improve readability and correct out-of-date web links.

In-situ flow measurement practice procedures

Figure 3. Transit time unit in use on a groundwater bore

Report: MHL2753

Date: June 2020

Prepared for:

Department of Planning, Industry and Environment

Water Renewal Taskforce

1 Introduction

Duly qualified persons (DQPs) will perform in-situ flow (reference) measurements to assess the performance of non-urban water meters (meter-under-test). In-situ testing covers closed conduit full pipe flow and partial pipe or open channel flow conditions. A range of in-situ measurement techniques are available and selected to match the meter-under-test's site arrangements and conditions to provide accurate testing in a practical, reliable and cost-effective manner.

This document provides guidance notes on in-situ flow measurement to assist develop training materials for DQPs. It covers three techniques:

1. Clamp-on (ultrasonic) measurement devices
2. End of pipe (Doppler) profilers
3. V-notch thin plate weir box.

Other potential in-situ flow measurement techniques include in-series pattern approved reference meter, pump-around methods, insertion probes (laser Doppler, ultrasonic Doppler and electromagnetic), tracer dilution and travel time techniques, as well as standard flow gauging methods. These techniques are described in *Measured in-situ verification of meters for non-urban water supply, Technical Report 10/08* (Jeremy Cape, 2008), *AS4747 Meters for non-urban water supply* (Standards Australia, 2013) and *AS3778 Measurement of water flow in open channels* (Australian Standards, 1991).

The common aspects of planning, in-situ measurement steps, relative error and test uncertainty estimates, and reporting are described. The specific aspects of each technique are outlined through description of measurement principles, equipment setup, primary and secondary measurements, test equipment and testing steps.

Tools developed to support DQPs perform in-situ testing include:

- The in-situ measurement technique selection matrix (Manly Hydraulics Laboratory, 2020).
- In-situ measurement uncertainty calculators (Manly Hydraulics Laboratory, 2020)[1].

[1] Excel based uncertainty calculators have been developed for: in-series reference meters; end of pipe multi-beam Doppler profilers; open channel manual gaugings; clamp-on transit time devices and V-notch thin plate weir boxes.

2 Common requirements

This section outlines some of the common considerations for in-situ meter performance assessment including common steps, taking measurements, defining error and measurement uncertainty, pre-site visit planning and site risk assessments. Specific equipment considerations for in-situ meter performance assessment and associated training are provided in Sections 3 to 5.

2.1 Pre-site visit planning

A broad range of information can be gathered, and field equipment prepared in advance of the site visit to make the in-situ meter performance assessment as effective as possible.

Available information may include:

- Property and meter locations and access details. Multiple landowner permissions may be required to access a site. Aerial photographs which may be viewed through web portals such as NSW's *Six Maps* (https://maps.six.nsw.gov.au/) can provide additional understanding of the site.
- Water user or on-site manager contact details with pre-booked meeting and test times.
- Water extraction infrastructure (pipes/pumps/meters/valves etc) work-as-executed drawings can provide critical information with respect to sizing, materials and class, anticipated flowrates, details of meter and discharge structures etc, especially when cross checked with the water user in advance. The water user or site manager may also be able to provide an understanding of the typical extraction flowrates from water usage data.
- Obtain a copy of the water users' water supply work approval to confirm the site details are correct and consistent with the works being requested to be undertaken.
- Previous validation records and previous flow assessment records.
- Report to rely on transitional arrangements to keep existing metering equipment which can be partially completed before the site visit and accessed via the DQP Portal at https://dqp.waternsw.com.au/.
- Risk assessments and Safe Work Method Statements (SWMS) can be setup in advance.
- Confirmation of test visit timing immediately before the site visit with the water user or site manager and confirm local weather forecasts.

The pre-site visit information should be adequate to provide an initial view on the likely in-situ testing technique/s to be adopted and the testing equipment to be prepared. The in-situ technique selection matrix tool (Manly Hydraulics Laboratory, 2020) will assist this process (referenced in Appendix A).

2.2 Site-based planning

On-site planning of activities will include a work, health and safety (WHS) risk assessment, as well as consideration of testing logistics, confirmation of communication methods and timing, and any potential environmental or asset damage risks posed by the proposed testing.

2.2.1 Safety

DQPs must comply with Australian work health and safety legislation and any specific work health and safety legislation in NSW.

The following information is provided as general good practice advice only. A DQP should follow installation guidelines recommended by certifying authorities. DQPs must adhere to all Australian standards relevant to the works being performed.

DQPs will need to undertake a risk assessment associated with the site and activities involved with in-situ meter testing activities. The DQP must ensure they comply with *Work Health and Safety Act 2011* and the Work Health and Safety Regulation 2017. For further advice refer to www.safework.nsw.gov.au/safety-starts-here.

Safe Work Method Statements are required for high-risk construction activities. The use of safe operating procedures may be included in the risk assessment.

The DQP will be ultimately responsible for the site and therefore all those who enter the site, including water users.

The in-situ testing must not proceed if WHS risks cannot be adequately addressed. In such cases, DQPs should document the risk assessment outcomes and advise the water user of the risks which need to be resolved before work can proceed. DQPs can seek further advice on managing WHS risks from SafeWork NSW.

Potential hazards at water meter installations typically may include, but are not limited to, the following:

- access & egress conditions (including steep, unstable and wet ground)
- asbestos
- biological/toxic hazards (including blue-green algae toxins, boars, ticks, spiders and snakes)
- confined spaces
- dust
- electricity (including energised electrical installations and overhead or underground services).
- environment extremes - hot/cold/wet/dark/bushfires
- excavation
- gas, fumes and foul air (including poorly ventilated pump houses)
- hot metal/hot surfaces/hot work (also consider fire restrictions)
- hydraulic pressure (including pressure vessels and gas mains)
- manual handling (including test equipment)

- moving machinery and plant (including unguarded equipment)
- multiple subcontractors in the work area
- noise and vibration
- overhead hazards (including power lines and tree limbs)
- other person/s threats or assault
- radiation (including solar/UV)
- remote locations and isolated work areas
- driving (Vehicle Traffic)
- working at height
- working over, near, on, in or under water (including changing flow/level conditions)
- working adjacent to road, rail and traffic corridors
- rural livestock (cattle, horses, goats) and domesticated pets (dogs)
- snakes and spider bites
- fatigue
- structures owned by others with unknown structural integrity.

End-of pipe, insertion probe and in-series testing methods (such as a weir box, in-series meter, tapping insertion device or strapped-in pipe device) will require complete and maintained **flow isolation** during critical test stages such as setup and dismantling.

2.2.2 Environmental and on-site assets

The in-situ measurement techniques presented in this report generally pose low environmental risks when performed correctly[2]. However, conditions vary at each meter installation and there are potential environmental considerations to be assessed before the commencement of testing, including (but not limited to):

- site access damage (particularly in wet conditions)
- any excavation or removal of materials, as well as reinstatement
- uncontrolled discharge returned flow or pipe breakage causing erosion
- any cease-to-pump and flow restriction considerations at the time of testing
- water usage test volumes and discharge wastage
- impact on fauna, vegetation and cultural heritage.

Existing infrastructure assets are to be protected from damage. Special consideration is required for preparation of insertion probe tappings and connection to end-of-pipe discharge points. End of pipe flow diversion and return arrangements must be self-supporting and include design and installation allowances for the water mass (weight), momentum (thrust at bends, valves and constrictions) and dynamic forces (water hammer) with pump and valve operation. Care should be

[2] Other in-situ testing methods not covered in the document such as tracer (dilution) methods which introduce a chemical for flow measurement, will require specific environmental and toxicity assessments.

taken with the operation of the extraction system (pumps and valves) — it is recommended that only the water user operates the system during testing.

2.3 Reference device location considerations

In-situ hydraulic conditions can distort velocity profiles at the point of measurement. Depending on the measurement technique this can impact the measurement accuracy. Significant flow disturbances can be caused by most fittings such as bends, tapers, diversions, tees, partially opened valves, entrance and exit conditions, as well as rough wall conditions. Swirl may be present following bends and persist for long lengths of straight pipe, particularly in large diameter pipes.

Laboratory tests help define the upstream and downstream straight (and constant diameter) pipe lengths for each type of reference device and is typically described as the number of times the pipe diameter (e.g., 5DN). There are no fixed rules for upstream and downstream lengths which vary with the type of device and its operating conditions. Meter pattern approvals and manufacturer manuals provide straight pipe lengths for ideal conditions. Where possible, DQPs should setup the reference device in accordance with these conditions.

Unfortunately, many existing meter installations are poorly designed for not well suited to in-situ reference measurements and do not readily allow for ideal measurement. Other site-based factors such as water quality, variable flowrates, entrained air, vibrations, changing control conditions, distorted pipework, unknown materials and difficult to measure dimensions can also impact the quality of the reference measurement.

Pump-around tests, weir boxes and fixed geometry in-series reference meters help reduce these impacts, however DQPs may be faced with limited in-situ measurement locations (and conditions) for available reference techniques. Measurements can still be taken with an understanding of the measurement uncertainty. Refer to Section 2.5 for further information on estimation of measurement uncertainty.

2.4 In-situ measurements

Following planning activities, there are several common steps for in-situ flow measurement:

1. Confirm the primary reference measurement method (and any beneficial secondary measurements such as internal pipe dimensions and water temperature depending on the reference measurement adopted).
2. Set up the reference measurement device and associated test arrangements including synchronised time with the meter-under-test (refer to Sections 2.4.1 and 2.4.1). This includes the devices' specific inputs, flow diversion arrangements, any secondary measurements and any safety and/or environmental mitigation controls (such as tag-outs and flow double isolation).
3. Confirm the meter-under-test flow volumes can be read and the correct settings are in place for the in-situ test. Read and record the meter's self-diagnostic tool output (electronic

fingerprint), if available. Tamper protection measures may need to be considered and any broken seals replaced.

4. Record the readings of the meter-under-test before testing, to allow for the total test water volume to be discounted from overall usage.
5. Safely operate (by the water user) the extraction system and check the reference device operation is satisfactory.
6. Undertake the specific in-situ technique tests, observations and measurements as close to the operational flowrate as possible. If the extraction system enables variable operation rates, both low and high flow rates should also be considered. Photographs of the testing can be helpful for reporting and post-test assessments.
7. Stop the tests and extraction system operation, if applicable. Record the readings of the meter-under-test after testing is completed and calculate the test volume used. Return the meter's settings to normal operation, if applicable. Tamper protection measures may need to be considered and any broken seals replaced.
8. Calculate the relative error between the meter-under-test and the reference measurement/s.
9. Calculate the uncertainty of the measurement/s.
10. Repeat the in-situ tests if there are any obvious issues with the way the testing was performed. Note: impartial measurement is required and all reference device inputs/settings are to be justified (and recorded on the test sheet) through direct measurement, observation and/or independent references such as Australian Standards or manufacturer specifications.
11. Dismantle the in-situ reference device and associated arrangements. Clean up and reinstate the site. Photograph the completed test site.
12. Report the results in the approved form and manner.

For most in-field measurements the *flying start* method is used as opposed to a *static start*. For the flying start method, the water is delivered to the meter-under-test and testing does not start until the system and readings are stable. In the static start method testing starts before the system is active. The static start method is generally unsuitable for most field applications as the pipework and meter-under-test require time to be fully charged (and air removed) to read correctly. In general, there are two ways to compare a meter against a reference measurement in the field, either by cumulative flow over time, or a number of spot readings at a constant flow rate. Both approaches are discussed below and can applied for in-situ flow measurement.

2.4.1 Totalised flow comparison

This method is commonly used in laboratory testing as described in AS4747 (Standards Australia, 2013). The advantage of this method is that it is resilient to data noise (small spikes) during testing, however it requires increased test time and can have a larger uncertainty if the meter- under-test has a long scan or display update time rate. This can be overcome by switching the meter under test to a test mode, which is likely to involve breaking the meter seal and re-programming as per user manual for that meter. If a DQP breaks a meter manufacturer verification seal it must be recorded on the validation form and photographed[3]. For mechanical meters that do not display an instantaneous flowrate, the totalised flow comparison approach this is the only method available.

To undertake a reading the start and end volumetric readings of both the reference and the meter-under-test need to be taken simultaneously with a time stamp. This can be achieved with a camera and watch (Figure 4). The timestamp is important in calculating the flow rate of the test.

The relative error is then calculated as defined in Section 2.5.

Figure 4. Simultaneous readings

2.4.2 Flow rate comparison

This method involves several near simultaneous spot readings from the meter-under-test and the reference measurement to compare the relative error (Section 2.5). The key benefit is its relative short test time compared to the totalised method. Also, the reading can be taken just after an observed update of the meter-under-test, removing the some of the uncertainty related to the scan/display rate of the meter-under-test. The number of readings provide an understanding of the repeatability of the readings, which can also be used in the uncertainty calculation.

[3] DQPs are advised: meter validators must confirm that all of these seals are in place. Validation cannot proceed if any of these seals are not in place.

2.5 Relative error and measurement uncertainty

The general equation to compare the meter-under-test and a reference measurement is presented in Equation 1. This is called the *relative error* and is applied in all in-situ flow measurement comparisons.

$$E = \left(\frac{V_i - V_a}{V_a}\right) \times 100$$

Where:

E = relative error (%)

Vi = the meter-under-test's indicated volume or average flow rate

V_α = the reference measured volume or average flow rate

Equation 1. Relative error

The relative error is compared to the operational maximum permissible error (MPE) of +/-5% (k=2) to confirm the adequacy of the meter. Where there are multiple flowrates being tested, the average of the relative errors is typically adopted to assess the meter-under-test's performance.

In legal metrology and in accordance with the current Australian Standard 4747 *Meters for non-urban water supply* (Standards Australia, 2013) the in-situ reference measurement should not exceed one third of the meter-under-test's MPE i.e. the expanded uncertainty of the reference measurement should be +/-1.7% (k=2) or better. In practice, this can be hard to achieve with available in-situ measurement techniques in a cost-effective manner.

An estimate of the uncertainty of all reference measurements should be made and accompany the performance assessment results. An uncertainty estimation tool (Manly Hydraulics Laboratory, 2020) which applies the *Guide to the expression of uncertainty in measurement* (GUM) (International Standards Organization, 2008) component-based uncertainty estimation approach has been developed to assist DQPs with this.

2.6 Measurement uncertainty principles

Measurements of a physical quantity are subject to uncertainties. These may be due to systematic error biases in the equipment used for calibration and measurement, or the random scatter for example caused by a lack of sensitivity of equipment used for the measurement. Thus, the measurement result is only an estimate of the true value of the measured quantity and is to be accompanied by an understanding of measurement uncertainty to be useful.

The measurement uncertainly is expressed quantitatively as a parameter that characterises the dispersion of values that could reasonably be attributed to the measurement. Uncertainty can be reported as a percentage of the measurement or as a number with attached units. For example, as

+/-2.3% (k=2) or +/- 7.5ML/d (k=2).

Australian Standard 4747 (Standards Australia, 2013) adopts a volumetric percentage.

The measurement error is a combination of component errors that arise during the performance of various elementary operations during the measurement process. Determination of the measurement uncertainly involves identification and characterisation of all components of error, quantification of corresponding uncertainties, and combination of the component uncertainties. The standard reference for uncertainty calculation is the International Organization for Standardization's Guide 98-3:2008 Uncertainty of measurement — Part 3: *Guide to the expression of uncertainty in measurement* (International Standards Organization, 2008). The GUM approach is adopted in this study.

The mathematical model of the measurement is first defined to identify all measurement components and how they contribute to the final measurement. The uncertainty components are combined using statistical rules and considers correlations among all the various sources of measurement error. The resulting combined uncertainty value is termed *standard uncertainty* and corresponds to one standard deviation of probability of the measurement error. By international convention (and in AS4747) all uncertainties are reported at the 95% confidence interval.[4] The standard uncertainty is converted to the 95% confidence limit by multiplying by a coverage factor (k) of two.[5]

2.6.1 Repeatability

Repeatability is the closeness of the agreement between the results of successive measurements of the same measure carried out under the same conditions and is an essential part of estimating uncertainty in measurement. This can sometimes be referred to as Type A uncertainty data. In the in-situ testing environment there are two expected sources of this uncertainty component:

1. reference measurement test
2. meter-under-test.

Mathematically the repeatability may be calculated by taking the standard deviation of a number of readings taken closely together at a stable flow rate. This is considered as a standard uncertainty and can be expanded to an uncertainty at the 95% confidence interval recognising the number of readings.[6] Repeatability is included as an uncertainty component when flow rate comparison method is adopted. Ideally at least 30 paired observations should be undertaken to minimise test uncertainty.

2.7 Reporting

It is the responsibility of the DQP to ensure the quality of the reporting, including correct inputs, calculations and results. A check and review of processes are recommended to ensure quality outputs and reduce calculation errors. Refer to the department's website for the report requirements and templates to be used for in-situ testing performance assessments can be found on the DQP Portal at https://dqp.waternsw.com.au/.

[4] In effect this means that of 100 readings undertaken, 95% will be within the margin of uncertainty.

[5] Standard uncertainty is converted to the 95% confidence interval by multiplying by the coverage factor known as the k value, recognising the degrees of freedom of the measurement. A coverage factor of two (k=2) defines a confidence interval of approximately 95%. Standard statistics textbooks provide detailed description of this method.

[6] Multiply by the Student's t-factor using the number of samples less one as the degrees of freedom. The Student t-factors can be looked up in standard statistics textbooks or by using the *TINV* function in MS Excel.

3 Ultrasonic clamp-on measurement devices

Clamp-on (or strap on) ultrasonic (transit time) flow measurement devices are commonly used for in-situ flow measurement. They can be used across a large range of pipe sizes[7] in closed conduit full flow conditions (Figure 5). The considerations described in Section 2 apply to in-situ testing using these devices.

Figure 5. Transit time unit installed on a pipe

3.1 Description

The ultrasonic clamp-on measurement device for fluid flow uses pulses of ultrasonic signals (or sound waves) to measure the velocity of sound in the water. It is installed on the outside wall of a pipe and ultrasonic signals are transmitted through the pipe wall and piped water. The International Standard, (International Standards Organization, 2017) ISO 12242:2012(E), covers the standard requirements for the measurement of single-phase homogeneous fluid flow in closed conduits using ultrasonic transit-time meters.

[7] Generally > 100DN

Basic components of this device include:

- Transducer/s: device or sensor that can convert electrical energy into another form of energy such as ultrasonic signals and vice versa. It acts as a transmitter and receiver of ultrasonic signals.
- Meter body: the pipe to which the transducers are attached. The path configuration of different ultrasonic meters varies, depending on a meter's orientation on the pipe axis and whether it is a single-path or multi-path meter.
- Electronic unit: component which generates and receives electrical energy/signals and measures the time that the signals are in transit.

3.2 Measurement principles

An ultrasonic clamp-on flow meter has at least one or more pairs of transducers. Transducers are positioned apart from each other at a certain distance (known as path length) and in such a way that one is upstream of the other.

The upstream transducer transmits ultrasound or acoustic pulses travelling with the direction of the flow while the downstream transducer transmits pulses travelling against the direction of the flow. The transducers alternately send and receive ultrasound pulses between each other, measuring discrete path velocities – the average velocity of the fluid along the path travelled by an ultrasound pulse between two transducers.

In addition to distorted velocity profiles due to hydraulic disturbances, key variables for consideration in the overall uncertainty measurement include:

- defined pipe material and thickness (and any other pipe liners – internal and external – which the sound wave passes through)
- pipe internal diameter and roundness
- water temperature.

Other minor uncertainty components such as salinity level have not been included at this stage. Individual device models may include different input choices for these variables.

3.3 Equipment setup

The test equipment manufacturer's manual should be referred to for setup conditions and inputs. In general, the following steps are taken to setup the device (sub-steps options are shown in order of preference to reduce measurement uncertainty):

1. Position the device at the most hydraulically suitable available location to enable measurement of the flow through the meter-under-test. This will include a long straight section of pipe without ancillary fittings and away from bends or pumps (refer to Section 2.3 for further details). Measure the upstream and downstream pipe length to hydraulic disturbances and record in the test sheet.

2. Identify the pipe material and any known liner materials using one of the methods from the list below. Record the method(s) used and the results on the test sheet and enter details into the unit.
    a. Standard pipe markings provide pipe material, nominal diameter and pipe class. The relevant Australian Standard for each pipe type and/or manufacturer guides provide specifications.
    b. Visual observation, both external and internal can provide indication of the pipe material, its condition and any liners (internal and external).
    c. Work-as-executed drawings may assist in confirming details but are not reliable as a sole source of information.
3. Estimate the internal diameter of the pipe, using one of the methods from the list below. Record the method(s) used and the results on the test sheet and enter the transit time unit, this is best done through physical measurement of diameter and pipe thickness.
    a. Measure the pipe's internal diameter using either callipers or a tape measure at an exposed section or a measurement rod at a tapping hole or inspection port. This should be checked in several planes to confirm and allow for pipe roundness and will be considered as part of the uncertainty in measurement. If this method is chosen, consider taking the opportunity to use a flexible camera to observe the internal condition of the pipe at/near the point of measurement.
    b. Measure the pipe's external circumference using a tape measure or callipers and use the circumference formula to calculate the outside diameter. Measure the pipe thickness using multiple readings with a calibrated thickness gauge or callipers in an exposed section. Input the measurements in the transit time unit to calculate the internal diameter or manually calculate the internal diameter.
    c. If it is not possible to get good thickness readings, adopt the specified pipe thickness from the standard pipe markings (step 2 above) and manufacturer's reference tables to calculate the internal diameter using the measured outside diameter.
    d. Use pipe markings only to look up the manufacturer-specified internal diameter.
    e. Work-as-executed drawings may assist in confirming details but are not reliable as a sole source of information.
4. Measure water temperature and pipe temperature at, or at a representative location near, the measurement point. Record the methods and results on the test sheet and enter into the transit time unit (if available).
5. The transit time controller will calculate and display the distance to be set between the two measurement heads. On a cleaned section of the pipe use a straight ruler and spirit level to mark the pipe where the heads are to be placed. Ideally the heads are not placed at the pipe soffit (i.e., the top of the pipe) which is more prone to trapped air. The pipe may need to be cleaned with a cloth (or a wire brush if the pipe is heavily rusted and/or pitted) before mounting the sensors.
6. Apply coupling gel to the sensors and install the measurement heads, using either the straps/chain provided or mounting brackets.

7. Connect the leads (where required) from the measurement heads to the controller. Check if negative flows are being displayed. If so, reverse the leads.
8. Set the transit time units to show litres as either cumulative totals or flow rate (Section 2.4).
9. Check unit's diagnostics screen for signal strength, sound speed or other components to confirm it is suitable for operation.
10. Ensure all setup inputs and methods are recorded on the test sheet. Use photographs to support the test sheet inputs.

3.3.1 Test equipment list

Typically, the following equipment will be required to perform the in-situ test:

- test sheets and calculators
- pipe specifications
- transit time unit, with charged batteries
- spirit level
- rule / tape measure
- time piece (minimum 1 second resolution)
- wire brush / cleaning cloths
- callipers
- thickness gauge (calibrated and charged)
- transit time gel
- camera
- shovel.

3.4 Testing

To conduct the in-situ performance test:

1. Ensure the meter-under test and the water extraction system are setup for testing.
2. Place the transit time controller next to the meter-under test's display and time piece. Photograph all three devices at the start and end of the test or at each measured test flowrate.
3. Observe and note any fluctuations or vibrations or other potentially adverse conditions during testing.
4. Use the test readings to compare the results and develop the relative error/s.
5. Estimate the test uncertainty using the available test information.
6. Check that all field results necessary for reporting have been recorded before dismantling the unit and making the site presentable.

4 End of pipe HVQ multi-beam sensor

Head, velocity and flow (HVQ) Doppler flow measurement devices are commonly used in open channel flow measurement arrangements such as stormwater and sewerage systems. They can be used across a large range of pipe sizes both in open channel flow (partial pipe) and closed conduit full flow conditions. Only multiple-beam units (for measurement of velocity in multiple locations across the flow profile) are considered. Single-beam velocity measurement is not considered suitable in most of the applications likely to be found for non-urban meter testing. The considerations described in Section 2 apply for in-situ testing using these devices.

Figure 6 shows an example of a sensor and mounting strap.

Figure 6. End of pipe HVQ with mounting strap (Source: Sontek IQ Pipe)

4.1 Description

An end-of-pipe acoustic Doppler velocity device can obtain instantaneous discharge at a specific location based on multiple velocity measurements and calculate the cumulative volume over time.

These units measure velocity by using the Doppler shift principle. Doppler shift is the difference in the frequency of transmitted acoustic pulses or sound waves as they are reflected back from a moving body.

4.2 Measurement principles

In Doppler systems, the sensors contain a transmitting and receiving device. High frequency sound waves are emitted from the transmitting device into the fluid flow. Once these sound waves intercept acoustic particles, such as suspended solids or undissolved air (air bubbles) in the fluid, they are reflected back to the sensors and are detected by the receiving device. These resulting echoes return to the sensors at a shifted frequency that is proportional to the velocity of the fluid flow (International Standards Organization, 2010). The frequency of the sound waves decreases as the fluid flows away from the sensor. This frequency shift (Doppler effect) or the difference in frequencies between the original acoustic pulse and the detected echo is used to determine the velocity of the fluid (Masasi, Frazier, and Taghvaeian, 2017).

For Doppler shift to occur, there must be movement between the transmitted sound source and the reflected sound source along the acoustic path. The mean velocity of the fluid flow is obtained from the resultant frequency shift produced by many reflectors. Thus, the velocity being measured is the velocity of the moving suspended solids or air bubbles and not the water velocity itself. However, by including the velocity of many particles, an estimate of the average water velocity can be obtained.

The volumetric flow can be calculated by combining the water depth, the cross-sectional area, and the velocity profile of the cross-sectional area. The return signals are binned into sections with multiple measurements through the profile, which creates flow profiles. This means greater accuracy when there is asymmetric flow patterns.

Units can be bottom (or top mounted if the pipe always runs full) and usually include built-in pressure sensors to provide additional water depth measurement.

Distorted velocity profiles due to hydraulic disturbances impact measurement, however multiple velocity measurements across the profile enable improved flow estimation over a single velocity point measurement. Other key variables for consideration in the overall measurement uncertainty include:

- cross-sectional area dimensions at the point of measurement (in round pipes this is the pipe internal diameter and roundness)
- water temperature
- acoustic particle reflection to enable Doppler shift calculations
- choice of flow estimation model and number of velocity beam measurements
- hydraulic flow geometry (distorted velocity profiles).

Minor uncertainty components such as salinity level have not been included at this stage. Individual device models may include different input choices for these variables.

4.3 Equipment setup

The manufacturer’s manual should be referred to for setup conditions and inputs. Basic training is recommended to optimise the use of these instruments, which include multiple input options. In general, the following steps are taken to set up the device (sub-steps options are shown in order of preference to reduce measurement uncertainty).

1. Ensure pumps are off and flow to the end-of-pipe is stopped and isolated (Section 2.2.1).
2. Position the device at the most hydraulically suitable location to enable measurement of the flow through the meter-under test. Select end-of-pipe arrangements avoiding nearby bends and pumps — ideally a long straight section of pipe without ancillary fittings (Section 2.3). Measure the upstream and downstream pipe length to hydraulic disturbances, including the end of pipe (open discharge), and record in the test sheet.
3. Estimate the internal diameter of the pipe, record the method and results on the test sheet and enter into the transit time unit. This is best done through physical measurement, which is usually possible at the end of pipe.
    a. Measure the pipe internal diameter of pipe using either callipers or a tape measure at an exposed section of pipe or a measurement rod at a tapping hole or inspection port. This should be checked in several planes to confirm and allow for pipe roundness. Consider the use of a flexible camera to observe the internal condition of the pipe at/near the point of measurement.
4. Measure water temperature at or at a representative location near the measurement point. Record the method and results on the test sheet and enter into the reference device (if available).
5. Enter the distance of the sensor off the pipe internal wall, including the mounting bracket.
6. Data should be logged by the reference device and downloaded to a computer or tablet at the end of the test. The highest scan and log rate possible will reduce the rounding uncertainty and potentially decrease the repeatability uncertainty.
7. Test the unit. Check the unit's diagnostics screen for signal strength, sound speed or other components to confirm it is suitable for operation.
8. Ensure all setup inputs and methods are recorded on the test sheet. Use photographs to support the test sheet inputs.

4.3.1 Test equipment list

Typically, the following equipment will be required to perform the in-situ test:

- test sheets and calculators
- acoustic Doppler velocity unit with charged batteries
- laptop or tablet with the device's software, with charged batteries
- suitably sized mounting straps
- callipers and rule or tape measure
- stopwatch (minimum 1 second resolution)
- camera
- communication methods for coordinating pump operation and testing.

4.4 Testing

To conduct the in-situ performance test:

1. Ensure the meter-under-test and the water extraction system are setup for testing. There may be significant distance between the meter-under test and the end-of-pipe device placement, so ensure communication devices are working.
2. Synchronise the stopwatch being used against the instrument's internal clock via a laptop, computer or tablet.
3. Ensure all workers are clear of the end-of-pipe and flow discharge before releasing flow or starting pump/s. Confirm the flow rate is stabilised before logging the device outputs and record the meter-under test with a time stamp and photograph.
4. Record the logged data from the reference device and the paired meter-under test flow rate over an extended period – ideally at least 30 paired readings to improve repeatability uncertainty. The camera and stopwatch will allow accurate readings of flow rate and a timestamp.
5. Observe and note any fluctuations, vibrations or other potentially adverse conditions during testing. Ensure the supporting band does not move during testing.
6. Download the data from the device and compare totalised volumes with the meter-under-test and calculate the relative error/s.
7. Estimate the test uncertainty using the available test information.
8. Check that all field results necessary for reporting have been recorded.
9. Isolate the flow and reinstate safety control measures. Remove the device and reinstate the site.

5 Thin-plate V-notch weir box

Thin-plate weirs are a common and highly reliable method of flow measurement. A V-notch weir box arrangement is described for in-situ flow measurement. This arrangement is restricted to a maximum flow rate and depends on suitable conditions to divert and return the flow from the meter-under-test. Other weir types may also be considered recognising measurement uncertainty requirements and flow capacity.

5.1 Description

Thin-plate weirs are flow-regulating structures that are built to measure flow rate in main channels or emplacement arrangements, typically where there is a fixed geometry and a free-flowing outlet. Thin-plate weirs can be quickly installed and removed to get a comparison of flow rate of the meter in the emplacement (Figure 7). They are installed at the front of the emplacement and ensure that water is free flowing. A mounted ruler is used to read the water level, which is converted to a flow rate for comparison against the installed meter. Thin-plate weirs can also be built into a portable weir box that can be used to measure discharge at the end of the pipe.

The International Standard 1438 (International Standards Organization, 2017), and the Australian Standard 3778.4.1 (Standards Australia, 1991) cover the standard requirements for the measurement of open channel water flow using thin-plate weirs.

There are various thin-plate weirs available including the:

- supressed rectangular-notch thin-plate weir
- contracted rectangular-notch thin-plate weir
- triangular-notch or V-notch thin-plate weir (of various V angles)
- Cipolletti thin plate weir.

Figure 7. Removable weir plate

Key advantages of weir plates include:

- High accuracy: AS 3778.4.6 shows that a 90-degree thin-plate weir can achieve an uncertainty of ±1.0% to ±1.5% (k=2).
- Robust and simple technology: relatively cheap to manufacture and deploy, quick to use in the field, and when used by a trained operator should give highly accurate and reliable flow measurements.

Key limitations include:

- Fixed sizes and associated flow rates (for example a 400mm high 90° V-notch weir can measure flow rate up to 10ML/d)[8].
- Adequate upstream head is required to drive the measurement.
- Connection to existing installations and return flow can make it difficult to both avoid leakage and provide self-supporting connections. Heavy lifting equipment and a flat level space is required for large weir boxes.

[8] Higher flow rates should be possible with laboratory calibration.

5.2 Measurement principles

Thin-plate weirs can be used to obtain volumetric flow rate. Flow rate is calculated using the following parameters:

- head on the weir or the upstream gauged head above crest level, *h*
- the size and shape of the discharge area
- a coefficient that is based on the head on the weir, the geometrical properties of the weir and approach channel and the dynamical properties of the water.

AS 3778.4.1 states that thin-plate weirs are especially dependent on its installation features which control the velocity distribution in the approach channel and on the construction and maintenance of the weir crest in meticulous conformance with the standard specifications. Weir boxes should be constructed in accordance with ISO standard dimensions.

For V-notch weirs the width of the approach channel (B); the measured head (h); the height of the crest relative to the floor (p); the angle of the V-notch (α); and the head measurement section, which has a distance of $2h_{max}$ to $4h_{max}$ upstream from the weir are used in accordance with ISO 1438:2017(E).

Figure 8 shows the connection of a 300 mm lay flat hose to a metering discharge point and Figure 9 shows the lay flat hose connected to a weir box.

Figure 8. Connection of 300 mm lay flat hose to discharge point

Figure 9. A 300 mm lay flat hose connected to a weir box in operation

Weir boxes overcome distorted velocity profiles at the end-of-pipe discharge point through the design of the box itself, which includes a baffle and adequate length and volume to stabilise flow. Key variables for consideration in the overall measurement uncertainty include:

- Weir box construction, water-tightness and true shape. High-quality construction is vital, including tight dimension tolerances and adequate structural design to avoid distortion during transport and usage. It is recommended the performance of weir boxes be periodically verified in an independent NATA accredited laboratory to ensure they work within designed measurement uncertainties.
- Depth measurement upstream of the notch the depth-flow rate relationship. Drawdown effects are to be taken into account. The depth-flow rate relationship includes experimentally established discharge coefficient and equations limited to specific flow rates for standard weir heights. Other weir heights would require laboratory calibration to establish height and discharge factors.
- Weir boxes must be designed so the horizontal weir is perpendicular to flow.
- Leakage between the meter-under test and the weir box.

5.3 Equipment setup

The following description is for a 90-degree V-notch weir box constructed according to ISO standards. The dimensions are adequate for stabilised flow measurement and maximum rated flow rate. Refer to International Standards Organization, 2017 for details. AS 3778 (Standards Australia, 1991) provides guidance for the use of thin-weir plates including approach channel (upstream of the weir plate) and downstream channel considerations.

Site selection and installation is paramount to ensure the:

- flow through the approach channel is uniform and steady with a velocity distribution that is similar to a smooth normal flow (resistance-controlled flow) in a long straight channel (Cape, et al., 2008). The channel must be rectangular, straight, and horizontal.
- water level in the downstream channel is below the crest with a sufficient vertical distance ensuring that the:
  a. discharge is free or not submerged into the downstream water level
  b. lower water surface of the nappe[9] is fully ventilated with atmospheric air pressure.
- thin-plate V-notch weir is rigid, perpendicular to the walls and the floor of the approach channel in the weir box and smooth (especially the upstream side of the plate). Care must be taken to avoid damaging the weir notch itself. Small nicks and dents can reduce the accuracy of an otherwise good weir installation. The smooth surfaces and sharp edges of the notch can be maintained with a constant coating of a thin, protective film (e.g. oil, wax, silicone) applied with a soft cloth. It is recommended that the weir plate in the vicinity of the notch is made of corrosion-resistant metal.
- weir box structure should be placed horizontal on site for best operating conditions. Water flowing to weir should be free of debris or weeds which might accumulate at the weir or block flows.

To setup a weir box:

1. Ensure:
   a. pumps are off and flow to the end-of-pipe is stopped and isolated (Section 2.2.1)
   b. the meter-under test and the extraction system are setup for testing
   c. communication devices are working as there may be significant distance between the meter-under-test and the end of pipe device placement.
2. Identify a suitable flat location to direct end-of-pipe from the meter-under-test to the weir box and enable return flow to the irrigation channel. The weir box must be horizontal (and weir plate vertical and perpendicular to the line of flow). Preparation of the ground surface and/or the use of wedges may be required. Allow for the weight and force of the diverted water and in the weir box.
3. Prepare the diversion system from the end-of-pipe. Each installation will have different requirements. One approach is to use supported lay flat hose and/or open channel sections. Section joins should be made tight without leakage.
4. Set up the depth measurement instrument. The head on the weir is the measured vertical distance from the water surface to the vertex of the notch.[10]

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[9] The nappe is the sheet of water flowing over the weir notch.

[10] The head-measurement section, or the section where the headwater level is measured, is located upstream from the weir at a distance equal to 2-4 times the maximum ($2h_{max}$ to $4h_{max}$) upstream from the weir. This is the satisfactory distance where energy loss between the head-measurement section and weir is negligible and surface drawdown is avoided.

a. Measure the head on the weir with a laboratory-grade measuring device (e.g., hook gauge, point gauge, or manometer). Continuous measurements of the head can be obtained using precise float gauges and servo-operated point gauges.[11]

b. Headwater level can be measured directly if surface velocities and disturbances in the approach channel are negligible. However, if there are variations in water level caused by waves, turbulence, or vibration, the headwater level can be obtained in a stilling well:

   i. Connect the stilling well to the approach channel by using a conduit. To reduce oscillations, a throttle valve may be installed to the conduit.

   ii. The connection at the conduit's channel end can be floor or wall piezometers or a static tube positioned at the section where the headwater level is measured.

   iii. If there are disturbances in the water level at the head-measurement section, install several pressure intakes so that the head measurement can be averaged from heads measured at several points.

5. Ensure all workers are clear of the end-of-pipe and flow discharge before releasing flow or starting pump/s. Carefully charge the system, ensuring stable diversion pipework and equipment, and ensure there are no leaks. Clean the stilling well, connecting conduits and piezometers.

6. Determine gauge zero. Head-gauge datum (gauge zero) is the measurement of the level of the vertex of the notch for V-notch weirs. Head-gauge datum must be accurately measured to provide high accuracy head measurements. One acceptable method to determine the gauge zero is described as follows:

   a. Allow the water in the approach channel to be still and then be drawn to a level below the vertex of the notch.

   b. Mount a temporary hook gauge over the approach channel with its point positioned at a short distance upstream from the vertex of the notch.

   c. Place a cylinder (with a known diameter measured by a micrometer) horizontally, with one end resting in the notch and the other end balanced on the point of the temporary hook gauge. Make the cylinder precisely horizontal by using a machinist's level placed on the top of the cylinder and then adjusting the hook gauge. Record the temporary gauge reading.

   d. Lower the temporary hook gauge to the water surface in the approach channel then record the reading. Adjust the permanent headwater gauge to read the level in the gauge well and then record this reading.

   e. Compute the distance from the top of the cylinder to the vertex of the notch by applying the known values of the notch angle (α), and the radius of the cylinder to the following equation:

   $$y = \left(r \,/\, sin\frac{a}{2}\right) + r$$

   Subtract y from the reading recorded in step (c), with the result being the reading of the temporary gauge at the vertex of the notch.

[11] Staff and tape gauge measurements are less accurate.

f. The difference between the computed reading in (e) and the reading of the temporary gauge in (d) is added to the reading of the permanent gauge in (d). The sum is the gauge zero for the permanent gauge.

   An advantage of this method is that it refers the gauge zero to the geometrical vertex which is defined by the sides of the notch.

7. Ensure all weir box setup details are recorded on the test sheet. Use photographs to support the inputs recorded on the test sheet.

5.3.1 Test equipment list

Typically, the following equipment will be required to perform the in-situ test:

- test sheets and calculators
- V-notch weir box and transport method e.g. trailer or flatbed truck
- lifting machinery and excavation tools (if required)
- depth measurement instrument/s including rule or point or hook gauge
- suitably sized diversion pipework/channels/lay flat hose with connectors
- suitable supporting structures and wedges
- spirit level
- timepiece (minimum 1 second resolution)
- camera
- shovel or rake for site re-instatement
- communication methods for coordinating pump operation and testing

5.4 Testing

To conduct the in-situ performance test:

1. Synchronise the timepiece being used against the instrument's internal clock if the level is being logged.
2. Ensure all workers are clear of the end-of-pipe and flow discharge before releasing flow or starting pump and confirm the flow rate is stable.
3. Estimate/measure and record any leakage that can't be sealed between the meter under test and the weir box and record the quality of this value.
4. Synchronise weir box head measurements with the meter-under-test. Record measurements via photographs with timestamps. This may require the assistance of a second person.
5. Weirs only record an instantaneous value, so they can either be compared to flow rate of an electronic meter or a number of readings over time and calculated volume for mechanical meters.
6. Record the reference device logged data over an extended period (ideally 30 paired observations should be undertaken to improve test uncertainty).

7. Keep the approach channel and downstream channel free of silt, vegetation and obstructions so that desired flow conditions specified in the standards are maintained. Keep perforated plates of a flow straightener clean so that the open area remains greater than 40%. Observe and record any fluctuations or vibrations or other potentially adverse conditions during testing.
8. Convert weir box head measurements into flowrates using the V-notch weir formula.
9. Compare totalised volumes with meter-under-test and develop the relative error/s.
10. Estimate the test uncertainty using the available test information.
11. Check that all field results necessary for reporting have been recorded.
12. Isolate the flow and reinstate safety control measures. Remove the weir box and diversion equipment, and reinstate the site.

6 References

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Standards Australia (2013) 'AS4747-2013 Meters for non-urban water supply'. Australian. .

Appendix A – Technique Selection Matrix and Uncertainty Calculators

The following documents are available for download:

- In-situ Accuracy Testing – Technique Selection Matrix
- Multi-beam HVQ Uncertainty Calculator
- Transit Time Uncertainty Calculator
- In Series Uncertainty Calculator
- Open Channel Manual Gauging Uncertainty Calculator
- Weir Discharge Uncertainty Calculator

Appendix B – Glossary

Term	Description
Authority	A water supply work approval or an access licence under the *Water Management Act 2000* or a licence or other entitlement under the *Water Act 1912*.
Authority holder	Person or entity who holds an authority.
CMI	Certified meter installer.
DAS	Data acquisition system. This is the cloud-based platform used by the department to store data acquired from meters. The DAS provider is eagle.io.
DQP	Duly qualified person. This is defined in the dictionary to the *Water Management Act 2000* and in clause 236 of the *Water Management (General) Regulation 2018*.
LID	Local intelligence device. A combined data logger and telemetry unit that complies with the Data Logging and Telemetry Specifications 2021. A list of devices that have been tested by the department is published on the department's non-urban metering website.
Metering equipment	Includes any device used for, or in connection with measuring the flow of water and any ancillary wiring, pipework, telemetry equipment or apparatus and any supporting structure.
NRAR	NSW Natural Resources Access Regulator
Open channel	A channel or conduit used for conveying water that is not enclosed.
Pattern approved meter	Pattern approved means the design of these meters has been verified by the National Measurement Institute (NMI) to meet national metrological specifications. A list of these meters is published here: https://www.mdba.gov.au/sites/default/files/pubs/pattern-approved-non-urban-water-meters.pdf
WaterNSW DQP Portal	On-line portal for DQPs to register for installing telemetry, filling in validation of metering equipment, accuracy testing and open channel design. The DQP Portal is accessible here at https://dqp.waternsw.com.au/.

Appendix C – Additional Resources

The following interactive tools, documents and publications can be found in the non-urban metering document library at www.dpie.nsw.gov.au/water/nsw-non-urban-water-metering/document-library.

Resources	Resource description and links
Data logging and telemetry specifications	This instrument is the approved data logging and telemetry specifications for metering equipment that holders of water supply work approvals, water access licences and Water Act 1912 licences and entitlements that are subject to the mandatory metering equipment condition must comply with.
Frequently asked questions	Find answers to frequently asked questions posed by water users and duly qualified persons.
Further information	Access the full suite of information regarding the NSW non-urban water metering framework, in the water reform section of the department's website.
Maintenance specifications	These specifications set out the maintenance that needs to be carried out in relation to metering equipment.
Metering guidance tool	Decisions support tool to assist water users to determine if they are required to comply with the current metering framework. It consists of a series of short questions and will take less than 5 minutes to complete. Access the metering tool from here.
NSW Non-Urban Water Metering Policy	The policy explains the requirements of the new framework.
Pattern approved non-urban water meters	From 1 April 2019, all new and replacement meters must be patter-approved (except for open channels), the Murray–Darling Basin Authority updates the pattern approval list as soon as any relevant new information is available. Access the most recent update list from here.
Tamper evident seals guide on non-urban water meters	Produced by IAL to provide information to DQPs on appropriate placement of tamper evident seals on non-urban water meters.
DQP Data Logging and Telemetry Guide	A guide for duly qualified persons installing and connecting data logging and telemetry devices to non-urban water meters in NSW.