GUIDELINES FOR THE MEASUREMENT AND REPORTING OF WATER TAKES

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Contents

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Section A: Introduction & Background

A1 Introduction

A1.1 Purpose of Guidance Document

The purpose of this guidance document is to outline the requirements and good industry practice for the selection, installation verification, and validation of water measurement devices/systems required for water permit holders to meet their obligations under the Resource Management (Measurement and Reporting of Water Takes) Regulations 2010 (the Regulations).

This guidance has been developed to:

- Provide guidance on the selection, installation, verification and validation of suitable water measurement devices/systems for compliance with the Regulations; and

- Promote accurate measurement of water takes to assist in the monitoring process for water permit compliance and enforcement.

A1.2 Scope

This document provides guidance as to how water permit holders are to meet their obligations under the Regulations. This document is separated into three main sections; full pipe systems, open channel and partially filled pipe systems, and data management issues.

The sections of this document outline the requirements of the Regulations, and then provide guidance as to the minimum standards, typically used in the industry to meet these requirements.

Please note that a water measurement system or device that fulfils the guidelines in this document is not automatically deemed to comply with the Regulations, i.e. these guidelines do not confer compliance with the Regulations. It is strongly recommended that a permit holder seeks expert advice to ensure they select and install a water meter or measurement system that is fully compliant with the Regulations.

A1.3 Background

A1.3.1 Regulations

In 2010, the Regulations were established to provide a tool to aid in the planning, monitoring, and management of New Zealand's water resources. All holders of water permits (except for non-consumptive takes) that allow fresh water to be taken at a rate of 5 litres per second (L/s) or greater must comply with the requirements of the Regulations.

The Regulations have been passed pursuant to section 360(1)(d) of the Resource Management Act 1991 (RMA), and therefore apply both to water permits held at the commencement of the Regulations (10 November 2010) and to water permits granted after that date.

For water permits held on 10 November 2010, compliance with the Regulations is not required immediately. A transitional period allows existing permit holders to implement any works necessary to become compliant. Table 1 outlines when holders of existing permits must comply with the Regulations. Forward planning should ensure that the necessary works are completed in time to comply with the Regulations by these dates.

Table 1: Compliance dates for existing water permit holders

Water Permit	Date for Compliance with the Regulations
20 L/s or more	10 November 2012
10 L/s or more, but less than 20 L/s	10 November 2014
5 L/s or more, but less than 10 L/s	10 November 2016
Less than 5 L/s	Not required to comply with the Regulations

For water permits granted after the 10 November 2010, there is no transitional period, and hence compliance with the Regulations are required immediately, as soon as water is taken.

A1.3.2 Relationship between the Regulations and Regional Rules or Permit Conditions Set by the Relevant Consenting Authority

The Regulations, as a part of the RMA, apply to water permit holders (as described above) nationwide. In general, the requirements of the Regulations prevail over a regional rule or a condition placed on a water permit by the relevant consenting authority. However, if a regional rule or water permit condition is more stringent than the Regulations, the regional rule or permit condition will prevail over the Regulations.

It is recommended that the water permit holder identifies any relevant regional rule/s or water permit conditions prior to the selection and installation of a water meter to ensure the correct, more stringent, requirements are adhered to.

A1.4 Definitions

Accuracy refers to the qualitative description of the closeness of the measurement to the true value, based on the measurement uncertainty which is quantitative.

Calibration refers to the process of regularly checking and standardising the measurement of the water metering device or system against another measurement of known accuracy.

Full pipe flow refers to flow in a closed pipe or conduit that is full of water.

Open channel flow refers to flow driven by gravity, exposed to the atmosphere, and in a conduit such as a canal, flume, ditch, or race.

Partially full pipe flow refers to flow driven by gravity in a closed conduit where the conduit is not full, and the flow has a free surface subject to atmospheric pressure.

Permit, in relation to a permit holder, means the water permit held by the permit holder.

Permit holder means a person who holds a water permit to which the Regulations apply.

Range of expected flow rates refers to the range of minimum to maximum flow rates that the specific conduit would be expected to convey under normal conditions. The maximum expected flow rate is not limited to the maximum permitted flow rate, but to the capacity of the intake structure/system[1].

Relevant regional council refers to the regional council or unitary authority[2] that granted the water permit.

Suitably qualified hydrologist refers to a hydrologist with no less than 5 years of relevant practical experience and trained in the practical aspects of open channel flow measurement.

Uncertainty refers to the range of values within which the true value of a measured quantity is expected to lie, to a stated level of confidence.

Validation refers to formal inspection of the system to establish that the water metering device has been installed according to manufacturers' specifications.

Verification refers to formal inspection and testing of the water metering device or system to prove and document that it meets the accuracy requirement of the Regulations.

Water meter *or* water measurement system refers to all components of the measurement configuration that measures and records the volumetric flow rate of water that passes through the conduit.

Water year refers to a period during the term of the water permit:

(i) Starting on 1 July or, for the permit's first water year, starting on the first day on which the Regulations apply to the permit; and

(ii) Ending on the next 30 June or, for the permit's last water year, ending on the last day on which these regulations apply to the permit.

A1.5 Further Advice and Information

For more information and advice, the relevant regional council should be contacted. The relevant regional council can then provide direction as to who best to contact for the particular advice or information sought.

[1] This is because the Regulations state that the water measurement records must include water taken in excess of what the water permit allows.

[2] Based on the definition of regional council in the Resource Management Act 1991.

Section B: Water Measuring Devices for Full Pipes

B1 Requirements of Regulations for Full Pipes

B1.1 Requirements of a Water Meter

B1.1.1 Records of Water Taken

The Regulations require that a permit holder keep records that provide a continuous measurement of the water taken under a water permit, including any water taken in excess of the amount allowed under the permit. The records must include the cumulative volume (in cubic metres) of the water taken each day. In some cases the regional council may allow the measurement to take place on a weekly basis. Written approval from the regional council is required for this to occur.

A water meter is therefore required to be capable of measuring and displaying the cumulative volume of water taken, in cubic metres.

Please see Section D2 for further information on data management.

B1.1.2 Accuracy

For full pipe water take systems, the Regulations state that a water meter must measure the volume of water taken to within ± 5% of the actual volume taken.

B1.1.3 Suited to Expected Conditions

The Regulations require that the water meter used for monitoring the volume taken must be suited to the qualities of the water that it is measuring. Such water qualities that should be considered include temperature, algae content, and sediment content.

B1.1.4 Security

A water meter, and any essential external components (e.g. power supply), is required under the Regulations to be sealed and as secure against tampering as practical. Tampering could affect the credibility of the measured data collected by a water meter. Seals should help prevent tampering with the meter and/or indicate when tampering has occurred.

B1.2 Installation Requirements

B1.2.1 Location of Water Meter

The Regulations require that a water meter be located at the location from which the water is taken, or as close as practical to this place as permitted by the regional council. As the Regulations also require that the water meter be verified on a regular basis and is required to be located in a position with suitable access for this purpose.

B1.3 Verification Requirements

B1.3.1 Frequency of Verification

Verification of a water meter is required by the Regulations. The verification process gives confidence that a meter meets the required accuracy standard. A water meter must be verified as suitably accurate within the first water year of it being installed and at a maximum period of no greater than 5 years thereafter, or at an interval specified by the regional council.

Verification of a water meter may be performed either on-site or at an accredited laboratory. A meter can only be verified on-site if the system has been set up allowing for this to be carried out. If a meter is to be verified off-site in a laboratory, the verifier is likely to require that a section of up and down stream pipe work lengths from the on-site system also be taken to the laboratory to replicate the in situ conditions. It is therefore necessary to consider the verification process when selecting the installation and pipe work configuration for a water meter.

B1.3.2 Approved Verifiers

The Regulations require that the verification of a water meter must be carried out by a person, who in the opinion of the regional council that granted the consent, is suitably qualified. This could be a person from the regional council or an external organisation, provided that the criteria are met.

B2 Guidance for Water Permit Holders for Full Pipes

The following section provides guidance to the minimum requirements for a water meter, its installation and verification, when installed in a full pipe. These requirements are not explicitly stated in the Regulations, but are considered necessary in order to meet the requirements that are stated in the Regulations. Please note that meeting the requirements of this guidance section will not guarantee compliance with the Regulations. It is strongly recommended that water permit holders seek expert advice to ensure that a water meter that is able to be verified as fully compliant with the Regulations is selected and installed.

Figure presents a recommended flow diagram/decision tree which summarises the issues to be considered by permit holders when selecting and installing a meter for a full pipe system.

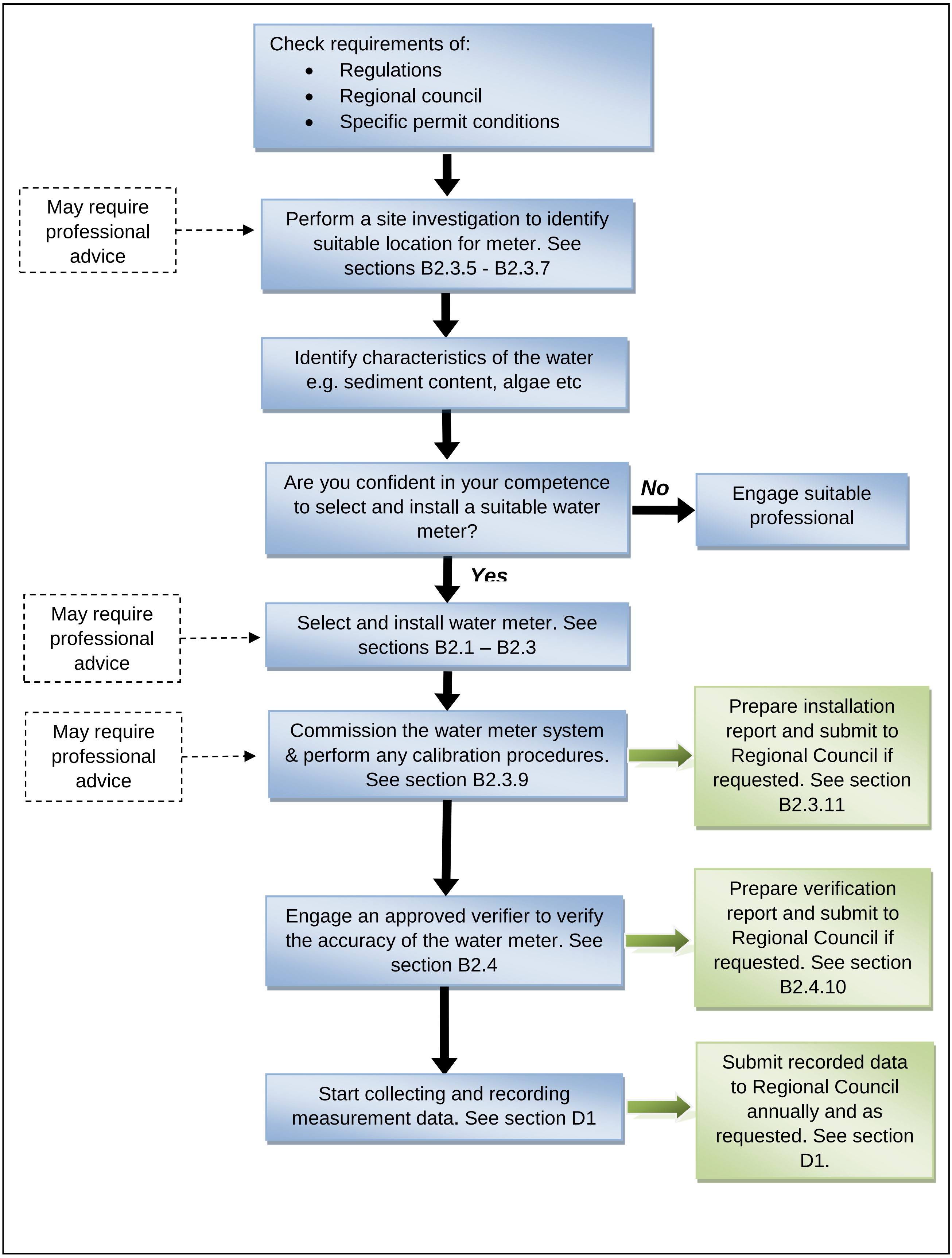


Figure 1: Recommended Decision Process for Permit Holders with Full Pipes

B2.1 Water Meter Requirements

B2.1.1 Water Meter Accuracy

The water meter must be warranted by the manufacturer, that it will meet the required accuracy standard, such that when it is installed according to the manufacturer's instructions, the in situ determination of water volume meets the accuracy limits as stated in the Regulations (±5%)..

The meter must be supplied from a manufacturer certified as compliant to ISO 9001 – Quality Management Systems and the meter's metrological accuracy must have been laboratory-verified prior to installation.

B2.1.2 Water Meter Display

The purpose of an on-site display is to provide a reliable and unambiguous visual indication of the real-time measurement data. The display must have the following characteristics:

- Displays the cumulative volume expressed in cubic metres (m^3), with:
  - sufficiently large registering range to record cumulative volume corresponding to 1 year at the maximum flow rate for which the meter is rated without passing through zero, and
  - a scale interval such that verification can be completed in a practical and cost effective timeframe onsite -the least significant digit should ideally be small enough to ensure that the resolution error of the display does not exceed 0.5% of the equivalent volume passed at the minimum rated flow rate during a 15 minute period

- The values displayed must be precisely the same value as that recorded in a data logger (if installed);
- Be of a size and type that is easy to read with clearly specified units;
- Capable of continuous measurement and totalising; and
- Resistant to corrosion and fogging.

Some regional councils may also require that the meter display the measured flow rate in litres per second (l/s) or cubic metres per second (m^3/s) with a minimum resolution of two decimal points for verification purposes. The permit holder is responsible for checking the requirements of the regional council.

B2.1.3 Data Logging

The Regulations require that the meter be able to provide data in a form suitable for electronic storage. This is not a requirement to fit an electronic data logger. However, the meter must be capable of being fitted with an electronic data logger, i.e. the meter must provide a suitable output signal that can be measured by electronic data loggers, and must have suitable data transfer port/s.

Where a data logger is used, the data from the meter would be recorded in the data logger for later retrieval. It is recommended that data loggers, if installed, should have sufficient

capacity to store no less than one year of flow data, with a logging interval of 1 hour for groundwater takes and 15 minutes for surface water.

Some regional councils may also require that the data loggers are connected to transmission/telemetry equipment. See Section D2 for further information about data management.

The National Environmental Monitoring Standards (NEMS) is a suite of documents dealing with different aspects of environmental monitoring by regional councils. The NEMS document on Measurement of Water Takes indicates how Regional Councils would like data to be presented and how they will manage and use the data. The NEMS document is available at: http://www.landandwater.co.nz/#/nems/

B.2.1.4 Electrical Power Source

Where an installed meter relies on an electrical power source, it shall have a non-volatile memory to ensure that recorded data is not lost in the event of a power or battery failure. The meter must be designed such that in the event of an external power supply failure (AC or DC), the meter indication of volume immediately before failure is not lost, and remains accessible for a minimum of one year. Any other properties or parameters of the meter shall not be affected by an interruption of the electrical supply.

B2.1.4 Security

The Regulations state the water measurement system must be sealed and be as tamper-proof as practicable. Tampering would affect the credibility and hence the usefulness of the data collected. Therefore, the design and installation of the water metering system must take into account all practicable steps to protect the components of the water metering system from intentional tampering. This includes protection devices/seals for individual components that prevent tampering and/or indicate when tampering has occurred.

B2.1.5 Labelling of Water Meter

The meter must have a clearly identifiable manufacturer's serial number securely attached to or imprinted on the meter. This should be located in a position that is easily visible when taking manual readings from the meter display unit. Any certification specific to a meter type, such as C-tick certification for an electromagnetic meter, should also be clearly visible.

Some regional councils may assign an exclusive identification number for each water permit. This number, if assigned, should also be attached to the meter in a clearly visible manor to aid in the identification of the meter.

The meter must also be labelled so as to show the direction of flow, orientation and any other necessary installation information required to achieve the required accuracy.

B2.1.6 Element Protection

Installations should incorporate a degree of environmental protection required to ensure reliable operation in the installation environment. The environmental enclosure rating for the measuring mechanism of the meter should reflect the degree of protection required for the

installation environment. Refer to Appendix A for more information on environmental enclosure ratings.

B2.1.7 Materials

The meter should be manufactured from sound, durable, corrosion resistant materials. All parts of the meter in contact with water must be manufactured from materials that are non-toxic and both chemically and biologically inert.

B2.1.8 Manufacturer's Guidelines

The meter must be supplied with an installation instruction manual from the manufacturer. The manual is to detail all installation requirements (e.g. rated operating flow range and conditions) to achieve the meter's stated accuracy and the type of fluid it is designed for. The manual should also detail any maintenance activities required for normal operation (between verification tests), whether a particular maintenance activity requires a certified maintainer, and when metrological performance can be affected by maintenance (and therefore requires recalibration in a laboratory).

The meter should also be supplied with a wet certification from the manufacturer, certifying the accuracy of the meter.

B2.1.9 Maintenance

The meter must be maintained in full accurate operating condition whenever it is in use. Servicing and maintenance of the meter must always be performed in accordance with the manufacturer's specifications. Any servicing that will affect the accuracy of the meter must be undertaken by a service provider approved by the meter manufacturer or agent.

Water permit holders must retain copies of maintenance records as evidence of the service record of the meter. These must be made available for inspection when requested.

B2.2 Water Meter Selection

B2.2.1 Suitable for Specific Requirements

When selecting a meter, it is important to consider both the quality and quantity of the water that it will be measuring. Regulations require that the meter used in the measurement of water take is suited to the water type. During normal operation, the meter must be capable of maintaining the required accuracy for the expected water quality (temperature/algae content/sediment content) and range of flow rates it is being used for. Any expected or known flow disturbances should not cause the accuracy to deteriorate beyond the approved accuracy range of the meter.

B2.2.2 Life-cycle Costs

It is recommended that the permit holder consider full life-cycle costs of the meter, not just the initial capital costs, when selecting a water meter. Life-cycle costs refer to the total cost of ownership over the life of the water meter. This includes the costs of operation

(electricity/batteries etc), maintenance, inspection/verification and replacement/renewal costs in addition to the capital cost of the meter and its installation.

The costs incurred during the life-cycle of a water meter depend on the meter type and its specific installation parameters (location, water type etc). The life-cycle costs can therefore vary greatly. Furthermore, different water meter technologies have different typical service lifetimes. When considering these, the permit holder should consider the term of the water permit, and the likelihood of the permit being renewed after the current term expires.

B2.2.3 Water Meter Types

There are many types of water meter that meet the technical requirements specified in this guidance document. This section outlines the common types of water meter used to monitor flow in full pipes. The purpose of this section is to give a general overview of common meter types. It is not intended to replace technical information or advice given by manufacturers or suitably qualified professionals.

Table 2 below provides a general description of common meter types, and advantages and disadvantages of them. Appendix B provides a flow chart to help permit holders select the most appropriate type of meter of the three main types; mechanical, ultrasonic, electromagnetic; for their full pipe system.

Table 2: Common Water Meter Types

Meter Type	Description	Advantages	Disadvantages
Helical Vane (Mechanical)	A multi-bladed impeller with helical shaped blades is positioned with the axis of rotation aligned with flow. Rotation of the impeller/vane triggers a magnetic counter to record the flow rate.	• Fully tested replacement mechanisms usually available.	• Bearings wear if the water is not clean. • Stones/grit can stop or damage the vane. • Sensitive to flow disturbances in the system.
Single / Multi Jet (Mechanical)	Single or multiple ports surrounding an internal chamber create a jet/s of water against an impeller. The impellers rotation is related to the flow rate.	• Suitable in situations where meeting minimal pipe lengths is difficult. • Suitable for low flows.	• Bearings wear if the water is not clean. • Internal strainer usually required to prevent clogging of the jet port/s.
Positive Displacement / Volumetric (Mechanical)	The water physically displaces a moving measuring element in direct relation to the amount of water that passes through the meter. The measuring element (piston or disk) moves a magnet that drives the register.	• Suitable in situations where meeting minimal pipe lengths is difficult. • Suitable for low flows.	• Impurities in water cause wear to the chamber, affecting the accuracy of the meter. • Chambers require calibration and replacement over time. • Head loss across the meter can be significant.
Electromagnetic Meters (Mag-flow meter)	Use the physics principle of Faraday's Law of Induction to measure flow within a pipe. A sensor creates a pulsating, alternating magnetic field on the inside of a pipe. The liquid in the pipe moves through this magnetic field and generates a signal current proportional to its velocity.	• Not damaged by dirty water, stones or grit as has no moving parts in flow stream. • No (or low) head loss across meter. • Can be used on wide range of pipe sizes	• Mains power source or long life batteries required • Sensitive to 'electrical noise' • Mag-flow meters encompass a section of the same diameter as the pipe work in which they are being installed, they can therefore be costly in large pipes

Meter Type	Description	Advantages	Disadvantages
Electromagnetic Insertion Meters	The electromagnetic insertion meter uses the same principle as the mag-flow meter described above to measure flow.	• No (or low) head loss across meter. • Unlike electromagnetic meters, the meter does not encompass the full pipe diameter therefore more cost effective in large pipes. • No moving parts in flow stream • Meter is easily removed for calibration or cleaning	• Mains power source or long life batteries required • Sensitive to 'electrical noise'
Reflection Ultrasonic - Doppler	Doppler ultrasonic meters contain a transducer that sends an ultrasonic pulse into the flow stream. Impurities within the flow (such as particles, entrained bubbles) reflect the acoustic sound wave. The meter determines the flow velocity from the velocity of the impurities which is then converted to a flow rate.	• Not damaged by dirty water, stones or grit as no part of the meter is located within the flow stream. • Clamp on models attached to the outside of the pipe work making access for maintenance and verification easy. • Can be used on large diameter pipes.	• Mains power source or long life batteries required • Cannot be used in very clean water • Fluctuating water quality (e.g. varying particle sizes or concentrations) can introduce errors to the measurement • Pipe material may interfere with the measurement if clamp on meter used
Transmission Ultrasonic – Time Transit	Transmission ultrasonic flow meters measure flow velocity (and flow rate indirectly) by directing ultrasonic pulses diagonally across the pipe both up and downstream. The meter measures the difference in time required for the signal to travel through the moving water and converts it to flow velocity.	• Not damaged by dirty water, stones or grit as no part of the meter is located within the flow stream. • Clamp on models attached to the outside of the pipe work making access for maintenance and verification easy. • Can be used on large diameter pipes.	• Mains power source or long life batteries required • Pipe material may interfere with the measurement if clamp on meter used

Meter Type	Description	Advantages	Disadvantages
Insertion Paddle Wheel (Mechanical)	An insertion paddle wheel flow meter uses a paddle wheel, inserted into the pipe, perpendicular to the flow direction. A sensor detects the passage of magnets located on the paddle wheel rotor blades, from which the flow is determined.	• Relatively easy to install in existing pipe systems. • Stones/grit can pass under the paddle wheel. • Can be used in large diameter pipe work.	• Mains power source or long life batteries required • Sensitive to flow disturbances in the system.

B2.3 Installation of Water Meters

B2.3.1 Accuracy Limits & Manufacturer's Instructions

The Regulations require a water meter and any ancillary apparatus to be installed such that the meter achieves the required in situ measurement uncertainty of ±5% of the actual flow. Therefore, the installer is recommended to take all practicable steps to install the meter in such a way to achieve this accuracy.

To ensure measurement accuracy, any operational limitations identified by the manufacturer with respect to the in situ conditions (pipework configuration and water quality, etc) shall be complied with.

B2.3.2 Minimum Installation Requirements

Flow disturbances can have a significant effect on the measurement accuracy of a water meter. Flow disturbances can be caused by proximity to pumps, elbow bends, valves and changes in pipe size. Where possible, components that might cause flow disturbances shall be either eliminated or installed downstream of the water meter installation. In some cases, this will not be practicable; therefore, specific attention will have to be given to minimise any possibility of flow disturbances affecting the accuracy of a water meter.

If a component that causes flow disturbance cannot be eliminated or installed downstream, a minimum length of straight pipe before and after the water meter is considered necessary to minimise the effect of the flow disturbance on a water meter.

Industry best practice for minimising the effects of flow disturbances requires the minimum straight pipe lengths to be:

- Equivalent to 10 times the pipe nominal diameter (DN) on the intake side of the meter; and
- Equivalent to 5 times the pipe DN on the discharge side of the meter.

These minimum straight pipe lengths refer to straight, clean lengths of pipe of uniform cross-section that have the same internal diameter as that of the meter and have no fittings or obstructions.

This configuration and others common within the industry are shown in Appendix G.

Other configurations which do not meet the minimum straight pipe lengths stated above may be acceptable. If another configuration is to be used, written confirmation from the manufacturer of the water meter that the meter will operate to the required accuracy under the revised in situ conditions is required. A water meter should not be installed in any configuration in which the required in situ accuracy cannot be achieved or accuracy adequately verified.

Where installing a meter of the same diameter as the pipe work is impracticable, it is acceptable to install a meter with a smaller diameter than the pipe work (e.g. a 50mm diameter meter into 80mm diameter pipe-work) using reducers with the correct

tapers. To minimise flow disturbance, industry best practice requires the installation of a meter with a smaller diameter be conditional on:

- The use of a 6 to 1 ratio taper followed by a minimum straight pipe length equivalent to 10 times the pipe DN on the intake side of the meter;
- The use of a minimum straight pipe length equivalent to 5 times the pipe DN on the discharge side of the meter followed by a 6 to 1 ratio taper back to the existing pipe work; and
- The flow must still be within the specified flow parameters of the meter.

A water meter may be fitted onto a vertical pipe work (as usually found in wells) provided it is certified for that purpose by the manufacturer of the meter endorsing its installation on upward flow direction.

In circumstances where the meter is not located at a fixed point and is used in conjunction with a portable pump, the meter and associated pipe work must be connected to the pumping equipment when in use, but may be disconnected during relocation. However it is preferable the pipework is fixed to eliminate vibration and bumps which could affect the meters accuracy.

B2.3.3 Future Verification Requirements

Verification can be carried out by a suitably accredited person either in situ or in a laboratory. If verification is to occur in a laboratory, the verifier is likely to require that a section of up and down stream pipe work from the water meter configuration are also taken to the laboratory to replicate the in situ conditions.

It is therefore necessary to consider the practicalities of the verification process of a water meter when selecting the installation and pipe work configuration.

The meter installation configuration (including any enclosure) must also allow removal and dismantling of the meter for inspection of the internal components by the verifier to ensure ongoing compliance.

Replicating the true in situ conditions in a laboratory may be difficult therefore onsite verification is recommended. The following are possible arrangements that could be installed with a water meter installation to allow for future in situ verification testing:

- Flow diversion devices to allow water to run through an independent meter (ie: an appropriately sized, dedicated discharge point downstream of the meter.);
- A section of suitable pipe to allow the appropriate use of a portable clamp-on independent meter;
- A section of pipe with flanges to allow an independent meter to be inserted in-line; or
- A valve to close off the downstream system and an outlet to allow the ‘known volume’ (on-site volumetric or gravimetric method) system to be used.

B2.3.4 Installers, Maintainers & Accreditation

Although the Regulations do not require that an accredited and approved person is used for the installation or maintenance of a water meter, it is recommended that such people are used for these tasks.

Installers and maintainers must hold accreditation under the “Blue Tick” Program. Accreditation is competency based and consists of basic training and workplace workbook based assessment. The Blue Tick Accreditation program provides the permit holder with an assurance that a meter installed or maintained by the accredited person, will be done so in a way that complies with the requirements of the regulations and consent conditions.

The installation configuration of a water meter installed by an accredited person must still be verified by an accredited verifier as meeting the required accuracy as per the regulations, prior to any flow data being recorded for use in reporting.

B2.3.5 Installation Considerations

The installer should carry out adequate pre-installation site investigation and post-installation site reinstatement to ensure the water meter operation and accuracy is not compromised. Practicable precautionary consideration must be taken in the installation to prevent damage from sources such as the following:

- vehicles, livestock, vandalism, and flooding;
- unfavourable hydraulic conditions (cavitation, surging, water hammer)
- shock or vibration induced by the surroundings;
- undue stresses caused by misaligned or unsupported pipes or fittings;
- agressive environmental conditions (eg. corrosive);
- possible electrical interference from electric fencing, overhead power lines or pipe system components such as variable speed drives (VSDs); and,
- extremes of temperature of the water or ambient atmosphere.

The following should also be taken into consideration by the installer:

- The meter must not be installed in a section of pipe where there may be air pockets or the pipe does not run full of water. If it is likely that air will become entrapped near the meter, then an air valve must be installed.
- A meter approved for operation in full flowing pipes, shall be installed so that it is completely filled with water under all conditions during operation. Non-pressurised systems may require elbows or pipe elevation to ensure that this requirement is met.
- Any filtering, straining or screening equipment, if installed, must be installed on the intake side of the meter.
- Any backflow prevention devices, if installed, must be installed on the discharge side of the meter.
- Any chemical injection system, if installed, must be installed on the discharge side of the backflow prevention device.
- A meter may be fitted on the suction side of a pump provided that it is certified for that purpose by the manufacturer of the meter.

- The meter must be installed in the correct direction of flow.
- Where the meter is to be fitted to polyvinyl chloride (PVC) or polyethylene (PE) pipelines, it must be supported by a concrete thrust block or fabricated steel bracing to ensure stability.
- In accordance with current consent conditions.

B2.3.6 Location of Water Meter

The water meter location must be selected with consideration to the following:

- Meters must be located at the location from which the water is taken under the permit, or if approved by the consenting authority, as near as practicable to that location.
- There must be no off-take (except those for permitted water takes e.g. domestic, stock water and fire-fighting), diversion or branch between the meter and the location from which the water is taken under the permit.
- The meter must be mounted in a way that allows for both easy access and manual reading of the display unit (without, for example, the use of a mirror or ladder).
- The meter must be installed in a location that allows for verification of the meter to occur in situ or for the meter to be readily removed to be transported to a laboratory for verification.

The preferred location of all meters is above ground. However, in instances where a meter needs to be installed below ground level, the following must be considered:

- The correct IP rated meter is selected for subsurface use.
- It shall not be installed deeper than 1.5 m below ground level;
- There must be sufficient space to facilitate easy access for maintenance, inspection and reading at all times;
- Meters located up to 0.5 m below ground level must be housed in a suitable meter box to protect the meter whilst still allowing full access to the meter;
- Meters located between 0.5 m and 1.5 m below ground level must include a suitable access pit;
- There must be no risk of water collecting in the access pit/meter box. Measures must be taken to prevent the ingress of surface water and / or provide adequate draining of the access pit or meter box. Such measures could include a concrete apron graded away from a secure lid;
- The access pit/meter box must be secure against the ingress of ground water; and
- Any meter installation located below ground level must comply with the requirements of the ASNZS 2865: Confined Spaces.
    -

B2.3.7 Site of Water Meter & Safety

The meter must be accessible at all times to allow for manual reading, inspection and verification. The installation of the meter shall include the consideration of protective devices and fittings for the protection of the equipment, operators, the public and the environment from damage and harm.

The site of the meter and access to it must:

- be kept clear of any oil, grease, noxious fumes and hazardous materials;
- be kept clear of any unguarded moving machinery;
- be kept clear of vegetation and other obstructions;
- be safe and free from danger;
- have adequate vehicular access provided from the nearest public road; and
- minimise the need for climbing of fences or gates, or passing through any streams, channels or gullies at any time.

B2.3.8 Electrical Standards

Where a mains electricity supply is connected to the meter or to any ancillary apparatus, the installation works must comply and be operated with the relevant New Zealand electrical standards and any associated requirements.

If a meter relies on mains power source it must be hard wired to a dedicated circuit to ensure that the power supply cannot be deliberately interrupted.

B2.3.9 Commissioning

Commissioning shall be conducted by the installer to ensure that the meter is ready for verification and subsequent use. The commissioning procedure will include the following checks:

- Check that all components have been installed according to the specific manufacturer's installation requirements;
- Check that there are no leaks in the installation;
- All tamper seals are fitted;
- Check that required calibration (if any) has been completed;
- Check that all components are sufficiently protected from damage; and
- Check that the installation is in accordance with any more stringent requirements of the consenting authority.
- Check that the meter is working correctly and accurate to ± 5%.

B2.3.10 Maintenance Requirements

The meter installation configuration must allow for maintenance.

The meter and its ancillary equipment must be periodically maintained over its working life such that there is an acceptable level of confidence that the meter continues to operate within its permissible in situ measurement uncertainty of ±5% of reading. The regional council may ask for a maintenance plan to be developed based on the manufacturer's recommendations and submitted for approval.

If the maintenance activity undertaken was identified by the manufacturer as affecting the metrological performance of the meter, then the meter must be recalibrated in a laboratory. If the maintenance activity undertaken interferes with the installation configuration, then in situ re-verification is required.

Preventative maintenance generally includes checking the structural integrity of pipe-work and fittings, an assessment of components for wear or damage, and replacement of components at the appropriate time.

The details and findings of any maintenance/inspection works shall be recorded in a logbook kept by the permit holder, for that purpose. A copy of the logbook shall be kept as some regional council's may request to view it.

B2.3.11 Submission of Installation Report

Upon completion of the meter installation, the installer should submit the following installation information to the relevant regional council to aid in record keeping:

- A report providing specifications of the meter installation, signed by the installer;
- A detailed as-built diagram and photograph of the installation configuration, including dimensions and verification facilities provided;

The report should include the following information:

- The installer organisation's name, address and contact phone numbers
- Installation date;
- The make, size, type, and serial number of the meter;
- Permit holder's name;
- Meter location description including Global Positioning System (GPS) coordinates;
- Name and signature of the installer; and
- Any other information requested by the regional council.
- A template for an installation report is included in Appendix H.

B2.4 Verification of Accuracy

B2.4.1 Purpose of Verification

Verification gives certainty that a water meter meets the accuracy standard required in the Regulations, i.e. the in situ determination of water volume must have a maximum permissible error of ±5% plus uncertainty of ±3% of reading for the entire rated flow rate range under rated operating conditions.

B2.4.2 Required Verification Frequency

The installed meter must be independently verified at the times stipulated in the Regulations, i.e. initially after installation, and then every 5 years.

The accuracy of all water meters must be verified every 5 years by a suitably accredited person. This can be performed either on-site or at an accredited laboratory. However, if the meter is verified in a laboratory, the verifier may require that the minimum upstream and downstream pipe work lengths required to minimise flow disturbances in the configuration (as set out in Section B2.3.2), are also dismantled and used in the laboratory verification.

B2.4.3 Approved Verifiers

Verification of the meter must be carried out by a person, who in the opinion of the relevant regional council that granted the water permit, is suitably accredited to verify the particular meter.

The verifier can be part of the relevant regional council or an external organisation, provided that the criteria are met.

B2.4.4 Verification Equipment

- The equipment used for verification must be suitable for the use of verifying the accuracy of water meters:
- Best practice: The verification device must have a greater or equal accuracy to the meter being verified.
- Each Brand and Model of reference device shall have an initial independent test to determine its suitability.

The reference devices used for verification must also be:

- Calibrated and certified annually to within a known measurement error that is no more than ±2% of reading.
- Calibrated and certified by an ISO17025 accredited laboratory.
- Installed as per the manufacturers specification to guarantee accuracy of the device
- Operated by a suitably qualified person.

B2.4.5 Verification Test Flow Rate & Replication

The verification test should be conducted for the typical flow rate of the system. If practicable it is also recommended that the verification test should be undertaken for a range of different flow rates, to include:

- Low – The minimum flow rate the water meter is required to perform at to within ± 5% of reading.
- High – The maximum flow rate the water meter is required to perform at to within ± 5% of reading.
- Medium – Halfway between the low and high flow rates.

The maximum flow rate to which the meter is required to perform is equal to the maximum water take system capacity, e.g. the maximum pump rate or pipe capacity.

If it is not possible to test at the different flow rates, a minimum of three replicates of the verification test must be performed at the same flow rate.

B2.4.6 Verification Test Volume & Duration

The verification volume must be sufficiently large to allow a meter reading of at least 0.5% of the meter’s lowest measuring increments. For example, if the meter counter’s lowest increments are 0.001 cubic metres (1 litre) then 0.2 cubic metres (200 litres) must past through the meter.

A meter test must not exceed 90 minutes in duration and typically each test should be run for 10 minutes at a steady flow rate.

B2.4.7 General Inspection

For all meters, it is suggested that the verification includes the following inspection steps (as appropriate) to ensure that the meter measurements are reliable:

- Check that the meter is used in an appropriate manner;
- Check that the totaliser is non-resettable;
- Check maintenance records and preventative maintenance plans;
- Check that the readings on the display are clearly visible and unambiguous;
- Check for evidence of interruption of signal transfer between the measurement component and the recording component;
- Check that power supply is reliable (e.g. if the meter uses batteries, then the expected replacement date are marked and not yet due);
- Check that tamper-proof seals are in place and unbroken;
- Check that there are no leaks that bypass the measuring point;
- Check that earthing and lightning arrestors, if installed, are sound;
- Check for scaling or build-up of calcium, iron oxide or iron bacteria;
- Check that filters/strainers/screens, if installed, are clean;
- Check that environmental element protection from weather and other damage are adequate; and
- Check that meter usage is within stipulated design life (e.g. years, cumulative volume, etc).
- Check that the meter installation complies with consent conditions.

B2.4.8 Verification Report

A verification report shall be issued by the approved verifier for all meters verified. The regional council may request a copy of this for its own records.

The verification report shall have as a minimum:

- The verifier organisation's name, address and contact phone numbers;
- Verification date;
- The make, size, type, and serial number of the service meter;
- Permit holder's name;
- Permit Identifier
- Meter location description, including Global Positioning System coordinates (optional);
- Meter reading (m^3) prior to verification;
- Meter reading (m^3) after verification;
- Flow rates tested and individual accuracy requirement compliance/non-compliance for each flow rate;
- Verification test procedure including all input data as applicable, for example pipe thickness, water temperature;
- General inspection notes;
- Confirmation that the reference device is currently certified. Information such as a calibration reference number and details of the reference meter including make, model and serial number, is available on request;
- Photographs of the verification meter installation and
- Name and signature of the verifier.

A template for a verification report is included in Appendix L, however some regional councils may require more information, check with the relevant regional council before undertaking the verification

B2.4.9 Verification Methods

An outline of the methods which may be used for verification is shown below. Not all of these methods are acceptable by Regional Councils in New Zealand. A table of which verification methods are acceptable to each Regional Council is provided in Appendix S and the methods of performing these tests will be provided during training. The verifying contractor should consult the local authority in the area(s) in which he intends to operate and clarify which methods of verification are acceptable.

Ultrasonic Clamp-on Meter

The ultrasonic clamp-on flow meter is a non-invasive device used to measure full pipe flow in closed conduits. These meters are unique in their ability to measure flow with little or no modification to existing pipe configuration. They are used extensively in the water industry to provide measurements where there is no permanently installed meter and to verify the accuracy of permanently installed meters.

Best practice installation requires 10 straight diameters of pipe free of obstructions upstream and at least 5 straight diameters free of obstructions downstream from the meter. A common problem found in irrigation meter installations is that an upstream, unobstructed, straight pipe length cannot be achieved. This often results in attempts to perform ultra-sonic clamp-on verifications in piping configurations that are less than ideal.

A location should be chosen where the pipe is new or free of imperfections and unlined, and where accurate pipe dimension data is available. The area of the pipe where the transducers are applied needs to be treated to ensure a smooth finish free of debris or corrosion. Care must also be taken to avoid reflecting the ultrasound on an internal area which may be uneven.

To reduce repeatability error, the position of the transducers may be marked for subsequent tests. This way the transducers can be fixed to the same position and previous setup information used. It is also prudent, although not essential, to protect a designated section of pipe surface from the weather.

Clamp-on ultrasonic meters should not be used on downward flowing vertical pipes as this can introduce uncertainties in the flow profile, combined with the possibility of a loss of signal due to the pipe wall interior not being wetted by the fluid.

When setting up transducers it is important to apply enough gel to the transducer face to ensure good signal transmission between the pipe surface and transducer. The signal configuration is also an important consideration, for example, large pipe signal transmission may be poor with a double transverse configuration in comparison to a single transverse configuration. For horizontal pipe setups the transducers should not be positioned at the top or bottom of the pipe as air or debris may be present. Records stating the transducer set should also be kept for each site.

Given the importance of set-up requirements and the need for proper knowledge of the conditions, it is essential comprehensive data recording is carried out, both initially and for subsequent tests. This should include; site details; dimensional characteristics of the pipe; set-up parameters; diagnostics parameters and relevant observations. These data can be used to verify or confirm future measurements and also reduce uncertainty through human error.

To achieve both high accuracy and low uncertainty it is essential that; the pipe is in good condition externally and internally; the site where the transducers are installed is free of welds / joints and is situated well downstream of any potential sources of flow turbulence such as bends or valves.

The ultrasonic clamp-on method has numerous advantages, making it the common choice for many full pipe meter installations, However it also has disadvantages, the three key potential sources of error are; the pipe’s internal diameter; the flow velocity profile (turbulent flow); and acoustic interference (caused by sediment or other build up in the pipe). If these are managed, this method is the quickest, easiest and most cost effective full pipe in-situ verification method available.

Reference Meter In-Series (In-line or Bypass)

A reference meter placed in series with a service flow meter has the potential to be an effective in-situ verification method. With this technique a reference meter is brought to site and fitted to the service meter installation pipe work (either in-line or through a by-pass after the service meter). The reference meter can also be located somewhere in the pipe system where hydraulic conditions are favourable or on a purpose built test rig. It is important to ensure no losses/leaks occur between the service and reference meter. This technique requires a number of conditions to be met to achieve a good level of accuracy.

Verification procedures must be done carefully and with attention to detail. Issues that require special attention include handling, installation configuration disturbances, logging, and flow rate profile.

It is best to record the register readings of both meters simultaneously using the pulse output function with loggers. Generally, a longer reporting period will result in smaller expanded error.

Accuracies for reference meters in series typically range from 0.5 to 2%. Expanded errors and uncertainty analysis of both meters need to be determined

Insertion Meter

Insertion meters are used to measure fluid velocity at a point within a pipe's cross-section. They do not measure the surrounding flow velocities outside of the immediate location of the probe sensor point. The user of a secondary device must calculate the volumetric flow rate based on knowledge of the flow profile within the pipe. An insertion meter can take the form of a pitot tube, an electromagnetic sensor, a turbine type sensor, or a thermal sensor fitted to the end of a probe.

The electromagnetic and paddle wheel meters are the most common insertion probes used for measurement of water volumes. Using these probes is a specialised skill as each probe type differs in the way it should be operated.

The electromagnetic insertion meter consists of an electromagnetic sensing head mounted on the end of a support rod. It uses the same principle to measure the flow as a full-bore electromagnetic meter.

The paddlewheel meter requires an insertion depth of about half the pipe diameter so that around one half of the paddle protrudes into the flow stream. Fluid flowing through the pipe causes the paddlewheel to spin. As the magnets that are embedded in the paddle spin past the sensor, electrical pulses are produced that are proportional to the rate of flow.

Various pipe fittings styles are available. Some fitting styles are designed to install directly into the pipeline using connection methods such as male or female threads, socket weld, socket fusion, and butt fusion joints. These "in-line" fittings are available in a variety of materials such as PVDF, polypropylene, and stainless steel, and with and without union connections. Because the manufacturer can control the inside diameter of the fitting, in-line fittings are available in a variety of operating flow ranges to accommodate various applications. Saddle style fittings are designed to mount directly on an existing pipe. The saddle is installed by simply drilling a hole in the pipe and clamping the saddle onto the pipe. Saddles are available in a variety of materials.

Measurement accuracy generally ranges from 2 to 5 % but 1 to 10% can be expected in different circumstances. Calibration in a location without a well-developed flow profile can lead to large errors. Sources of inaccuracy with insertion probes include:

- Errors in internal pipe diameter, cross-sectional area and pipe ovality
- Blockage factor as a result of disturbances caused by the probe shaft
- Pulsating and unstable flows
- Temperature effects on the operation of the instrument
- Error associated with flow velocity profiling across the pipe cross-section
- Alignment of probe head to flow direction
- Insertion depth and angle
- Unsteady flow has the potential to create transient effects that greatly alter flow velocity
- Varying flow rates between point measurements while determining profiles
- Errors and uncertainties instrumentation calibration
- Particulate material in the fluid.

This technique works best for a fully developed flow profile usually achieved by installing the probe after a long length of straight pipe. The required straight length depends on the nature of the upstream disturbances to the flow.

The use of insertion meters as a method of verification is not acceptable to Regional Councils in New Zealand.

Volumetric and Gravimetric

These techniques involve either;

- The collection of an amount of liquid (weight or volume) in a tank within a certain time interval; or
- Passing a known amount (weight or volume) through the service meter and recording the time period taken for this to occur.

The first method is accurate, but of limited practical use as it is only suitable for very low flow rates, typically under 1l/s (the Regulations apply to takes of 5l/s and above). A detailed description of this method is provided in ISO 8316 – "Method by collection of the liquid in a volumetric tank".

The second method will likely be commonly used by the municipal water supply industries as storages of known volume and with level sensors, are frequently part of delivery system design.

On-site Electronic Validation

The on-site electronic validation method is available for a number of electromagnetic water meters. It validates the current functionality of the meters internal properties (transmitters, insulation integrity, magnetism, and digital and analogue output test) in relation to the original factory settings (the meters properties at the time of wet test certification).

However, despite being an excellent method for trouble shooting potential errors with the water meter itself, it does not provide certainty that installation is within +/-5% as required by the regulations. Therefore, the method is not suitable for initial verification. However providing there have been no changes to the pump, headworks and distribution system it is suited for use as an on-going verification mechanism.

Tracers

For the tracer method a pulse of tracer fluid is injected into the main flow stream and the time taken for the tracer to pass between two detection points is measured. The fluid flow rate is a function of the tracer injection rate and its downstream concentration. A detailed description of transit-time and the dilution methods is provided in ISO 9555.

Typical tracers used with this method are Rhodamine WT and lithium chloride both are considered not harmful to plant species when in low concentrations. Choosing an appropriate tracer should be based on quality of water and experience with the tracer and respective analytical techniques.

The test procedure is relatively complex and requires care to ensure that results are not affected by experimental error.

Rhodamine WT concentration is sensitive to temperature, and fluorometer calibration requires preparation of precise dilution solutions. Rhodamine is also adsorbed onto clay material, which may have a bearing in irrigation channels. Salt can also be used in freshwater flows and is sometimes used for dilution gauging of natural streams.

Lithium chloride has the drawback that it is not measurable in the field and thus checks cannot be made on the testing procedure (e.g. constant tracer injection, fully mixed flow conditions, attainment of steady-state conditions.

While this method can give accurate results it is unlikely to be of practical use in closed conduit metering installations for the following reasons:

- Not suitable for sluggish or slow moving flows
- Difficult to determine the volume between detectors
- Often requires many measurements, which can be time consuming
- Injection of tracers against pressure in pipelines can be a challenge
- Area measurements, tracer dispersion mixing control, and better measurement of tracer cloud take time
- It may be difficult to find an above ground pipeline that is long enough for accurate time measurement because of high velocities and pipeline fittings
- Tracers should be stable, should not deposit or react with chemicals in the water or with the pipe walls, and should neither fade in sunlight nor be absorbed by open channel beds and their biological growths
- The primary source of error occurs in accurately determining the tracer concentration
- Accuracy is sensitive to how well the centre of mass of the tracer clouds is determined with respect to time

The use of tracers is complicated and not generally used for verification when easier methods are available. Tracers are more commonly used in open channels.

Table 3: Verification Method Advantages & Disadvantages

Method	Advantages	Disadvantages
Ultra-sonic Clamp on	• Eliminates in-line installation • One meter can be used at many locations • Non-invasive installation eliminates pressure losses • Prevents leaking associated with in-line meter installations • Portable • Can be installed almost anywhere • Does not require a field calibration	• Good installation conditions necessary • Electronic technician required to troubleshoot and service • Must be configured for pipeline material, diameter and wall thickness • Internal pipe conditions are often unknown • Turbulence and/or suspended sediment affect the acoustic signal strength • Needs precise geometry and dimensional data for the clamping arrangement and pipe, plus the speed of sound in the wedge, the pipe wall and the fluid • Requires a correction factor to allow for variation in the flow profile • Signal attenuation due to liner separation or scaling • Verifier needs training to be competent in meters use.
Reference Meter In-Series	• Can be relatively quick if field installation is configured to accommodate the reference meter or there is an alternative location away from the service meter where the pipe work is adequate and no losses or leaks are present • May provide an opportunity to inspect the condition of the pipe internal surface	• Requires an installation that can accommodate the reference meter (in-line or bypass) and therefore can be expensive to retrofit • Good installation procedures and techniques are required to stop interference by the reference meter to the field meter
Insertion Meter	• Quick and simple method if the installation if meter installation consists of a permanent saddle arrangement to accommodate the insertion probe • Minimal downtime or impact to operation • Paddle wheel probe offers the least head loss • Some models have pulse output capability that can be extremely useful for in-situ verification assessment when logging flow data both the service meter and insertion probe	• Can be time-consuming for a partially developed flow profile (velocity profile is necessary in most cases) • Can cause disturbance in flow • Some insertion probes (electromagnetic) are limited to a maximum velocity • Probes that require a large insertion depth can cause notable head loss • 'Clean' water is necessary for the mechanical insertion probes to operate properly. Particles and debris will affect the paddle wheel operation • Method is not acceptable to most Regional Councils in New Zealand.
Volumetric and Gravimetric	• Very accurate method suitable for small volumes	• Not suitable for high flow rates - particularly set time and volume method • Expensive to retrofit installations • Potentially large errors associated with measurements depending on tank characteristics, level measurement and temperature.

B2.4.10 Verification Method Error & Uncertainty

Verification is carried out to verify that meter readings are an accurate record of the actual water flowing through the meter. Central to the verification process is the interpretation of the meter's accuracy from the results of the verification tests.

The verifier will need to identify all sources of error and uncertainty in the reference measurement, including the certified error of the reference meter, environmental/pipe conditions, and inaccuracy in any input values (e.g. pipe wall thickness, level sensors........) required for some reference meters.

Refer to Appendix F for more information on understanding and calculating verification error & uncertainty.

Ultrasonic Clamp-On Meter

A range of issues need to be considered when assessing the accuracy of ultrasonic clamp on flow meters. Accuracies between +/-2 to +/-5% (NEL 2002) are achieved when devices are installed properly and carefully set up in suitable flow conditions. While there are many sources of error, the three key ones are; the pipe's internal diameter, the flow velocity profile, and acoustic interference. Under adverse conditions, these and other factors can result in poor accuracies of between +/-5 and +/-10%.

To minimise uncertainty it is desirable to have 30 pipe diameters in length of straight-pipe section upstream of the clamp-on meters to ensure a well-developed flow profile, however such an approach would be impractical and costly. Since 30 pipe diameters are rarely used in installations at least 10 straight diameters free of obstructions upstream and at least 5 straight diameters free of obstructions downstream from the meter is recommended.

A common problem in irrigation meter installations is that an upstream unobstructed, straight pipe length cannot be achieved and metering is often performed in a non-ideal piping configuration. Eisenhauer (2008) from University of Nebraska recommends the use of a bias correction to find a more accurate flow rate in the circumstances where the ultrasonic clamp-on meter must be installed closer than 10 diameters.

Sanderson and Yeung (2002) assessed the performance of an ultrasonic clamp-on meter for a range of disturbances. Apart from the conical contraction disturbance the minimum upstream length requirement to achieve an accuracy of +/-2% was 18 diameters (see Table 4).

Table 4: Upstream length requirements to achieve an uncertainty of less than +/-2% for different disturbances Sanderson and Yeung (2002)

Disturbance	Number of Diameters required to reduce error to less than ±2%
Conical Contraction	4
Conical Expansion	18
Single 90° Bend	30
Two bends 90° in 'U'	22
Two 90° bends in perpendicular planes	47
Butterfly valve 2/3 open	18
Globe valve 2/3 open	15
Gate valve 2/3 open	20

Determination of internal pipe diameter

Errors in flow measurement can arise from uncertainties in measuring pipe dimensions, particularly internal diameter, pipe thickness, roughness of internal walls and the shape of the pipe.

Pipe manufacturer specification charts can be used as a good guide of pipe wall thickness. However, to accurately determine pipe wall thickness in situ an ultra sonic thickness gauge (micrometer) should be used. For this method a minimum of 5 measurements must be taken and the mean calculated.

To determine the internal pipe diameter in the field involves measuring the pipe external circumference and wall (and liner) thickness.

Both measurements are potential sources of error. A study (NEL 2001) that assessed the magnitude of the errors associated with pipe internal diameter determination revealed the characteristics of errors for different size pipes and wall thicknesses. Figure 2 and 3 show the relationship between dimensional error (circumference and wall thickness) and flow error (%).

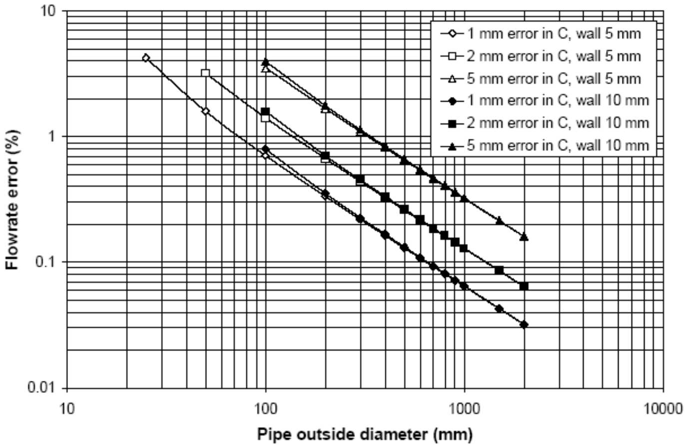


Figure 2: Errors resulting from measurement of circumference inaccuracies

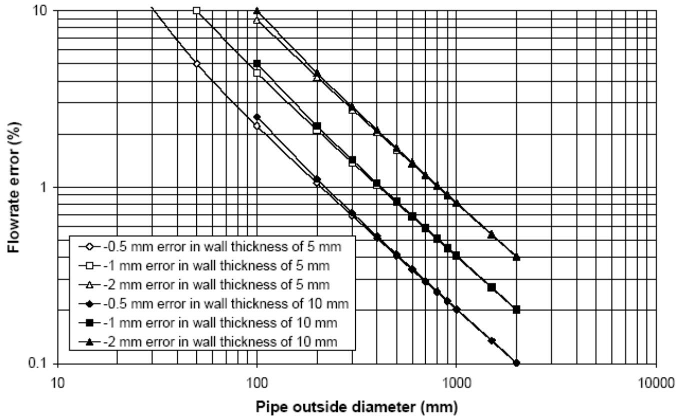


Figure 3: Errors resulting from measurement of wall thickness

Ovality error

Pipes can be damaged during handling and as a result of field conditions. The distortions result in the pipe cross-section having an oval shape, which causes an error of measurement when using ultrasonic clamp-on meter. An investigation by NEL (2001) was carried out to assess the magnitude of the errors. The error can be relatively small if the transducers are placed at 45 degrees to the horizontal axis, however, when the transducers are placed at other angles the errors can be significant. The errors are exaggerated when the transducers are placed diagonally along the longest distance of the pipe 'diameter'. The potential errors are shown in Figure 4.

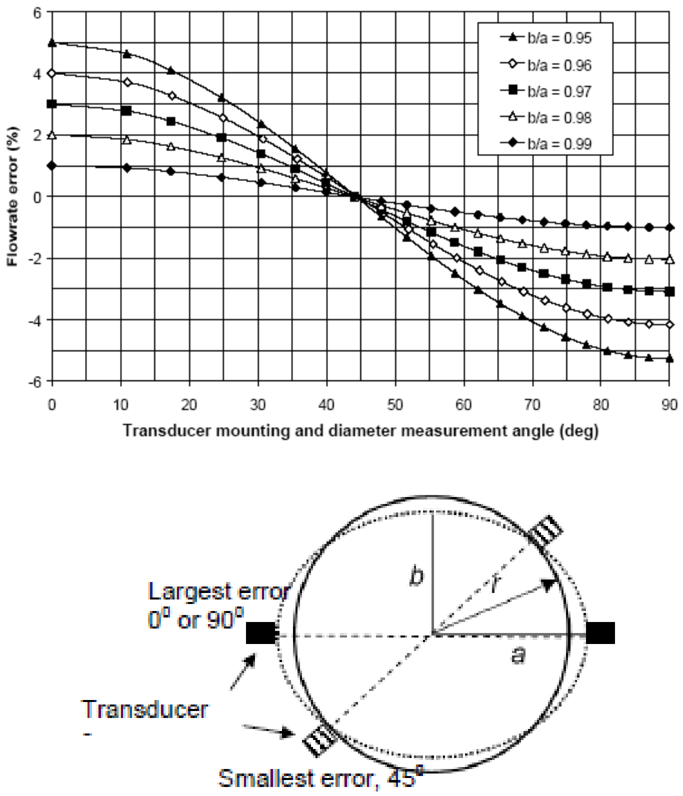


Figure 4: Errors due to ovality and positioning of transducers

Pipe roughness error

Internal - Pipe roughness affects the velocity profile and is particularly important when determining the parameters for an ultrasonic clamp-on meter. An investigation by NEL (2001) on this effect was carried out to assess the magnitude of the errors resulting for surface roughness increase from 0.1 to 0.4 mm. Figure 5 shows the characteristic of error resulting from the pipe roughness with velocity. The influence of pipe roughness reduces as the pipe diameter increases.

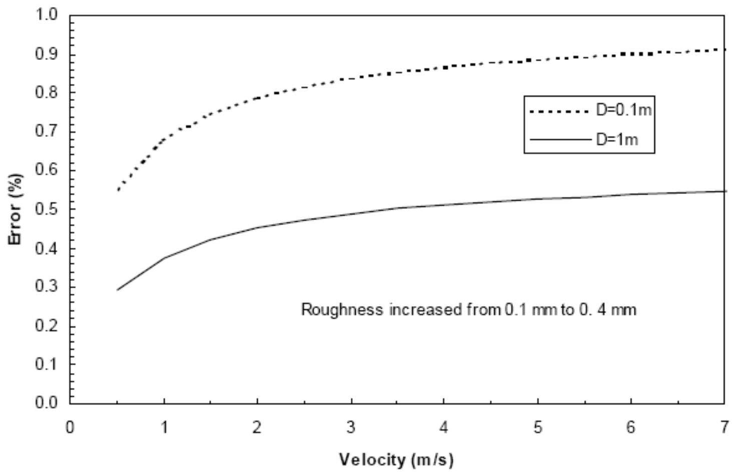


Figure 5: Errors due to pipe internal roughness

External – Pipe roughness and coatings (particularly galvanised) can affect signal strength of ultrasonic clamp-on meters. Carefully preparation of the surface too which the transducers are applied can help overcome this.

Flow disturbance error

Depending on their configuration and how close they are to the meter, hydraulic components such as bends, valves and pipe expansions can result in flow measurement error. Such disturbances cause severe flow distortion that can persist over a considerable distance downstream. An investigation by NEL (2001) was carried out to assess the magnitude of the errors resulting from a single bend in the pipe upstream of the ultrasonic clamp-on meter. The error was determined when the meter was placed at three distances (2.5, 12.5 and 22.5 diameters) downstream of the 90^o bend.

Figure 6 shows flow measurement error improves greatly as the distance between the bend and the meter increases. Dual path measurements were made using a double traverse meter.

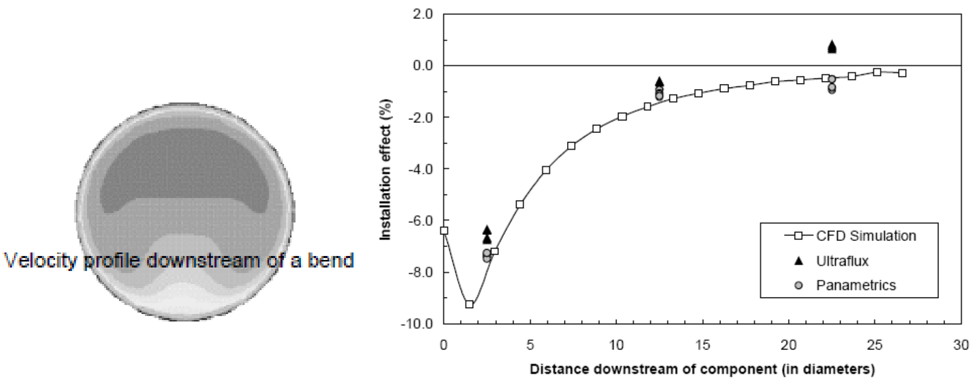


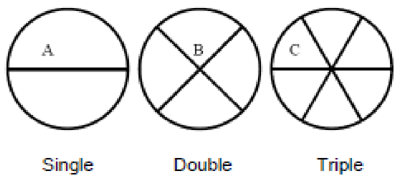
Figure 6: Errors downstream of a single bend (dual-path, double traverse)

Minimising errors due to distorted velocity profiles

It is common practice to minimise flow disturbance, however, where this is not practical it is possible to reduce the impact of flow velocity profile with improvement measurement techniques.

One technique is to undertake the ultrasonic Camp-on meter measurement in more than one plane or diametric path. This is particularly important when the velocity profile is not axisymmetric (cylindrical symmetry). A computational analysis (NEL 2001) was carried out to assess errors when flow measurements were made with single, dual and triple diametric paths.

Thirteen different distorted velocity profiles were assessed. Figure 7 shows that a dual diametric measurement is much better that a single diametric measurement but similar to a triple diametric measurement.



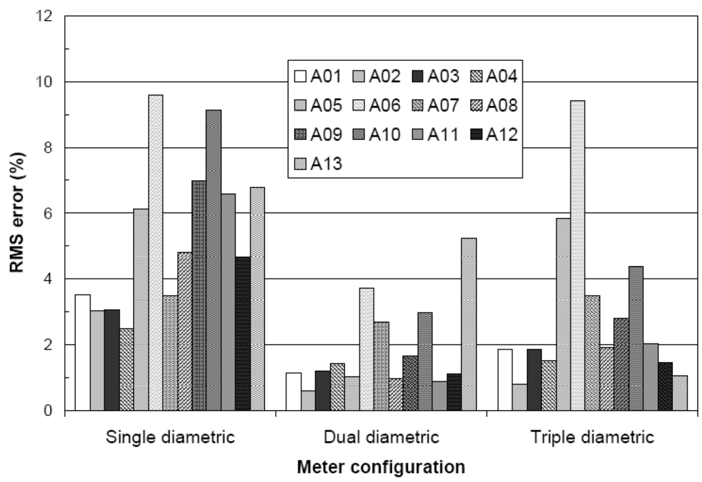


Figure 7: Errors characteristics for diametric paths

Other verification options

Many ultrasonic clamp-on meter installations can report parameters that can be used to verify the status of the meter. The diagnostic check does not determine accuracy but assesses the strength and speed of the signal for a range of configurations which can then be compared to the manufacturers' specifications. For example, a discrepancy of the sound of speed in water (at 20^{o}) of 15 m/s will result in a flow measurement error of 1%.

This technique can help the user select or confirm the material lining the pipe. One of the benefits of the ultrasonic clamp-on meter is that the diagnostic check can be undertaken at a site where conditions can be controlled.

Data collection

The initial set up of an ultrasonic clamp-on meter requires establishing some background knowledge, including determining specific details about the meter location. The information generated during each set up is valuable for checking or identifying information. Much of the information should be recorded and used in subsequent test set ups. A good recording system should include information such as setup parameters, pipe configuration details, transducer placement location, pipe material, dimensions and conditions, manufacturer's details, previous test data, and diagnostic checks. All sites should have their own set of information as each is likely be different or change over time.

Reference Meter In-Series (In-line or Bypass)

A reference meter placed in series with a service meter has the potential to be an effective in-situ verification method. In this technique a reference meter is brought to site and fitted to the service meter installation pipe work. Alternatively a take-off after the service meter (located so no changes in the flow characteristics occur) is used to attach a portable reference meter. This method allows the reference or check meter to be located somewhere in or outside the pipe system where hydraulic conditions are favourable. It is important to ensure no losses or leaks can occur between the service and reference meter. This technique requires a number of conditions to be met to achieve a good level of accuracy.

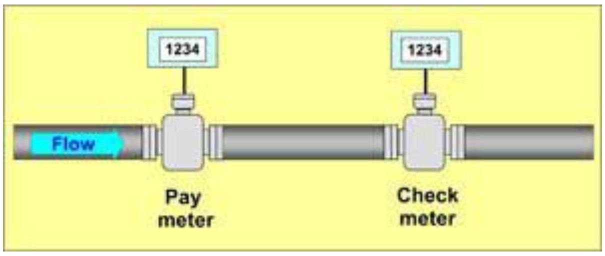


Figure 8: One flow meter verifies another (Livelli 2007)

Accuracies for reference meters in series typically range from +/-0.5 to 2%.

Expanded errors and uncertainty analysis should be determined for both meters. An example of an analysis is shown in Table 5.

Table 5: Uncertainty analysis, example error

Uncertainty in	Monthly Quantity		Value	275160	m3		
Source (1)	Expanded uncertainty % (2)	 m^3 (3)	Probability distribution (4)	Divisor (5)	Sensitivity Coefficient (6)	Standard uncertainty (7)	Standard Uncertainty Squared (8)
Meter 1							
Uncertainty at High Flow	0	0	Rect	1.732	1	0.0000	0.00E+00
Uncertainty at <10%	1	1800	Rect	1.732	1	1039.23	1.08E+06
Uncertainty at <1%	10	750	Rect	1.732	1	433.01	1.88E+05
Calibration	3.71	10213.51	Normal.	2	1	5106.75	2.61E+07
Calibration error (Tolerance)	2	5503.2	Rect	1.732	1	3177.27	1.01E+07
Ageing	0	0	Rect	1.732	1		
Installation	0	0	Rect	1.732	1		
Combined uncertainty	4.45%	12237.89	Normal	2	1	6118.94	3.74E+07

On-site Volumetric or Gravimetric Method

Uncertainties typically vary from 1 to 5%, and the main sources of error are the tank volume measurement or weighing device and temperature. However, usually this method involves test volumes that are too large to make the use of this technique feasible.

As a guide the test volume should be at least equal the Q_3 (or typical service flow) flow over a 30-second period. Small uncertainties in the tank internal diameter, level measurement and temperature can have a big effect on the calibration accuracy.

Significant site works with pipe work are required, and the potential for wasting water is high.

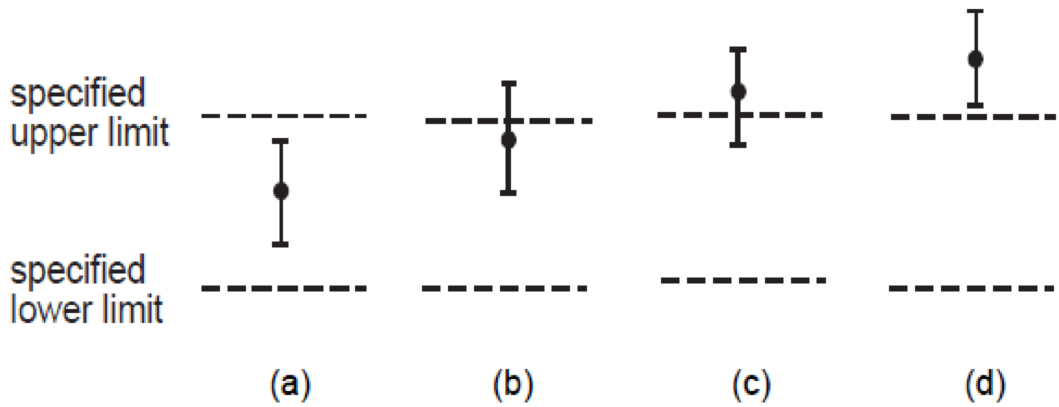
Level	Options	Requirements for electronic verification	Requirements for dry calibration
1	Checking electrode electrical contact with liquid	Yes	Yes
2	Checking for integrity of cables and earth shields	Yes	Yes
3	Simulation of flow signals into the electrode amplifier circuits	Yes	Yes
4	Checking for constancy of the magnetic field during signal measurement	Yes	Yes
5	Checking for constancy and integrity of the magnetic field and field coils since manufacture	Yes	Yes
6	Checking that the wetted geometry is unchanged and that the generated signal will have a constant relationship with the volumetric flow		Yes

B2.4.11 Verification and Compliance

The measurement accuracy of the service meter must be interpreted taking into consideration the error and uncertainty of the reference measurements. For example, if the verifier ascertains that the reference measurement uncertainty is +/-3% of reading, then the non-compliance with the accuracy requirement will be identified if the reference measurement is outside +/-8% of the installed meter measurement.

Uncertainty of the reference measurements must be taken into consideration when determining non-compliance because the Regulations state that the measurement by the meter must be within +/-5% of the actual volume taken (which is unknown), not of the reference measurement.

Sometimes a result may fall clearly inside or outside the specified limit (+/-5%), but the uncertainty may overlap the limit. Four kinds of compliance outcome are shown below



In Case (a), both the result and the uncertainty fall inside the specified limits. This is classed as a ‘compliance’.

In Case (d), neither the result nor any part of the uncertainty band falls within the specified limits. This is classed as a ‘non-compliance’.

Cases (b) and (c) are neither completely inside nor outside the limits. No firm conclusion about compliance can be made.
There is much complexity and subjectivity in calculating uncertainty for the verification of full pipe water measurement. Many factors are unable to be easily or practically determined in-situ and a sound knowledge of statistics is also required.

A number of detailed scientific studies have been undertaken with regard to the in-situ verification of full pipe water measurement. From these the uncertainty 'can be expected to be in the region of +/-2-5%' (NEL 2002) for both of the commonly used verification methods in NZ (insertion probe and clamp-on ultrasonic meters).

This guideline recommends that an uncertainty of +/-3% be applied as a standard for in-situ verification in NZ as this will save unnecessary cost and time associated with the calculation of uncertainty. If a greater degree of uncertainty is thought to influence the reference measurement then the verifier must undertake the uncertainty calculations and demonstrate this.

Failed verifications

Should a meter installation fail a verification:

- Do not adjust the verification results
- The meter installation should be checked to ensure it meets the manufacturer's recommendations. The installation may be checked by the manufacturer's representative.
- If the installation is correct the meter will need to be tested in a wet lab or replaced.

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Section C: Water Measurement Systems for Open Channels and Partially Full Pipes

C1 Section Introduction

C1.1 Section Summary

Measurement of flow in open channels and partially full pipes differs considerably from measurement of flow in full pipes. In general, for water takes in open channels and most partially full pipes:

- Site conditions play a very important part in the determining whether a measurement system is suitable.
- In situ calibration is crucial to ensure that the system for open channels and partially full pipes can measure to the required accuracy.
- Frequent inspection and maintenance are essential for continued reliable operation.
- Specialist expertise may be invaluable, especially for complex sites.

This guideline document is intended to provide a useful consolidated summary of information about meeting the requirements of the Regulations. Where the requirements of the regulations are discussed, the prescription of measurement methods is intentionally avoided so as to allow for future innovation in measurement methods.

The end of the section contains guidance information on measurement methods that may be suitable for open channels and partially full pipes. While this information can assist permit holders, it is not intended to be a substitute for specific professional advice and installation expertise, especially for complex sites.

C1.2 Section Structure

Section C of this document covers water measurement systems for measuring the volume of water abstracted by a method other than by a full pipe, i.e. by open channel or partially full pipe abstraction.

Section C2 covers the minimum requirements and associated best practice recommendations for *all* water measurement systems in open channels and partially full pipes. These requirements and recommendations allow for a wide range of site conditions, and for new measurement methods that may be developed in the future. This section is relevant for *all* permit holders to which the Regulations apply.

Section C3 then outlines the required verification process which is the primary means of quality assurance and the main process for assessing compliance with the accuracy requirement of the Regulations. *All* permit holders to which the Regulations apply should be aware of the process involved.

Sections C4 and C5 contain guidance information on measurement methods that may be suitable for open channels and partially full pipes.

C1.3 Assessment of the Task

Open channel flow measurement is generally more complex than full pipe flow measurement because site conditions may have a significant effect. Reliable flow measurement involves carefully selecting a suitable measurement site, constructing and calibrating an appropriate control section (generally with a flow restriction such as a weir or flume) and accurately measuring the upstream water level. It is unlikely that these requirements can be satisfied by the installation of a self contained, off-the-shelf 'water meter'.

Similarly, water measurement devices suitable for full pipe flow generally cannot be used to accurately measure partially full pipe flow.

The size of the water take (both physical dimensions and expected flow rate range) will affect the choice of water measurement system. No single measurement system would suit every water take. For example, a measurement system for a 5L/s water take may not be suitable for large flow rates used in power generation or an entire irrigation scheme.

All aspects of the measurement system, including its complexity, cost and inspection/maintenance frequency should reflect the size of the take. The larger the water take, the greater the importance of data accuracy, and the greater the risk if the system does not provide information at the scale and resolution required.

C1.4 The Need for Specific Considerations

Because every open channel water take is different, the water measurement system must be tailored to meet the specific characteristics and requirements of the water take. Selection and installation of a measurement system without first considering these specific site issues is unlikely to provide an acceptable water measurement system.

Four key steps are required before choosing and installing a measurement system:

1. Check the flow rates and conditions stated in the water permit issued by the relevant regional council;
2. Check any related water measurement requirements from the relevant regional council (the Regulations allow more stringent requirements to prevail);
3. Check Section C2 of this document for minimum requirements based on the Regulations; and
4. Perform a thorough site investigation.

Requirements issued by the relevant regional council (including conditions stated in the permit), and requirements in the Regulations must be considered together. The more stringent requirement prevails.

C1.4.1 Site Investigation

Thorough site investigation is a critical factor for the successful installation of water measurement systems in open channels. Poor site investigation may lead to poor site selection and system design. Site investigation should consider factors including:

- Channel gradient and shape;
- The range of expected flow rates;
- The impact of backwater effects (other water bodies or structures affecting water level);
- Expected sediment/debris load (e.g. branches, silt, etc.);
- Expected weed and algal growth;
- Possibility of strong wind affecting measurements;
- Migratory fish passage requirements;
- Allowable head loss across the measurement system;
- Possible ice/snow;
- Ability of the upstream channel to contain increased water levels caused by the measurement system;
- Accessibility of the site; and
- Site constraints that would affect measurement system layout.

The selection of the measurement site, the design of the measurement system, and the long-term inspection and maintenance requirements of the system must all take into account the outcomes of the site investigation.

System and site selection require experience; therefore, it is recommended that professional expert advice is sought. The diversity of site and take characteristics mean that there is no one standard approach that can be adopted.

C1.4.2 Considering Possibility of Conversion to Full Pipe Flow

Measuring flows in open channels or partially full pipes is generally more complex and costly than flows in full pipe. Consideration should therefore be given to the possibility of converting any open channel or partially full take into full pipe flow. In some cases this might be easier and cheaper, particularly from a life-cycle cost model perspective because of the lower ongoing maintenance requirements of full pipe flow measurement systems. Conversion to full pipe flow is commonly achieved by incorporating an inverted siphon in a pipe – either as part of existing piped infrastructure or added to an open channel take. This would then allow the use of a meter suitable for full pipe flow. If such configurations are

used, then the relevant guidelines are detailed in the *Section B: Guidance on Water Meters for Full Pipes*.

C1.5 Trained Installers

The permit holder should be aware that there are trained professional installers and suitably qualified hydrologists who have specialist experience in the design, installation and maintenance of measurement systems for open channels and partially filled pipes. Some regional councils may also require the use of selected approved installers only.

The Regulations, however, do not specify who are permitted to install measurement systems, and do not require the use of an approved installer.

C1.6 Life-cycle Cost Model

When considering options, it is recommended that the permit holder takes into account the life-cycle costs of the measurement system, and not only the initial capital costs. The life-cycle cost refers to the total cost of ownership over the life of the water measurement system. This implies that cost optimisation should consider not only the initial capital cost, but also operational, inspection, maintenance/repair, re-calibration, and replacement/renewal costs.

For example, choosing a measurement system that has the lowest initial capital costs but does not suit site conditions might lead to greater overall costs in the long term. Similarly, if site conditions require the professional expertise but the permit holder chooses not to seek any help, overall costs might be higher if the measurement system fails verification and then requires modification or an entirely different system.

Permit holders should also be aware that the required frequency of inspection, maintenance and re-calibration depends on the type and robustness of the measurement system, and site conditions. More frequent requirements for inspection, maintenance and servicing can add significantly to a system's total life-cycle cost. To provide indicative guidance on typical service intervals, please refer to Appendix P.

Furthermore, different measurement system technologies have different typical useful service lifetimes. When considering these, the permit holder should consider the duration of the water permit, and the likelihood of the permit being renewed beyond the current permit term.

C2 Water Measurement System General Considerations

This section outlines the minimum requirements and associated best practice recommendations for water measurement systems used for open channels and partially filled pipes.

All water measurement systems for open channels and partially full pipes, regardless of whether they are based on techniques suggested in this guideline document or not, must meet the requirements in this section.

C2.1 Accuracy

C2.1.1 Interpretation of Accuracy Requirement

For flows in open channels or partially full pipes, the Regulations state that the continuous water measurement records to be provided must be kept using a system that measures the volume of water to within ±10% of the actual volume taken. This means that when the water measurement system is installed, the in situ measurement of water volume has a maximum permissible uncertainty of ±10% of reading over the entire range of expected flow rates under the specific site's operating conditions, to a confidence level of 95%. In other words, 95% of instantaneous volumetric flow rate measurements are within ±10% of the true volumetric flow rate. Refer to Appendix F for more information on how accuracy compliance is determined.

Verification of this accuracy is covered in Section C3. The accuracy verification will be the primary means by which compliance or non-compliance with this requirement is established. However, the requirement for the water measurement system to continuously provide accurate data leads to other implied obligations.

C2.1.2 Suitable for Specific Site

The water measurement system must achieve the required measurement accuracy for the specific site conditions and the entire range of expected flow rates. The Regulations also state that the water measurement system must be suited to the qualities of the water it is measuring (including temperature, algae content, sediment, pH, conductivity and any other relevant water quality characteristics). No reasonably expected disturbances should cause the accuracy of the measurement system to deteriorate beyond the permitted limits.

Therefore, a thorough site investigation (described in Section C1.4.1) must precede the selection/design and installation of a water measurement system.

Furthermore, the water measurement system must meet the conditions of the water permit and the requirements by the relevant regional council.

C2.1.3 Flow Disturbances

To achieve the required accuracy, consideration should be given to eliminating flow disturbances (or if not practicable, then minimising their effect) when designing the water measurement system and selecting its location.

The water measurement system should be located such that anything that can cause flow disturbance is sufficiently far upstream or downstream of the water measurement system to minimise its effect. Note that flow disturbances can often have an effect well beyond the lengths used in the following standard good industry practices, but they would be minimised.

Open Channel Systems

In open channels, flow disturbances can occur anywhere there is a change in flow direction, channel width, or water depth. Good industry practice generally requires that the water measurement system has a *minimum* straight upstream channel length with no flow disturbances equivalent to 10 times the channel width. The appropriate management of flow disturbances immediately downstream depends on the specific type of water measurement system used.

Partially Full Pipe Systems

In partially full pipes, flow disturbances are generally caused by fittings such as valves, bends or junctions. Good industry practice for partially full pipe systems requires that the water measurement system has sufficient straight pipe lengths with no flow disturbances (what is a sufficient length will depend on the specific situation).

C2.1.4 In Situ Calibration

Calibration is the process of checking and adjusting the measurement system (including its measurement parameters and ratings) to achieve the required accuracy. Calibration is not to be confused with verification, which is a formal assessment of the water measurement system for compliance with the accuracy requirement of the Regulations (covered in Section C3). Calibration must be performed in situ (without removing the system) to ensure that the accuracy takes installed (on-site) conditions into account.

In situ calibration must be performed as soon as practicable after:

- installation,
- any maintenance/repair work that may affect the system's calibration parameters, and
- any significant flood event or channel disturbances.

In addition, periodic, planned calibration checks are required to ensure that the measurement system continues to achieve the required accuracy. The frequency of planned calibration checks should depend on the specific site conditions, and the type and robustness of the system. Permit holders are strongly recommended to seek professional advice to determine a suitable calibration frequency. Some regional councils may also require a range of flows or a minimum number of calibrations to be performed annually for open channel systems.

Permit holders must also keep calibration records which include the magnitude of rating changes (i.e. what changes had to be made), dates of the changes, and any reasons for the changes. These must be made available for inspection when requested by the relevant regional council

Any suitable technique may be used to calibrate the water measurement system. Currently, calibration normally involves taking flow rate measurements using another device or system of known accuracy and using these measurements to calibrate the water measurement system. Measuring the flow rate can be done using a variety of methods, including bucket-and-stopwatch volumetric measurement (measuring time to fill a container of known volume) and the velocity-area method (using a current meter to measure velocity at several locations across the channel). Other techniques may be developed in the future.

In general, increasing the number of calibration points will increase the overall accuracy of the measurement system (e.g. more stage-discharge data points provide a more accurate stage-discharge rating). This accuracy is assessed during the formal verification processes, as well as the regulatory compliance inspections by the regional council. Therefore, it is important to use a sufficient number of data points, which depends on the measurement system and the expected range of flow rates.

C2.1.5 Inspection and Maintenance

To continue to provide records which comply with the Regulations' accuracy requirement, the water measurement system must also be regularly inspected and maintained throughout its operational life. As with calibration, the frequency and thoroughness of the inspection and maintenance work must suit the specific site conditions and type of installed water measurement system, such that there is an acceptable level of confidence that the system continues to operate within its permissible in situ measurement uncertainty of ±10% of reading. This is important to ensure the integrity of the water take measurement data. Therefore:

- The installed configuration of the water measurement system must allow for its maintenance;
- The permit holder must ensure that a regular maintenance plan is developed (and submitted for approval if required by the relevant regional council); and
- The permit holder must ensure that all planned maintenance and necessary repairs are performed in a timely manner by appropriately qualified persons.

Permit holders must retain copies of maintenance records as evidence of the service record of the water measurement system. These must be made available for inspection when requested by the relevant regional council.

Servicing and maintenance of any proprietary components (e.g. sensors) must always be performed in accordance with the manufacturer's specifications, normally by a service provider approved by the component manufacturer or agent. Preventative maintenance generally includes an assessment of components for wear or damage, and replacement of components at the appropriate time.

For open channel water measurement systems, maintenance normally includes:

- Checks for water leakage/diversion that bypasses the control section (that would, therefore, not be measured) and associated repairs;

- Keeping the approach channel and control section free of debris, deposition of silt and bed material, twigs, algae, weeds/vegetation and ice;
- Checking the approach channel for erosion and subsidence; and
- Checking any water level measurements against a reference level such as a staff gauge and adjusting if necessary. The staff gauge should be periodically checked against survey benchmarks.

For partially filled closed conduits, preventative maintenance normally includes checking for structural integrity of pipe-work and fittings, and removing any debris and blockages.

C2.1.6 Evidence of Maintenance and Calibration

Maintenance and calibration records (covered in Sections C2.1.4 and C2.1.5) provide evidence of efforts to ensure continued compliance with the accuracy requirement of the Regulations.

In the event that a measurement system is found to be non-compliant during verification or spot checks, the relevant regional council is likely to consider the suitability of the calibration and maintenance frequencies in deciding whether all practicable steps have been taken to ensure that the system continues to achieve the required accuracy. Furthermore, the frequency of spot checks by the regional council is likely to be influenced by the suitability of the maintenance and calibration frequencies.

As previously highlighted, the required maintenance and calibration frequencies depend highly on the type and robustness of the system, and site conditions. Appendix P provides guidance on typical maintenance and calibration frequencies.

C2.2 Measuring Range Capability

The Regulations state that the water measurement system must be able to provide records pertaining to the continuous measurement of the water taken under water permit, including water taken in excess of what the permit allows. Therefore, the water measurement system must be capable of accurately measuring the entire range of expected flow rates, i.e. not only up to the flow rate specified in the water permit, but what the conduit would be reasonably expected to convey (based on intake structure or system capacity).

C2.3 Location

The Regulations require that water measurement systems be installed at the location from which the water is taken under the permit, or if approved in writing by the relevant regional council, as near as practicable to that location. Therefore if, for example, a site investigation establishes that the actual measurement site needs to be somewhere other than the abstraction point specified in the water permit, the permit holder must apply to the relevant regional council for approval.

Because the intention is for all water taken under the water permit to be measured, there must be no off-take (except those for permitted water takes e.g. domestic, stock water and

fire-fighting), diversion or branch between the location from which the water is taken and the water measurement system.

C2.4 Record Keeping

The Regulations state that the permit holder must keep records comprising measurements (in cubic metres) of the volume of water taken each day, or each week if granted approval in writing from the relevant regional council. The responsibility of ensuring that records are kept and reported to the relevant regional council lies with the permit holder (but they can be done by a representative of the permit holder). The requirements relating to the form of records kept is outlined in the Guidance for Consent Holders on Data Management Issues in Section D.

The relevant regional council may also require more frequent volumetric measurements to be kept (for example, instantaneous flow rate every 15 minutes) over and above the Regulations' requirements.

C2.4.1 Electronic Data Logging Capability

The Regulations state that the water measurement system must be able to provide data in a form suitable for electronic storage. This is not a requirement to fit an electronic data logger. However, the water measurement system must be capable of being fitted with an electronic data logger, i.e. the water measurement system must have suitable output data ports and have a signal output that is suitable for electronic data loggers.

Therefore, unless the relevant regional council has more stringent requirements, the permit holder may manually read and record the cumulative water volume taken and the time of reading on paper. There are, however, various problems associated with manual records on paper:

- There is a possibility of error when they are initially written;
- It is difficult for the relevant regional council to analyse and manage the data without first copying them onto an electronic spreadsheet; and
- There is a possibility of error if they are copied onto an electronic spreadsheet.

For these reasons, although not required by the Regulations, some regional councils may require permit holders to use of electronic data loggers as part of the water measurement system. Electronic data loggers store the measurement records for later retrieval. Where data loggers are used, it is recommended that they have sufficient capacity to store data for no less than 1 year of flow measurement data (at the frequency required by the regional council).

Some regional councils may also require that the electronic data loggers are connected to telemetry equipment. Telemetry allows:

- quick detection of data logger failure, thus reducing the problem of missing records; and

- real-time resource management and compliance monitoring.

C2.4.2 Preventing Lost Data

The permit holder must take all practicable steps to prevent lost data. If the water volume is not read manually, the records are usually stored on or off site by the water measurement system. Where the water measurement system relies in any way on an electrical power source, it must have a non-volatile memory. This is to ensure that recorded data is not lost, and remains accessible for a minimum of one year, in the event of a power or battery failure.

There should be reasonable backup battery power for all systems to ensure that water measurement and recording continues in the event that the primary power source fails.

To further prevent missing data records, the permit holder should ensure that the water measurement system is frequently checked to ensure that it is still recording data.

C2.4.3 Record Reporting

The Regulations state that the permit holder must provide records that cover each water year of the permit to the relevant regional council no later than 1 month after the end of the water year. This requirement is additional to any requirements by the relevant regional council to provide records that cover a different period or periods.

The permit holder must be able to obtain measurement records from the water measurement system in a form suitable for reporting to the relevant regional council. The requirements relating to the form of records provided to the relevant regional council is outlined in Section D.

To check the reliability of the measurement records, the Regulations state that the relevant regional council may request evidence from the permit holder that the water measurement system that kept the records has been verified as accurate, i.e. a verification report as described in Section C3.11. The permit holder must provide the relevant regional council with the evidence as soon as practicable after receiving the request. Although not covered by the Regulations, some regional councils may also require more data (e.g. water level records) from the water measurement system to validate the accuracy of the flow measurement records.

C2.5 Allowing for Verification

The Regulations require accuracy verification of water measurement systems. Therefore, the design and installation of the water measurement system must facilitate the in situ verification process.

For open channels, the verification facilities required depends on the type of measurement system used. Due consideration must be given to ensure that the configuration of the system facilitates verification.

For partially filled closed conduits, possible configurations that may be installed to facilitate verification include:

- Flow diversion devices to allow volumetric measurement or to allow water to run through an independent measurement system; or
- A section of pipe with flanges to allow an independent measurement system to be inserted in-line (with sufficient pipe lengths on each side).

Unless there can be sufficient confidence that in situ conditions can be replicated, verification should be performed in situ instead of in a laboratory.

With further technological innovation and its availability, regional councils may also permit other verification-facilitating configurations.

C2.6 Security

The Regulations state the water measurement system must be sealed and be as tamper-proof as practicable. Tampering would affect the credibility and hence the usefulness of the data collected. Therefore, the design and installation of the water measurement system must take into account all practicable steps to protect the components of the water measurement system from intentional tampering. This includes protection devices/seals for individual components that prevent tampering and/or indicate when tampering has occurred.

Where it is impracticable to make the entire system tamper-proof because of the configuration of the system (this is likely for most open channel water measurement systems), the relevant regional council may perform more frequent random checks to discourage tampering. However, even when the entire system cannot be made tamper-proof, individual components that can be made tamper-proof must be made tamper-proof.

In addition, the design and installation of the water measurement system should consider the protection of operators, the public and the environment from harm from the system.

C2.7 Other Considerations

There are other requirements that are not directly related to the Regulations, but are important for the long-term integrity of the water measurement system and the measurement records it provides. These are covered in Appendix D.

C2.8 Commissioning

Commissioning must be conducted at the end of installation to ensure that the water measurement system is ready for verification and subsequent use. The commissioning procedure will include the following checks:

- Check that all components of the water measurement system have been installed correctly;
- Check that the entire flow passes through the measuring point;
- Check that all required calibration has been completed;

- Check that the correct software has been installed and configured in the central processing unit; and
- Check that all components are sufficiently supported and protected from damage.

C2.9 Submission of Installation Information

Upon completion of the commissioning of the water measurement system, the installer (which may be the permit holder) must submit within one month the following installation information to the relevant regional council:

1. An installation commissioning report describing the water measurement system, signed by the installer; and
2. A photograph and a detailed as-built diagram of the installation configuration, including dimensions and verification facilities.

The installation commissioning report should contain at least the following information:

- Permit holder's name and water permit number;
- Commissioning completion date;
- Brief description of the type, dimensions and identification/serial number (if any) of the water measurement system;
- Location description and GPS coordinates of the water measurement system;
- The initial reading (m^3) at the time of commissioning;
- Name and signature of the installer; and
- The installer organisation's name, address and contact phone numbers.

If any major repairs/reconfigurations that alter the system layout are subsequently performed, updated information must be submitted to the relevant regional council.

Templates for installation commissioning reports are included in Appendix I for open channel systems and Appendix J for partially full pipe systems.

An example of a typical site plan is included in Appendix K.

C3 Verification

This section outlines the key features of the verification process which forms the primary means of quality assurance and the main process in assessing compliance with the accuracy requirement of the Regulations. It does not contain the full breadth of information required by verifiers for the wide range of different systems; this is better covered in detail in proper training courses. Instead, it lays down the basic features for the verification process

to give sufficient confidence that verified water measurement systems provide accurate, quality water take data.

C3.1 Purpose and Scope of Verification

Verification gives confidence that the water measurement system meets the accuracy standard required in the Regulations, i.e. the in situ measurement of water volume has an uncertainty of no more than ±10% of reading for the entire range of expected flow rates under the specific site's operating conditions, to a confidence level of 95%.

Although verification and calibration may involve similar techniques, they are two different processes. Calibration, which is covered in Section C2.1.4, involves periodic checking and adjusting of measurement parameters and ratings to enable accurate volumetric measurements by the water measurement system. Verification, which is covered in this section, involves formal assessment of the water measurement system for compliance with the accuracy requirement of the Regulations.

Verification also differs from regulatory compliance inspections. Verification involves the permit holder engaging a verifier approved by the relevant regional council. On the other hand, a regulatory compliance inspection typically involves a representative of the regional council contacting the permit holder for a visit at short notice to discourage intentional tampering, poor/infrequent maintenance, misreporting of data and non-compliance with the Regulations.

C3.2 Approved Verifiers

Verification of the water measurement systems must be carried out by a person, who in the opinion of the relevant regional council that granted the water permit, is suitably qualified to verify the particular measurement system.

The verifier can be part of the relevant regional council or an external organisation, provided that the criterion is met. Some regional councils may also require that the verifier was not involved in the installation nor provided any advice to the permit holder.

C3.3 Required Verification Frequency

The installed water measurement system must be verified on site at the times stipulated in the Regulations, i.e.:

1. Initially, after commissioning but before end of the first water year,
2. Subsequently, at least every 5 years.

For example, if the first verification is performed on 1 March 2013, the second verification must be performed no later than 1 March 2018. The second verification may be performed earlier than 1 March 2018, e.g. on 1 March 2017; however, if this is done, then the third verification must be performed by 1 March 2022.

Although not required by the Regulations, some regional councils may require more frequent verifications for some open channel measurement systems.

C3.4 Reference Measurement Equipment

The key part of the verification process involves taking reference measurements with which the measurements from the water measurement system can be compared.

The equipment used to for reference measurement as part of the verification process must be suitable for verifying the accuracy of water measurement systems. The reference devices used for verification must be:

- Maintained and calibrated to within a known measurement uncertainty that is no more than ±2% of reading at 95% level of confidence;
- If required, the equipment shall be tested and certified yearly by an ISO 17025 or 9001 accredited laboratory;
- Used within the normal purposes and range for which they were certified; and
- Operated by a trained and certified person.

Current meters should be calibrated in accordance with ISO 3455, and recalibrated whenever their performance is suspect.

C3.5 Test Volumes

The minimum reference measurement volume for each test depends on the resolution of the real-time flow data available (either through an installed on-site display or alternative means). The test volume must be sufficiently large to allow the flow rate to be measured with minimal error associated with reading the data.

C3.6 Test Flow Rates

The verifier will decide the number of flow rates to be tested based on the measurement system type and site conditions.

The verifier will typically alter the flow rates, e.g. using a gate for open channels or using a valve for partially full pipes. The flow rates for each test will be set by the verifier, but should consider the full range of expected flow rates, for instance:

- A low flow rate – e.g. 1.2 x (the minimum expected flow rate to be measured);
- A high flow rate – e.g. 0.9 x (the maximum expected flow rate); and
- A medium flow rate – Halfway between the low and high flow rates

For more critical water takes with high flow rates, the verifier may choose to perform sufficient tests (normally no less than 5) to check that the rating is correct.

C3.7 Verification Methods for Open Channels

C3.7.1 Bucket-and-Stopwatch Volumetric Measurement

Bucket-and-stopwatch volumetric measurements have the highest potential for accuracy. Where there is sufficient fall and a suitable structure, the bucket-and-stopwatch volumetric method may be suited. However, there are many situations where this is not applicable.

This method involves direct measurement of the time taken to fill a container. There are practical limitations with respect to manageable container size and sufficient filling time to provide accuracy. Therefore, this method is often not suitable for flows greater than 10 L/s.

There are two general procedures that can be used:

- Position a calibrated container to collect flow discharging from the weir/flume, and simultaneously starting a stopwatch. Stop the stopwatch when the water volume reaches the calibration volume mark. Divide the calibration volume by the filling time to determine the flow rate.

- Position an uncalibrated container to collect flow discharging from the weir/flume, and simultaneously starting a stopwatch. Stop the stopwatch when the container is nearly full. Transfer the collected water into a calibrated container and measure the collected water volume. Divide the collected water volume by the filling time to determine the flow rate.

The container used for collecting water should be sufficiently large such that the filling time is at least 10 seconds (for more accurate filling time measurement). The calibrated container should be of a suitable shape to allow for accurate reading.

Where practicable, for each flow rate test, the verifier should repeat the measurement for a sufficient number of times (at least 10) to calculate the mean and standard deviation of the measured flow rate.

The measured flow rate is then used as a reference flow rate against which the flow rate measured by the water measurement system can be checked.

C3.7.2 Velocity-Area Method

The velocity-area method can be used to verify the flow rate, especially where bucket-and-stopwatch volumetric measurement method is not practical and/or not sufficiently accurate. This method generally involves:

- Using a current meter to measure the velocity at locations or ‘verticals’ spaced across the channel width;

- Measuring the water depth at each vertical, at the same time as measuring velocity; and

- Calculating the flow rate from the velocities and water depths.

The use of a current meter will require the expertise of a suitably trained person. The flow measurement should be undertaken in accordance with ISO 748.

C3.7.3 Alternative Reference Measurement Method

Alternative reference measurement methods are acceptable provided that they are approved by the relevant regional council.

C3.8 Verification Methods for Partially Full Pipes

Based on the in situ verification facilities outlined in Section C2.5, verification would involve:

- Volumetric measurement of water taken via a flow diversion device (similar procedure to Section C3.7.1), or
- Using an independent measurement system, measuring water taken via a flow diversion device or inserted in-line.

The verification procedure for partially full pipes would depend on the specific verification method used, which in turn depends on the in situ verification facilities provided.

C3.9 Determination of Measurement Accuracy Compliance

Central to the verification process is the interpretation of the measurement system's accuracy from the results of the verification tests. The results of the tests should not be generalised because the measurement system's measurement accuracy would be affected differently at varying flow rates.

The verifier will need to identify and combine all sources of uncertainty in the reference measurement. While the reference/verification equipment used should have a certified uncertainty of no more than ±2% of reading at 95% level of confidence, the combined uncertainty at 95% level of confidence may be no more than ± 5% of reading.

The accuracy compliance of the installed water measurement system should be interpreted in consideration of the combined uncertainty of the reference measurement. Uncertainty of the reference measurement system must be taken into consideration when determining non-compliance because the Regulations state that the measurement by the water measurement system must be within ± 10% of the actual volume taken (which is unknown), not of the reference measurement.

Refer to Appendix F for a more information on how measurement accuracy compliance is determined.

C3.10 Site Verification

Reference measurements allow a 'snapshot' verification of the accuracy of the water measurement system. Inspection of the water measurement system during the verification process will not guarantee that the water measurement system will continue to provide accurate measurements between verifications, but it will help promote that outcome and highlight to the permit holder any problems that need to be addressed.

Therefore, for all water measurement systems, verification should include the following inspection steps to evaluate the integrity of the water measurement system:

- Check that the water measurement system is used in an appropriate manner
- Check the overall condition of the water measurement system;
- Check that the submitted installation information is correct and still up to date;
- Check the water measurement system against the installed benchmarks (e.g. level measurement checked against the staff gauge reading)
- Check preventative maintenance plans and maintenance records;
- Check the channel for scour/fill and weed/algae growth;
- Check the system for damage;
- Check for evidence of interruption of signal transfer between the sensor(s) and central processing unit;
- Check that power supply is reliable (e.g. if the water measurement system uses batteries, then the expected replacement date are marked and not yet due);
- Check that the system has been made as tamper-proof as practicable, and where installed, that tamper-proof seals are in place and unbroken;
- Check that there are no leaks that bypass the measuring point;
- Check for scaling or build-up of calcium, iron oxide or iron bacteria;
- Check that filters/strainers/screens (where applicable) are clean; and
- Check that protection from weather and other damage are still adequate.

C3.11 Verification Report

The Regulations state that the relevant regional council may request evidence from the permit holder that the water measurement system that kept the submitted records has been verified as accurate. Therefore, after verification of a water measurement system, a verification report must be issued by the approved verifier to the permit holder as evidence of verification. When requested by the relevant regional council, the report must be provided as soon as practicable after receiving the request.

The verification report must have as a minimum:

- Permit holder’s name and water permit number;
- Verification date;

- Brief description of the water measurement system (open channel/partially filled pipe, sensor type(s), control section type, data logging/telemetry, other notable features, etc);
- Conduit dimensions (e.g. width, depth, etc. depending on shape);
- Capability of being fitted with an electronic data logger;
- Location description and GPS coordinates of the water measurement system;
- Water measurement system reading (m^3) immediately before and after verification tests;
- Brief description of the verification method used;
- Verification equipment description and serial number;
- Confirmation that the verification equipment used (e.g. calibrated containers, reference measurement system, etc.) are currently certified and are available on request;
- Verification results, including individual accuracy requirement compliance/non-compliance for each flow rate tested;
- Decision on compliance/non-compliance;
- General inspection notes;
- Name and signature of the verifier; and
- The verifier organisation's name, address and contact phone numbers.

Templates for verification reports are included in Appendix M for open channel systems and Appendix N for partially full pipe systems.

C3.12 Non-compliance

If the verifier determines that the water measurement system does not comply with the accuracy requirement of the Regulations, the permit holder is responsible for ensuring that all practicable remedy steps are taken as soon as possible to achieve compliance. Within a period determined by the relevant regional council to allow for these remedy steps, the permit holder must arrange for verification of the water measurement system to be performed again.

If the verifier determines that the water measurement system complies with the accuracy requirement, but highlights other issues arising from the general inspection, the regional council may require that the permit holder to fix the issues within a specified timeframe. This does not constitute non-compliance with the accuracy requirement of the Regulations, and therefore, there is no requirement for re-verification (but relevant regional council retains discretion to require this).

C4 Open Channel Water Measurement Technique

This section outlines the current best practice used for measuring open channel flow. Regardless of the technique used, all installed water measurement systems must be verified as accurate, as described in Section C3.

C4.1 Measurement Techniques

There are many techniques that could theoretically be used to measure flow in open channels. However, the main technique currently used is the stage-discharge method.

Other techniques include the velocity-area method, volumetric method, slope-hydraulic-radius (Manning) method and dilution method. However, these are generally impractical for continuous, long-term in situ measurement of water flow, which is required in the Regulations.

This guidance document acknowledges that future technological advances are likely to create innovative techniques or improve currently inappropriate techniques. *It is important to note that a water measurement system based on any technique would be suitable provided that it meets the requirements outlined in Section C2, and is verified as accurate as described in Section C3.*

C4.2 Stage-discharge Method

The stage-discharge method is used widely to continuously measure flow in open channels. In an open channel, the water level (stage) is related to the flow rate (discharge). This technique involves the measurement of water level, and conversion of the water level into a flow rate based on a pre-determined stage-discharge rating curve.

The stage-discharge rating curve is the relationship between water level and flow rate established specifically for the site. The stage-discharge method relies on developing an accurate stage-discharge rating for the open channel. For the stage-discharge rating to be determined, the flow in the channel must be measured by another method, such as volumetric, velocity-area or dilution methods.

The likelihood of the specific site retaining the stability of this relationship over time is crucial for this method to continuously provide accurate water measurements in the long term.

C4.2.1 Control Section

The stage-discharge technique normally requires a control section, such as a weir or flume. The control section causes a change in upstream flow depth that can be measured by the water level sensing device. (In certain circumstances, a suitably qualified hydrologist might consider that a particular channel cannot have a control section, and will therefore, have to configure the system appropriately.)

A weir is a calibrated dam structure constructed across a channel to control the upstream water level, so that there is free-fall critical flow across the weir. A flume is an artificial

channel with a symmetrical constriction in the sides or bottom, which for a particular flow range, can cause critical flow and hence a standing wave to occur.

There are a wide range of weirs and flumes of various shapes and angles, which have different strengths and weaknesses, including different accuracy capabilities. There are thin-plate weirs and broad-crested/long-base weirs, with various cross-sections (including V-shaped, rectangular, and trapezoidal). Flume types include H-type, Parshall, Palmer-Bowlus, and trapezoidal flumes. The control section choice must take into account the specific site characteristics and the requirement to achieve the ±10% measurement uncertainty for the expected flow rate range to be measured.

There is a predetermined, theoretical stage-discharge rating for the particular weir or flume used based on its design. However, this rating must be confirmed on site after installation. Usually, the rating will need to be corrected on site because of discrepancies in design/installation or non-ideal site characteristics. This rating must also be periodically checked and corrected over the lifetime of the water measurement system.

The control section increases the upstream water level, therefore the upstream channel banks must be sufficiently high and structurally strong to handle water flowing at the maximum expected flow rate.

C4.2.2 Level Measurement

The stage-discharge technique requires a water level measurement device (level sensor). Level sensors available currently include:

- *Float and counterweight encoder:* Consists of a pulley rotated by a float/counter-weight system. Each increment of rotation is converted to a signal. Signals are converted to water level.

- *Submersible pressure transducer:* The difference between the atmospheric pressure and water pressure acting on the sensing component is converted into a signal that varies with pressure. Water pressure increases linearly with water depth, therefore the latter can be calculated.

- *Ultrasonic sensors:* Can be upward-looking or downward-looking. For downward-looking sensors, sound waves are transmitted through the air and reflect off the water surface and are received by the sensor. The time interval between the transmitted and received signal is measured to calculate water level. Some ultrasonic sensors can also measure velocity.

- *Bubbler sensors:* The pressure of an air-filled tube/chamber with an open, submerged bottom end is measured. Water level is proportional to the difference between hydrostatic pressure in the tube and atmospheric pressure, therefore it can be calculated.

Advantages and disadvantages vary widely between level sensor sub-types (even those using the same technology) and manufacturers, and these are likely to change over time

with innovation. Therefore, no comparison has been included in this guidance document. The permit holder is encouraged to seek current advice to choose a suitable level sensor.

C4.2.3 Other Basic Components

To allow flow rate and cumulative flow volume to be measured, the level sensor outputs data to a central processing unit. The central processing unit records the measured flow depth, converts the flow depth to flow rate based on the stage-discharge rating, and totalises the flow rate over time to give the cumulative flow volume.

A staff gauge should be installed securely upstream of and close to the measuring point. A staff gauge is a graduated linear scale that acts as a secondary level measure. The water level can be read directly on the scale. This allows manual performance checking and calibration of the level sensor. Where a stilling well is used, having an external staff gauge in the channel and another internal staff gauge in the stilling well allows checks to ensure that the intake pipe is not blocked.

A stilling well is required:

- *always* for the use of certain types of level sensors (float and counterweight encoders, etc.;) and
- *sometimes* for all level sensor types, if the velocity and flow disturbances in the approach channel are not negligible.

The purpose of a stilling well is to provide a stable water level in the open channel, while dampening water level fluctuations (such as waves and ripples), and/or protecting the sensors. The stilling well is connected to the open channel via an intake pipe that allows sufficient water entry. This ensures that there is no significant lag in the well water level to follow changes in the channel water level.

C4.2.4 The 'Ideal' Open Channel Site

The 'ideal' site for open channel water measurement would have the following characteristics:

- Channel has a straight, uniform section of length at least 10 times the channel width.
- Long-term stability of the channel cross-section, i.e. channel is not prone to scour or fill/sedimentation.
- Channel is not prone to aquatic growth (e.g. weeds), or it can be managed within limits.
- Low debris/sediment load.
- Measurement site shielded from the effects of strong wind.
- No migratory fish passage requirements.

Most deviations from ideal site conditions can be overcome in the design, and subsequent inspection and maintenance of the water measurement system. Examples are:

- Constructing a concrete channel will minimise channel scour and weed growth.
- Installing a screen and/or lid can prevent debris from damaging/blocking the system.
- Regular inspection and maintenance can prevent sediment, algae and ice build-up.

Some sites are simple and straightforward sites with minimal deviations from ideal site conditions. For these sites, the system outlined in Appendix E might be suitable.

C4.2.5 Complex Open Channel Sites

The following factors will create a complex environment for the measurement of open channel flow:

- High sediment/debris load;
- Man-made (e.g. concrete) approach channel cannot be constructed immediately upstream of measuring point;
- No straight section of sufficient length is available;
- Very steep channel slope;
- Migratory fish passage required;
- Regular maintenance is not practicable;
- Head loss across measurement system may affect downstream systems; and
- Effect of strong wind cannot be mitigated.

It is strongly recommended that the expertise of a suitably qualified hydrologist be used to define appropriate site-specific solutions if the site has any of these characteristics.

C4.3 Recommended Decision Process

Figure 13 presents a recommended decision process for permit holders with open channel flow measurement sites.

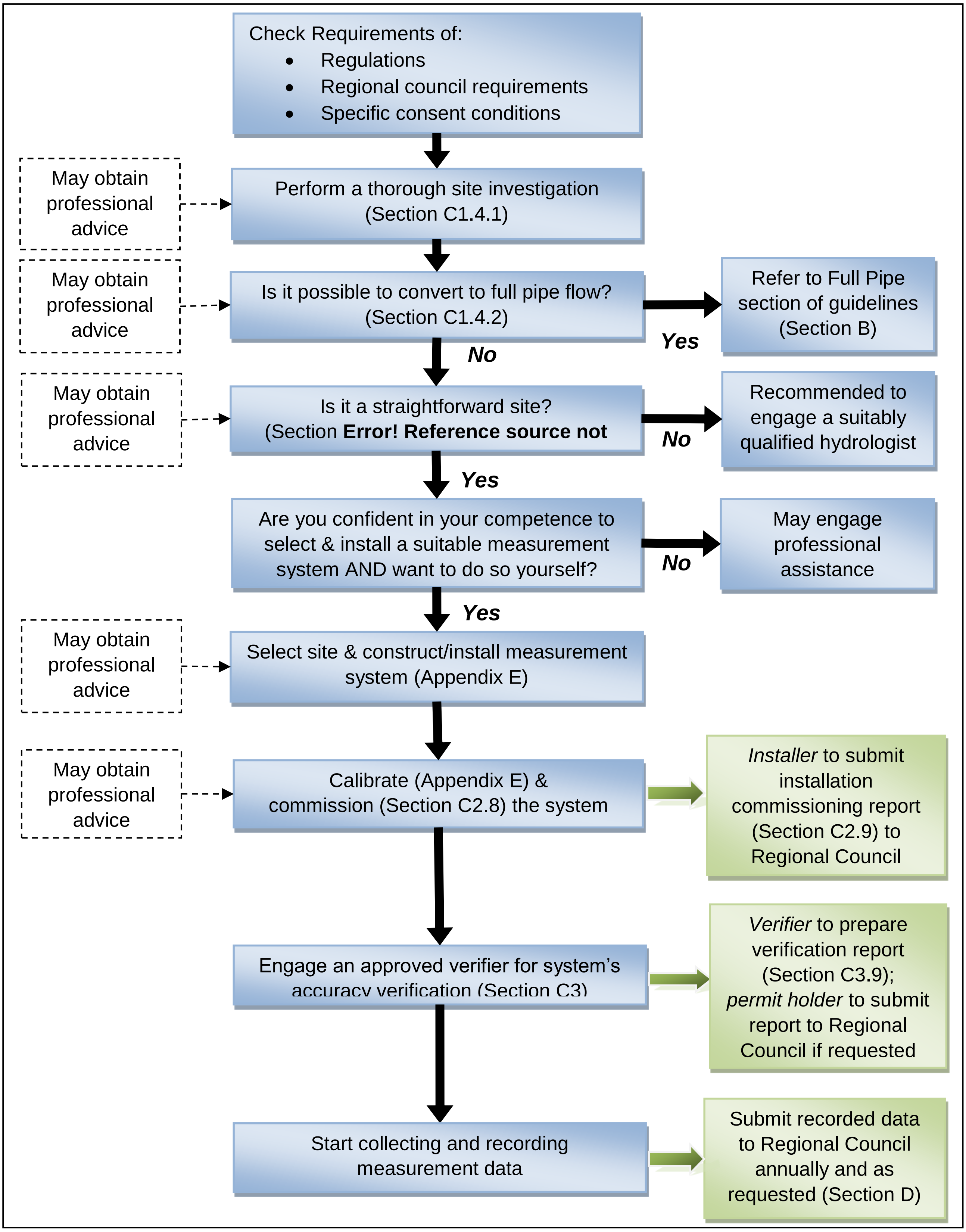


Figure 13: Recommended decision process for permit holders with open channel sites

C5 Partially Full Pipe Flow

In hydraulic terms, the flow in a partially full pipe is a special case of open channel flow. The obvious difference is that the conduit is completely enclosed.

The stage-discharge method commonly used for open channel flow can be used for partially full pipes providing there is sufficient access to allow flow measurement and calibration. While the use of a pipe provides a stable bed compared to a natural channel, there is still the same potential for complex flow conditions to develop, thus it is recommended that professional advice is sought for the specific site.

Measurement systems specifically for partially full pipes are currently available, but are not widely used for flow measurement of water takes in New Zealand. Therefore, the local experience history of these systems is insufficient to give confidence surrounding the reliable performance of these systems. Further information on some of these specific systems for partially full pipes is given in Appendix O, but it is recommended that expert professional advice is sought before any of those systems are installed.

Section D: Data Management Issues

D2 Requirements of the Regulations for Data Management

D2.1 Requirements for Records from Water Measurement Devices/Systems

In the majority of cases, the recording intervals for water measurement will be each day. However, to allow for cases where providing daily recordings is impractical or considered unnecessary, the recording interval may be extended to each week. Weekly recording intervals shall only be permitted if the permit holder has written approval from the regional council.

To achieve consistency and uniformity, water take records must be generated by a device or system that meets the following minimum requirements:

- Have the ability to continuously measure the amount of water being taken;
- Have the capacity to record daily volumes in cubic metres to an accuracy standard of +/-5 percent for full pipes, and +/-10 percent for water taken by another method;
- Be capable of providing data output in a form suitable for electronic storage;
- Be capable of appropriately reporting information to meet the permit conditions imposed by the consenting authority;
- Be appropriate to the qualities of the water being measured (including temperature, algae content and sediment content); and
- Be sealable and as tamper-proof as practicable
- .

D2.2 Requirements for Reporting and Data Transfer

To achieve consistency, reporting requirements need to conform to a minimum standard. Specific reporting requirements imposed by a regional council may exceed the minimum requirements of the Regulations, but will not be less than the minimum standard.

The key requirements for reporting data and data transfer are that:

- The responsibility for recording and transferring the data to the Regulatory Authority rests with the permit holder;
- Daily volumes (or weekly volumes for some takes) in cubic metres are recorded in an auditable manner;
- A permit holder must keep records that provide a continuous measurement of the water taken under a water permit, including water taken in excess of what the permit allows;
- Data is transferred to the regional council on request or at least, an annual basis;
- A permit holder must provide records that cover each water year of the permit to the regional council that granted the permit, data is to include zero readings; and
- The record for a water year must be provided no later than one month after the end of the water year.

The implementation requirement is to ensure that water takes are measured in a manner that meets the Regulations, and that the data is recorded and reported in an appropriate manner for compliance to be assessed.

D2.3 Approval to Measure Water Takes on a Weekly Basis

The regional council that granted a water permit may, at its discretion, grant approval to the permit holder to keep records of measurements of the volume of water taken under the permit each week (instead of each day).

The regional council must grant approval by providing a written notice to the permit holder that specifies the period of approval.

D3 Guidance for Permit Holders on Data Management

D3.1 Water Use monitoring

D3.1.1 Data Required

The volume of water being taken under a water permit for 5 litres/second and greater must be measured, and these measurements must be recorded and monitored. The specific details required include:

- Daily volumes (in cubic metres) time stamped with a date and time;
- Data that is able to be stored electronically; and
- Data that is based on measurements taken at the point where the water is first abstracted from the water body – that is, data on actual water taken.

A regional council may have monitoring requirements that differ from the minimum requirements of the Regulations. In such circumstances the more stringent, of either requirement, will apply.

D3.1.2 Method of Data Collection

A measuring system or device appropriate for the specific water take, situation and permit conditions should be used. Consideration should also be given to the requirements for the storage, transfer, and subsequent use of the data once it has been collected.

D3.1.3 Methods of Recording

All possible steps should be taken to reduce the corruption of data. Consideration should be given to:

- Reducing the number of steps involved whereby water use is measured and then recorded; and
- Reduce the number of people involved in the ‘data train’.

Systems which involve the direct recording of data and transferred via telemetry are likely to produce the highest quality and most reliable data. In situations where such systems are not feasible, efforts must be made to make the system as efficient as possible.

The quality assurance of water use data can be improved by following a few guidelines that are consistent across all data monitoring issues. These include:

- Annual device or system checks and site inspections;
- Regular check readings;
- Unambiguous raw data;
- Multiple readings (or instruments) to corroborate data quality and accuracy;
- Processes to detect transcription errors, instrument malfunction, or anomalous readings;
- Data screening for obvious errors and stored in both raw and corrected/calibrated files;
- Secure data storage and backup of data; and
- Systems for auditing data quality and completeness.

D3.2 Data Collection by Regional Council

D3.2.1 Data Required by the Regional Council

The Regulations require that data on the volume of water being taken is recorded, and that this data is transferred to the regional council. The Regulations do not prescribe the manner with which the water use data is to be transferred to a particular regional council. Appendix R provides a template for the provision of recorded data, which is considered appropriate.

It is also worth noting that the Regulations require that the data is capable of electronic storage but not that it is actually stored electronically. While many regional councils store water measurements electronically this also goes beyond the requirements of the Regulations.

D3.2.2 Frequency of Delivery to the Regional Council

The Regulations place the responsibility for recording and transferring data to the regional council on the permit holder. The records must be transferred to the Regional Council at least annually or upon request. The regional council can, however, require more stringent conditions including that the data is provided more frequently.

While the Regulations require that the water use data is transferred at least annually there are a number of advantages of more frequent transmission. For example, more frequent transmission reduces the risk of lost or missing data, and allows problems to be recognised and corrected more quickly. It also raises awareness of the importance of the data and allows regular feedback to the permit holder. While the more frequent transmission of data may increase cost slightly, both to the permit holder and the regional council, in terms of data handling these are likely to be more than offset by the advantages mentioned. Overall, a greater frequency of delivery is likely to lead to significantly higher quality and more reliable data.

D3.2.3 Methods of Delivery to the Regional Council

There are no methods for the delivery of the water use data to the regional council specified in the Regulations. Methods range from paper copies that are posted to the authority to automated telemetry systems.

Paper copies posted to the regional council are technically the simplest approach. While apparently the cheapest, this method has considerable hidden costs. For example, it

involves considerable time in checking the data and then loading it into any electronic storage system. There is also an ongoing cost to both the permit holder and the regional council in transferring and managing the data. Telemetry or electronic data loggers on the other hand involve greater up-front costs but thereafter the system is largely automatic with intervention only being required for maintenance and problem solving. The use of telemetry or electronic data loggers therefore involves minimal ongoing costs once the system is in place. It is important for both the regional council and the permit holder to consider both immediate and ongoing costs when assessing options for the delivery of water use data. It is likely that under the Regulations the key criterion with regard to data delivery will continue to be data delivery rather than the precise mechanism of transfer.

Whatever method is adopted it is useful if the data is in a format that allows quick and efficient integration with the hydrometric database maintained by the consenting authority. There are significant advantages therefore if the same format is used irrespective of whether the data arrives via paper copies, spreadsheets, cell-phone, internet, or telemetry.

A template for the recording of data for providing to the regional council has been provided in Appendix R. This is a simple template which should be used in the absence of any specific data requirements of the relevant regional council. It is intended to be used for recording manual readings, but also indicates an appropriate format for electronic data to be presented in.

D3.2.4 Verification and Accuracy

The benefits and value of the Regulations will only be obtained if the water use data is accurate and appropriate. It is therefore essential that systems are developed that verify the accuracy of the data supplied to the regional council (Figure 3).

Such a system must involve random checks on the device or system confirming that the reading is consistent with the data that has been supplied to the regional council.

Where the device or system readings and supplied data differ by more than an acceptable amount a mechanism must be in place to reconcile any difference.

Verification and accuracy procedures should also involve confirmation that, back-up copies of all the data are held by the permit holder until the data has been audited and archived by the regional council.

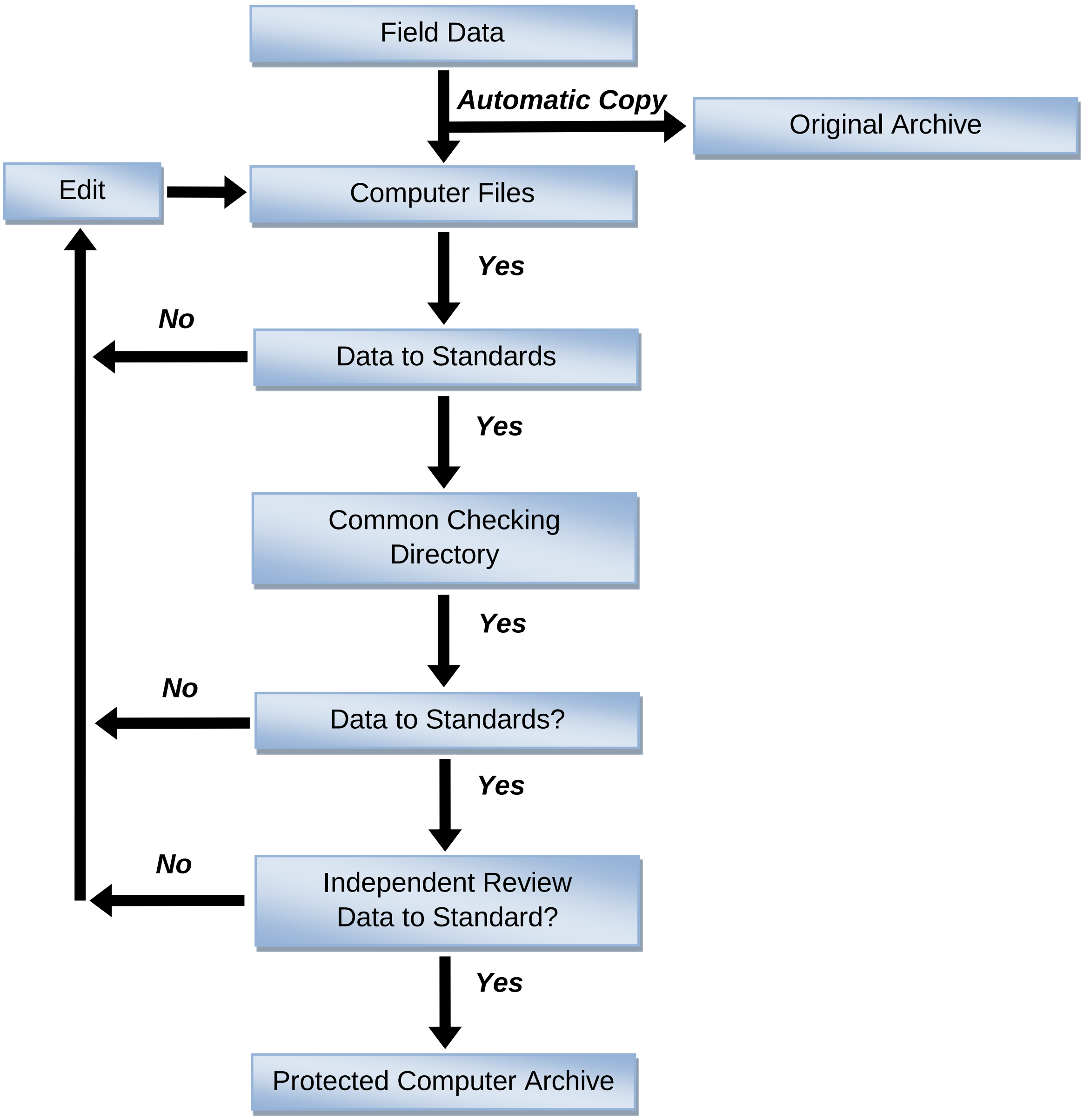


Figure 14: Data quality assurance process (Greater Wellington, 2006)

D3.3 Data Auditing and Archiving

The majority of the hydrometric database tools currently used by regional councils allow the seamless integration of water usage data. Such systems also allow the integration of this data with various consent conditions and reporting mechanisms. Such an approach therefore provides significant economies of scale, and water management benefits. The use of sophisticated monitoring and modelling may not be necessary, or wanted, at this stage. However, the integration of water usage data allows the versatility of the hydrometric analysis system to be applied at any stage in the future.

The integration of the water measurement data with existing hydrometric systems therefore allows:

- Rapid transfer of the data to the Regional Council information system;
- Consistent handling of all data;
- Often, and preferable, ISO certified data quality control;
- Seamless merging of water use data with other hydrometric data;
- Integration of water use data with consent conditions;
- Straightforward compliance monitoring;
- Standardised data quality control;
- Standardised data retrieval;
- Standardised file management and archiving; and
- Standardised range of data analysis tools and reporting options.

D3.4 Quality Assurance System

The Regulations only discuss data quality with respect to the actual measurement of the water take. There appears to be an inherent assumption that the quality of the device or system will carry through to the quality of the data held by regional councils. It is therefore essential that regional councils develop systems whereby the quality of the data held in their archive is both quantified and documented.

Issues of quality do not solely relate to the accuracy of the device or system recording the individual water take. For example, missing data and mistakes when taking manual readings also affect the overall quality of the data record.

All the commonly used hydrometric software tools used currently by regional councils have the facility to tag the water usage data with quality codes. However, at the present time these codes either do not exist or are not consistent across consenting authorities. There would be considerable advantage in developing a standard set of codes that reflect the accuracy of the water usage data by all regional councils. Codes could be used to reflect:

- Whether the data is from surface water or groundwater takes;
- Device or system accuracy;
- Differences between measurement device/system readings and manual readings;
- Missing data;
- Frequency of reading; and
- Time since last calibration

The use of data quality codes ensures that during subsequent analysis, whether for reporting or for compliance monitoring, the quality of the input data is reviewed. This quality must be considered along with the results and any conclusions that may be drawn.

It is therefore essential that all water usage data is incorporated into the hydrometric system used by the regional council whenever possible. This ensures that all the data is quickly and efficiently incorporated into the existing quality control system. Considerable confidence can then be placed in the management of the data, and any results and conclusions derived from subsequent analysis.

D3.5 Data Reporting

Data collected under the Regulations will be able to be used at a number of levels of reporting. For example, the data could be used to report against:

- Consent compliance;
- Consent allocation;
- Water resource allocation;
- Effectiveness of water resource management;
- National water use; and
- Areas of potential water stress.

While the majority of reporting is likely to be undertaken within the specific Regional Council, the data is also required for reporting at the national level. Therefore, consideration must be given to ensure that all data is able to be aggregated to different levels. For this to be practical there must be consistency of categorisation across the country, at least to the level of national reporting.

D3.6 Reading a Measurement System/Device

When taking manual readings from a water measuring system it is important that the reading is interpreted correctly. Two common sources of error in taking manual readings is misinterpretation of the decimal place (often denoted by differently coloured numbers rather than a decimal symbol) and failure to include the exponential component of a reading given in scientific notation (for example reading 12 m^3 instead of $12x10^3$ m^3 or 12,000 m^3). A guideline to taking manual readings is included in Appendix C. If still unsure about how to take a manual reading, please consult with the supplier of the device/system.

D3.7 Electronic Interference

Water meter users should be aware of electrical equipment which could interfere with the collection of water use data. “Electronic noise” emanates from electrical equipment such as variable speed pump motors and electric fences. Measures may need to be taken to isolate the installed meter from electronic interference.

Appendix A

Explanation of Element Protection Standards

There are two rating systems for element protection of electrical equipment. The National Electrical Manufacturers Association (NEMA) Standard No. 250 – 2003 addresses the installation of equipment in non-hazardous locations, enclosure design and its environmental performance requirements. The International Electrotechnical Commission (IEC) 60529 Standard addresses protection against ingress. The Ingress Protection (IP) rating describes the degree of enclosure protection provided, not the enclosure itself. The IP code consists of two numbers, the first of which describes the degree of protection against the ingress of solids (e.g. dust) whilst the second describes the degree of protection against the ingress of liquids.

The following table describes the NEMA rating system and the protection level it refers to.

NEMA Rating	IP Equivalent	NEMA Definition
1	IP10	Enclosures constructed for indoor use; to provide a degree of protection to personnel against incidental contact with the enclosed equipment and to provide a degree of protection against falling dirt.
2	IP11	Enclosures constructed for indoor use; to provide a degree of protection to personnel against incidental contact with the enclosed equipment; to provide a degree of protection against dripping and light splashing of liquids.
3	IP54	Enclosures constructed for indoor or outdoor use; to provide a degree of protection to personnel against incidental contact with the enclosed equipment; to provide a degree of protection against falling dirt, rain, sleet, snow and windblown dust; and that will be undamaged by external formation of ice on the enclosure.
3R	IP14	Enclosures constructed for indoor or outdoor use; to provide a degree of protection to personnel against incidental contact with the enclosed equipment; to provide a degree of protection against falling dirt, rain, sleet and snow; and that will be undamaged by external formation of ice on the enclosure.
3S	IP54	Enclosures constructed for indoor or outdoor use; to provide a degree of protection to personnel against incidental contact with the enclosed equipment; to provide a degree of protection against falling dirt, rain, sleet, snow and windblown dust; and in which the external mechanism(s) remain operable when ice laden.
4	IP56	Enclosures constructed for indoor or outdoor use; to provide a degree of protection to personnel against incidental contact with the enclosed equipment; to provide a degree of protection against falling dirt, rain, sleet, snow, windblown dust, splashing water and hose-directed water; and that will be undamaged by external formation of ice on the enclosure.
4X	IP56	Enclosures constructed for indoor or outdoor use; to provide a degree of protection to personnel against incidental contact with the enclosed equipment; to provide a degree of protection against falling dirt, rain, sleet, snow, windblown dust, splashing water, hose-directed water and corrosion; and that will be undamaged by external formation of ice on the enclosure.
5	IP52	Enclosures constructed for indoor or outdoor use; to provide a degree of protection to personnel against incidental contact with the enclosed equipment; to provide a degree of protection against falling dirt, against settling airborne dust, lint, fibres and flyings; and to provide a degree of protection against dripping and light splashing of liquids.
6	IP67	Enclosures constructed for indoor or outdoor use; to provide a degree of protection to personnel against incidental contact with the enclosed equipment; to provide a degree of protection against falling dirt, against hose-directed water and the entry of water during occasional temporary emersion at a limited depth; and that will be undamaged by external formation of ice on the enclosure.
6P	IP68	Enclosures constructed for indoor or outdoor use; to provide a degree of protection to personnel against incidental contact with the enclosed equipment; to provide a degree of protection against falling dirt, against hose-directed water and the entry of water during occasional prolonged submersion at limited depth; and that will be undamaged by external formation of ice on the enclosure.
12	IP52	Enclosures constructed (without knockouts) for indoor use; to provide a degree of protection to personnel against incidental contact with the enclosed equipment; to provide a degree of protection against falling dirt, against circulating dust, lint, fibres and flyers; and to provide a degree of protection against dripping and light splashing of liquids.

12K	IP52	Enclosures constructed with knockout(s) for indoor use; to provide a degree of protection to personnel against incidental contact with the enclosed equipment; to provide a degree of protection against falling dirt, against circulating dust, lint, fibres and flyers; and to provide a degree of protection against dripping and light splashing of liquids.
13	IP54	Enclosures constructed for indoor use; to provide a degree of protection to personnel against incidental contact with the enclosed equipment; to provide a degree of protection against falling dirt, against circulating dust, lint, fibres and flyers; and against the spraying, splashing and seepage of water, oil and non-corrosive coolants.

The table below outlines and explains the IP numbering system:

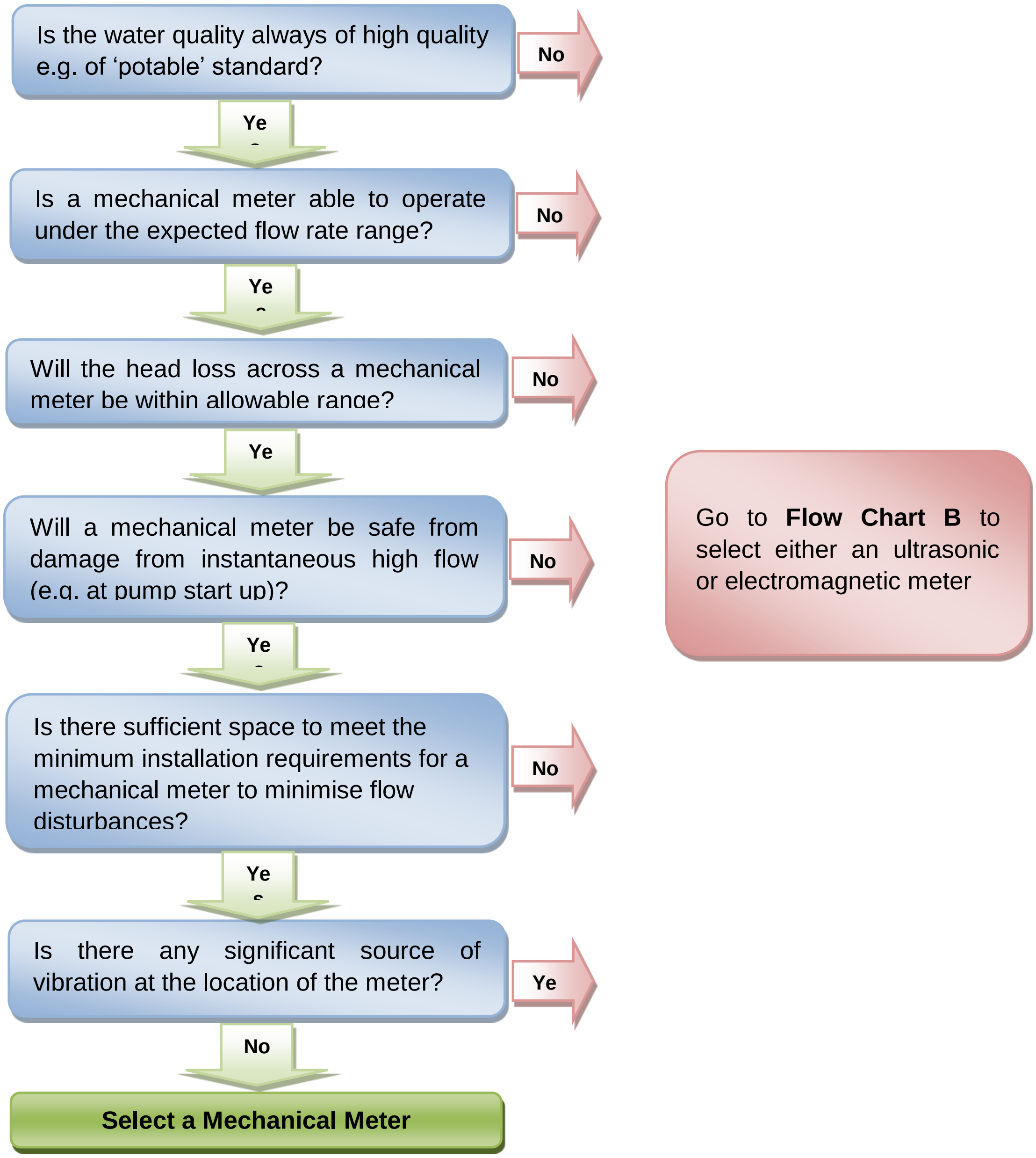
IP Against Objects (1st No.)	Explanation
1	Protected against solid foreign objects of 50mm diameter and greater
2	Protected against solid foreign objects of 12.5mm diameter and greater
3	Protected against solid foreign objects of 5mm diameter and greater
4	Protected against solid foreign objects of 1mm diameter and greater
5	Protected against dust; limited to ingress (no harmful deposits)
6	Totally protected against the entry of dust
IP Against Liquids (2nd No.)	**Explanation**
0	Not Protected
1	Protected against vertically falling drops of water
2	Protected against vertically falling drops of water when tilted at any angle up to 15° from the vertical
3	Protected against direct sprays of water at any angle up to 60° from the vertical
4	Protected against water splashed from all directions; limited ingress permitted
5	Protected against jets of water from all directions; limited ingress permitted
6	Protected against strong jets of water from all directions; limited ingress permitted
7	Protected against effects of submersion from 0.15 m to 1 m
8	Protected against the effects of submersion in water, up to 10 m

Appendix B

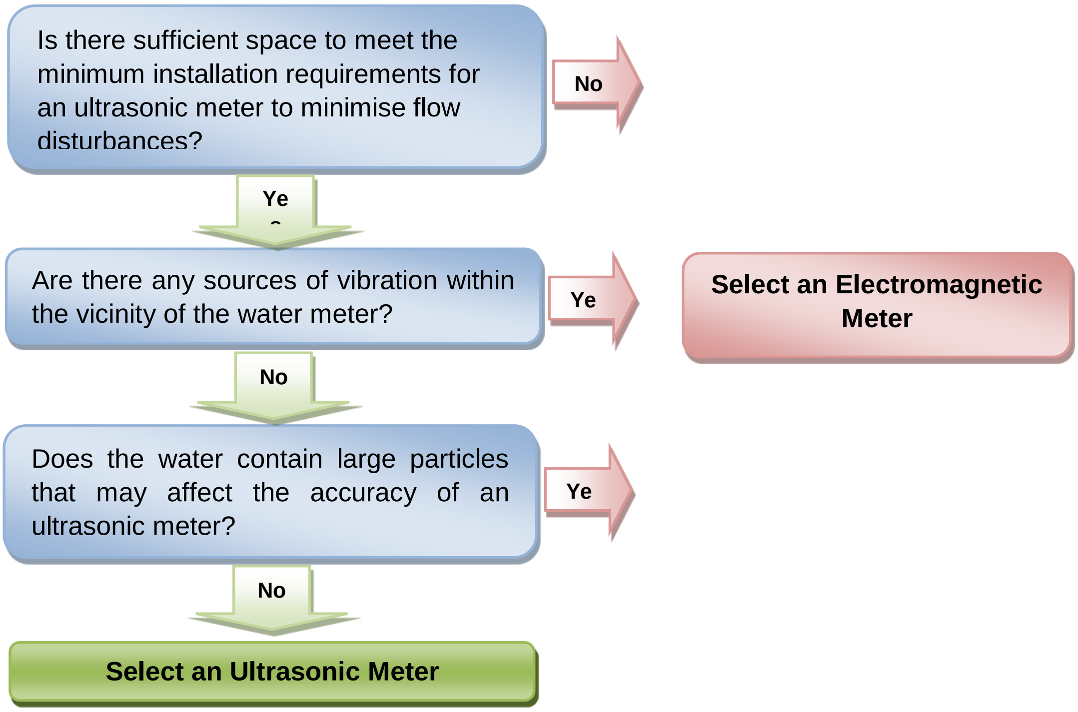
Meter Selection Flow Chart for Full Pipe Systems

The following flow charts are designed to provide guidance in the selection of a water meter for full pipe systems. It is designed to help identify which of the three primary water meter types (mechanical; ultrasonic; electromagnetic) is appropriate for a particular full pipe system. These flow charts are only basic meter selection tools. It is recommended that permit holders seek specific advice from their relevant regional council or local supplier prior to the purchase of a water meter.

Flow Chart A – Is a mechanical meter suitable?



Flow Chart B – Is an Ultrasonic or Electromagnetic meter suitable?



Other considerations for selection of electromagnetic or ultrasonic meters:

- Flow range and accuracy;
- Head loss, particularly if considering a meter size smaller than the pipe work;
- Power source; mains supply or long life batteries;
- Weight of meter;
- Provision for in situ verification;
- Data acquisition options;
- Skill level required for operation;
- Life-cycle costs for meter purchase, installation and operation;
- Electrical earthing requirements.

Appendix C

Instructions for Manual Reading of a Water Meter

Reading your meter

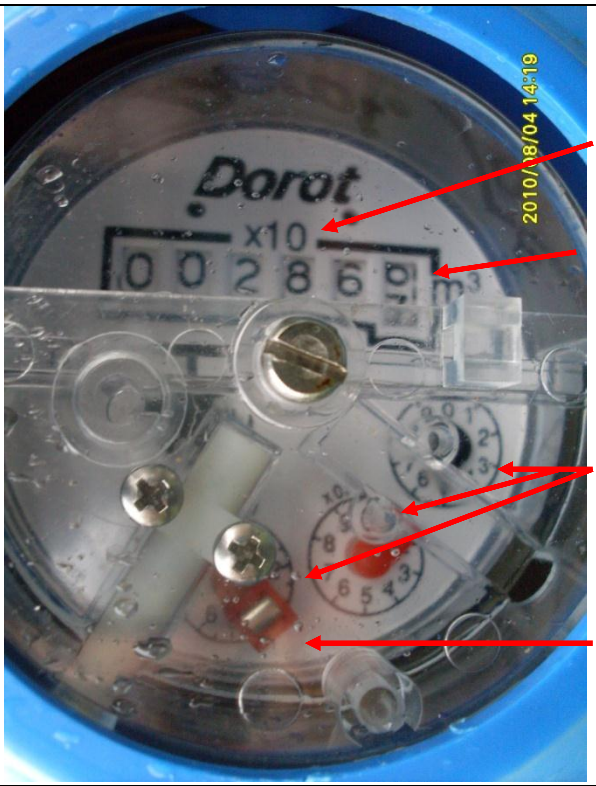
The display format of the available water meters varies between manufacturers and models and it is important to understand the format when providing water use records. The water meters can be generalised into two main categories, Rotary and electronic displays.

Rotary Display

These are primarily found on mechanical meters and general consist of two elements for the flow reading. An odometer style display gives the first part of the reading with the dials comprising the remainder of the reading. It is important to understand the units of each component to ensure an accurate reading. Inclusion of the leading zeros will greatly aid in reducing misreads and tracking errors in the data set.

In the below example the reading is:

10 m^3 odometer	002866
1 m^3 dial	5
0.1 m^3 dial	2
0.01 m^3 dial	9
Flow reading	0028665.29 m^3



Units of odometer

Odometer

Dials

Pulse output driver 1 complete revolution gives 1 pulse. The red needle above indicates the resolution of the pulse output. i.e. 1 pulse every 0.1m3

Digital Displays

Digital LCD display can be found on all meter types and come in a variety of formats. Some will show a multitude of data on the screen and others have a menu based display structure. When providing meter readings it is important to understand how your meter is set up and which screen show the accumulating flow total. It is also necessary to understand the units of the display as not all meters will provide this. If you are unsure talk to the installer or meter supplier.

The example below is a typical display and shows two flow fields. The top number is the instantaneous flow rate with the lower number showing the flow total. As evident on this meter the units of the flow total are not shown. In some cases, as with this meter, the units of the flow total are linked to that of the flow rate, m^3 for this meter

Instantaneous flow rate
With time units

Accumulating flow total

Rest button

This gives a flow total for the meter of 5163523.6 m^3.
Once again the units of the meter are important and should be displayed in m^3. Another important consideration is the maximum number capable of being displayed and this should allow for at a minimum, a year's use, this avoids the meter rolling over making meter checks more complex than necessary. For the same reason resetting the flow total should be avoided at all times.

Use of meter records

Keeping an accurate record of daily water use can help understand how and when you are using your water. It can also help in monitoring pump performance and system efficiencies. If your meter does not include a instantaneous rate, e.g. a mechanical, then the flow rate can be quickly derived by observing the change in flow total for a given time. The simplest method is to measure the length of time to pump a set volume, 1 or 10 m^3 depending on the size of water take. The rate is then the difference in flow reading divided by the time in seconds. For example, if you measure the

time to pump $10m^3$ of water and result in 5 minutes 13 seconds then the rate is $10m^3$ divided by 313 seconds. This equals 0.0319 m^3/s or 31.9 L/s. this can help manage your take to meet your consent conditions and ensure compliance.

Appendix D

Other Considerations for Open Channel and Partially Full Pipe Systems

On-site Access to Measurement Data

A water measurement system must have a simple, reliable and unambiguous means of access to the real-time data being recorded by the measurement system, for example:

- If the permit holder wants to manually take readings on site;
- For inspection and calibration of the water measurement system; and
- For accuracy verification of the water measurement system.

The following data must be accessible (the data does not need to be continuously displayed, but can be such that it is displayed, for instance, when a button is pressed):

- The cumulative flow volume expressed in cubic metres (m^3), with:
    - Sufficiently large registering range to record cumulative flow volume corresponding to 1 year at the maximum expected flow rate without passing through zero, and
    - Sufficient resolution for verification purposes (1 decimal point scale interval, unless the minimum expected flow rate is greater than 40 L/s, in which case integer scale interval is allowed);
- The measured flow rate in litres per second (L/s) (with a recommended minimum resolution of one decimal point for verification purposes);
- Where water level is measured as a basis for deriving flow rate (not a requirement), the measured water level expressed in millimetres (mm); and
- The rating and algorithms used to calculate the flow rate.

An on-site display is one way of providing visual indication of the measurement data. If used, an on-site display should have the following characteristics:

- Be of a size and type that is easy to read with clearly specified units;
- The values displayed must be precisely the same value as that recorded in the data logger or transmitted by telemetry (if these are required by the relevant regional council);
- Resistant to corrosion and fogging; and
- Mounted in a way that allows for both easy access to and manual reading of the display unit (without, for example, the use of a mirror or ladder).

The Regulations do not explicitly require an on-site measurement display. Therefore, if the same information can be made available on site through alternative means (e.g. by connecting a laptop to the measurement system), an on-site display is not required unless specifically required by the relevant regional council.

Construction Materials

The components of the water measurement system must be manufactured from sound, durable, corrosion-resistant materials. All parts of the water measurement system in contact with water must be manufactured from materials that are non-toxic, both chemically and biologically inert.

Identification

If a unique identification/serial number is supplied by the regional council, then the water measurement system should be securely tagged/attached/imprinted with the number in a position that is clearly visible to facilitate its identification.

Electrical Standards

The installation works must comply with all relevant New Zealand electrical installation standards and requirements. All components of the water measurement system that rely on electrical supply must have the supply maintained, as far as practicable, at all times. The installation must ensure that any electrical supply to the water measurement system cannot be deliberately interrupted without breaking a tamper-proof indicating seal visibly.

The measuring ability and calibration parameters of the water measurement system must not be affected by an interruption of the electrical supply.

If electromagnetic-based measurement systems are used, sources of electromagnetic interference (e.g. electric fences) should be considered in the site selection and system design.

Enclosure Protection Rating

The environmental enclosure ratings for the various components of the water measurement system should reflect the degree of protection required for the installation environment. Refer to Appendix A for more information on these Ingress Protection (IP) or National Electrical Manufacturers Association (NEMA) ratings.

Protection from Damage and Interference

Practicable precautionary consideration must be taken in the installation to prevent damage and interference to the components of the water measurement system from all sources including the following:

- Vehicles, livestock, vandalism, and flooding;

- Possible electrical interference from sources such as electric fencing or overhead power lines;
- Aggressive environmental conditions; and
- Extremes and fluctuations of temperature of the water or ambient atmosphere.

Health and Safety

The design and installation of the water measurement system should consider the protection of operators, the public and the environment from harm from the system.

Appendix E

V-notch Weir Measurement System Suitable for Some Open Channel Sites

This appendix presents a low life-cycle cost, reliable, low-maintenance, and easy-to-use system that might suit straightforward and simple sites that do not have complex characteristics. This section is not intended to replace advice from suitably qualified hydrologists for complex sites. This section is also not intended to prescribe a sole method that can be used for all sites. This is because every site has specific site conditions to consider, and several different systems may suit a particular site. The intent of this section is to allow permit holders with straightforward sites, and who are confident of their own competence, to set up a water measurement system without the professional services of a suitably qualified hydrologist.

The Regulations do not require using the services of a suitably qualified hydrologist. However, because of the uniqueness of each site, it is noted that most, if not all, permit holders would benefit from using the services of a suitably qualified hydrologist for part or all of the water measurement system set up.

Please note that all water measurement systems, both new and existing, are not required to suit any of the descriptions in this section. All water measurement systems must, however, meet the requirements in Section C2 and be verified as per Section C3.

Site Conditions

Every site has specific characteristics to examine during a thorough site investigation at the location from which water is taken (or near it if approved by the relevant regional council). The water measurement system suggested in the following sections should be used only if the site has all of the following characteristics:

- Flow rate below 1400 L/s (however, the higher the flow rate, the more complex construction process will be);
- Low to moderate sediment/debris load;
- Man-made (e.g. concrete) approach channel can be constructed immediately upstream of measuring point;
- Straight section of sufficient length is available;
- Channel slope is not very steep;
- Migratory fish passage not required;
- Regular maintenance is practicable;
- Sufficient available head so that head loss across measurement system does not affect downstream systems; and
- Not exposed to strong wind or its effects can be mitigated.

If the site does not fulfil any one of these characteristics, professional advice will be required to ensure that the water measurement system is suitable.

Control Section

The configuration described here uses a thin-plate, fully contracted, V-notch weir in the control section. A V-notch weir usually consists of a thin, vertical concrete wall with a sharp corrosion-resistant metal crest, or a steel or alloy plate as the wall. It has a symmetrical V-shaped notch located equidistant from the channel walls.

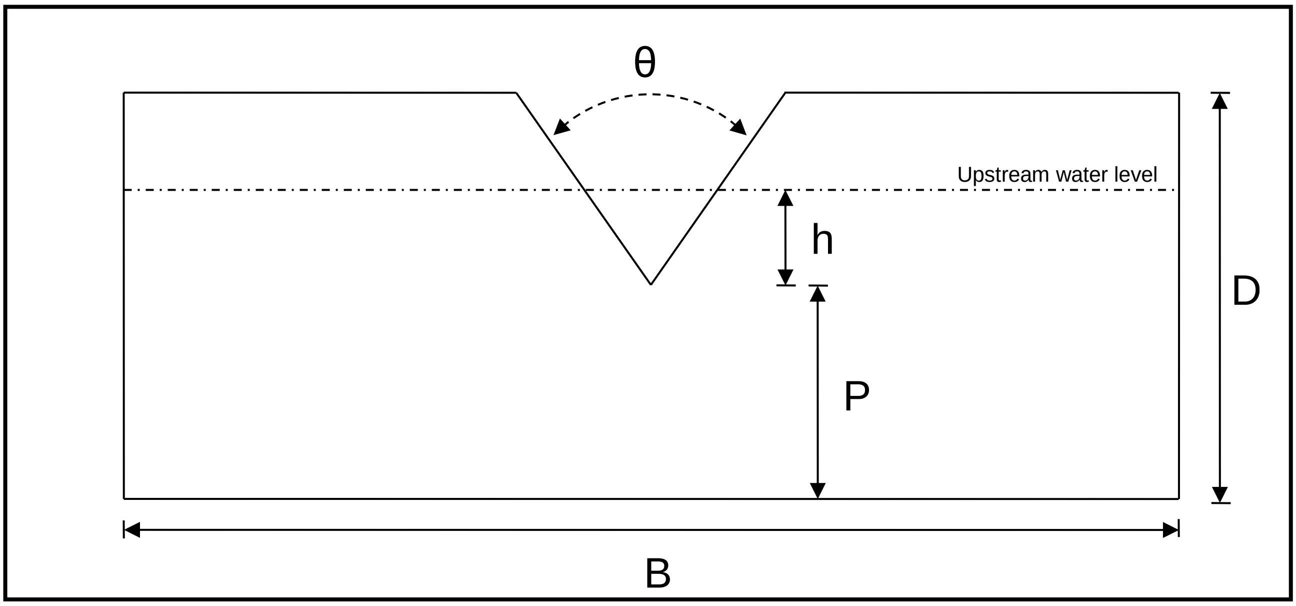


Figure E1: Diagram of a V-notch weir.

V-notch weirs facilitate accurate flow measurement covering a wide range of flows. However, they should only be used for measuring flows of up to approximately 1.4m^3/s. Very large V-notch weirs require a high head loss, and therefore may not suit some sites.

The choice of a suitable V-notch angle (θ) is dependent on the range of expected flow rates, the constructed approach channel depth, the debris load, and the required maximum uncertainty of ±10%. Smaller angles allow more sensitive measurement at low flows, but are more prone to blockage by debris. The depth of the constructed approach channel affects the head available above the vertex. Table E1 provides the basis for selecting a suitable V-notch angle based on the range of expected flow rates and the available head above the vertex. To maximise the resolution achieved, the smallest angle that suits the range of expected flow rates should be chosen.

Table E1: Range of maximum flow rates in litres per second (L/s) for various V-notch angles

Vertex angle, θ / Available head above vertex, m	20°	30°	45°	60°	90°
0.05 (minimum)	0.21	0.30	0.45	0.62	1.06
0.2	6.06	9.03	13.7	19.0	32.8
0.5	58.6	87.9	134	186	322
1.0	329	494	755	1050	1810[3]

Note on how to read the table: A 20° V-notch angle can be used to measure flow rates with a lower limit of 0.21 L/s and an upper limit of:

- 6.06 L/s if the top of the weir is only 0.2m above the notch;
- 58.6 L/s if the top of the weir is only 0.5m above the notch; and
- 329 L/s if the top of the weir is 1.0 m above the notch.

The weir plate must be smooth (smoothness equivalent to the surface finish of rolled steel) and planar, especially on the upstream side. The weir plate must be vertical and perpendicular to the sides and bottom of the channel.

The crest surfaces must be planar surfaces no more than 2mm in width (preferably 1mm wide) unless there are specific reasons for doing otherwise. The crest surfaces must be machined/filed perpendicular to the upstream face of the weir plate. The crest edges must be free from burrs and scratches, and untouched by abrasive cloth/paper (which will tend to round the edges unacceptably).

To withstand the forces exerted upon the structure, a weir plate thicker than the 2mm maximum allowable crest width may be used. However, the downstream edges of the weir must be chamfered to keep the crest width to no more than 2mm. The angle of the chamfered surface must be no less than 45°, and preferably about 60°, with the crest surface.

The weir structure and foundation must have sufficient structural strength to withstand forces exerted by expected high flows.

[3] Although the table has values going up to 1810L/s, sites with flow rates above 1400L/s are likely to require the expertise of a suitably qualified hydrologist.

The weir structure must be watertight, and not allow leakage around or under it. Joints in concrete must have a suitable water-stop material cast in, and joints in metal walls must incorporate a suitable rubber sealer.

The weir should be installed such that the vertex of the weir notch sufficiently high above the approach channel bed (recommended P ≥ 0.1 m – refer to Figure E1). This allows water to form a pool immediately upstream of the weir, thus reducing the approach velocity. This also acts as a sediment trap (which must be cleared regularly) without affecting accuracy.

Approach Channel

An approach channel is constructed immediately upstream of the weir with the following characteristics:

- Made of concrete or other durable material (these are more physically stable and less subject to vegetation growth);
- Minimum straight length of 10 times the channel width (however, if flow enters the constructed approach channel via a constricted section or immediately after a bend, an even greater length of approach channel is recommended);
- Uniform, rectangular cross-section;
- Minimal gradient kept to minimise the approach velocity;
- No flow disturbances/obstructions; and
- Sufficiently wide and deep.

The channel walls and bed should be far enough to have negligible influence on the flow through the weir (Recommended distance between the channel bed and walls from the vertex is at least two times the maximum head over the weir, i.e. $B \geq 4(h_{max})$ and $D \geq 2(h_{max})$; refer to Figure E1).

Downstream Channel

Free-fall flow of water over the weir (with an “aerated nappe”) for the entire range of expected flow rates is a critical requirement for the discharge to be calculated solely from the measured upstream water level. (When the downstream water level rises above the weir crest level, the weir is said to be ‘drowned’, and the discharge depends on both upstream and downstream water levels.)

Therefore, the water level immediately downstream of the weir should sufficiently below the vertex of the V-notch (recommended that the maximum expected downstream water level is at least 6cm below the vertex) to permit free discharge from the site for the range of flow to be measured without backwatering or submergence of the site.

To prevent scour to the downstream channel bed and sides, either of the following should be constructed immediately downstream of the weir:

- An apron of rip-rap/gabions; or
- A continuation of the upstream channel made of concrete or other durable material.

Screen

To prevent debris from causing damage to, or lodging, in the weir notch, screens (e.g. wire mesh fences or floating booms) are installed upstream of the weir at a minimum distance 10 times the approach channel width. These screens must be frequently checked and maintained, especially after heavy rainfall. Where the site conditions are such that debris is likely to enter the approach channel downstream of the screen, a lid could be installed between the screen and the weir.

The effects of strong wind on the water level measurement should be accounted for in the design of the water measurement system, e.g. by the use of barriers. Other site conditions that can affect the measurement need to also be considered in design.

Staff Gauge and Level Sensor

The configuration has a staff gauge with 10 mm scale resolution installed upstream of the weir near the level sensor. To prevent measuring water level at the drawdown area near the weir notch, the staff gauge and level sensor should be located in either of the following points:

- By the side of the weir crest, provided that the crest does not occupy the full width of the approach channel; or
- Upstream of the weir by a distance equal to about 3 times the maximum water depth; or
- In a stilling well (if it is used).

In Situ Calibration

The water measurement system requires calibration on site after installation and then periodically over its operating life.

Firstly, the level sensor is calibrated using the staff gauge as a reference.

Secondly, the stage-discharge rating (the relationship between water level and flow rate) is established. This usually involves 3 key steps:

1) Measuring many different flow rates and the corresponding water levels.
2) Plotting the flow rate and water level data points to obtain a curve of best fit.
3) Deriving the rating equation and inputting it into the central processing unit (which converts the water level measurement into flow rate data).

Measuring the flow rate (step 1) can be performed using various techniques, including the following:

- Using a bucket-and-stopwatch volumetric measurement for small flows (typically no more than 10L/s). This procedure is the same as that used in verification, as described in Section C3.7.1.

- Using a more complex procedure for larger flows, such as the velocity-area method. This typically involves using a current meter to measure velocity at several locations evenly spaced across the channel. The use of a current meter will require the expertise of a suitably trained person, and the measurement should be carried out in accordance with ISO 748.

It is important to have stage-discharge data points at many different stages across the entire range of expected flow rate. Generally, obtaining more stage-discharge data points, and repeating measurements at each data point, improves the accuracy of the rating curve.

Steps 2 and 3 are more complex and require the person performing the calibration to be capable of deriving an equation from a curve of best fit, and inputting information into the central processing unit.

Appendix F

Uncertainty & Error - Determination of Measurement Accuracy

It is important not to confuse the terms 'error' and 'uncertainty'.

- ***Error*** is the difference between the reference meter measured value and the 'true value' of the service meter.
- ***Uncertainty*** is a quantification of the doubt about the measurement result – it indicates the quality of the measurement.

There is always a margin of doubt about any measurement. To understand the uncertainty two questions must be answered - 'How big is the margin?' and 'How bad is the doubt?' Thus, two numbers are needed to quantify an uncertainty; the width of the margin or ***interval (+/-x%)***; and how sure we are that the 'true value' is within that margin or ***the confidence level (x percentile)***.

Known errors, for example, the error associated with the reference meters calibration certificate can relatively easily be corrected for. But any error whose value is not known must be regarded as a source of uncertainty.

Where do the errors and uncertainties come from?

Many factors can undermine a measurement. Flaws in the measurement may be visible or invisible. As real measurements are never made under perfect conditions, errors and uncertainties can come from:

- **The measuring instrument** - instruments can suffer from errors including bias, changes due to ageing, wear, or other kinds of drift, poor readability, noise (for electrical instruments) and many other problems.
- **The item being measured –** the flow may not be stable.
- **The measurement process** - the measurement itself may be difficult to make.
- **'Imported' uncertainties** - calibration of your instrument has an uncertainty which is then built into the uncertainty of the measurements you make.
- **Operator skill** - some measurements depend on the skill, judgement and reaction time of the operator. Note: gross mistakes are a different matter and are not to be accounted for as uncertainties.
- **Sampling issues** - the measurements must be properly representative of the process you are trying to assess.
- **The environment** - temperature, air pressure, humidity and many other conditions can affect the measuring instrument or the item being measured.

Where the size and effect of an error are known (e.g. from a calibration certificate) a correction can be applied to the measurement result. But, in general, uncertainties from each of these sources, would be individual 'inputs' contributing to the overall uncertainty in the measurement.

Kinds of uncertainty?

The effects that give rise to uncertainty in measurement can be either:

- **Random** - where repeating the measurement gives a randomly different result. If so, the more measurements you make, and then average, the better estimate you generally can expect to get. or

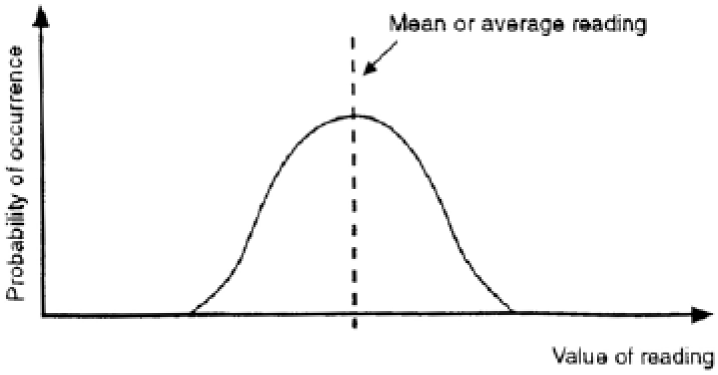
- **Systematic** - where the same influence affects the result for each of the repeated measurements (but you may not be able to tell). In this case, you learn nothing extra just by repeating measurements. Other methods are needed to estimate uncertainties due to systematic effects, e.g. different measurements, or calculations.

Distribution - the 'shape' of the error

The spread of a set of values can take different forms, or *probability distributions.*

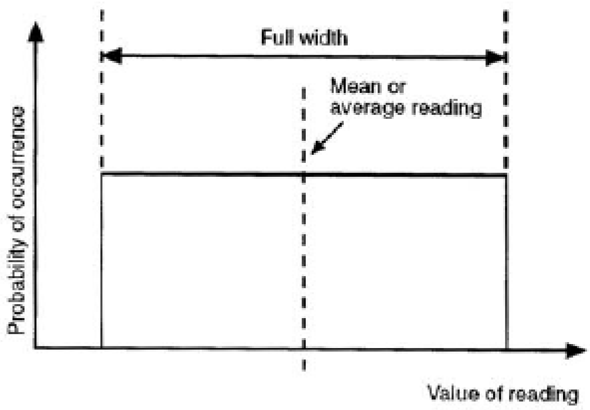
Normal distribution

In a set of readings, sometimes the values are more likely to fall near the average than further away. This is typical of a *normal* or *Gaussian* distribution.
The diagram below shows a set of 10 'random' values in an approximately normal distribution.



Uniform or rectangular distribution

When the measurements are quite evenly spread between the highest and the lowest values, a *rectangular* or *uniform* distribution is produced. For this distribution values would be as likely to fall on any one part as on another.
The diagram below shows a set of 10 'random' values in an approximately rectangular distribution.



What is not a measurement uncertainty?

- **Mistakes made by operators** are not measurement uncertainties. They should not be counted as contributing to uncertainty. They should be avoided by working carefully and by checking work.

- **Tolerances** are not uncertainties. They are acceptance limits which are chosen for a process or a product.
- **Specifications** are not uncertainties. A specification tells you what you can expect from a product. It may be very wide-ranging, including 'non-technical' qualities of the item, such as its appearance.
- **Accuracy (inaccuracy) is not the same as uncertainty**. Unfortunately, usage of these words is often confused. Correctly speaking, 'accuracy' is a qualitative term (e.g. you could say that a measurement was 'accurate' or 'not accurate'). Uncertainty is quantitative. When a 'plus or minus' figure is quoted, it may be called an uncertainty, but not an accuracy.
- **Errors** are not the same as uncertainties.
- **Statistical analysis** is not the same as uncertainty analysis. Statistics can be used to draw all kinds of conclusions which do not by themselves tell us anything about uncertainty. Uncertainty analysis is only one of the uses of statistics.

How to calculate uncertainty of measurement?

To calculate the uncertainty of a verification measurement, the verifier must identify the sources of uncertainty in the reference measurement, including the environmental/pipe conditions, measurement resolution, and inaccuracy in any input values (e.g. pipe wall thickness) required for some reference water measurement systems/devices. Then they must estimate the size of the uncertainty from each source.

Standard uncertainties

All uncertainties should be expressed at the same confidence level, by converting them into ***standard uncertainties***. A standard uncertainty is a margin whose size can be thought of as 'plus or minus one standard deviation'. The standard uncertainty tells us about the uncertainty of an average (not just about the spread of values).

Calculating standard uncertainties

No matter what are the sources of your uncertainties, there are two approaches to estimating them: 'Type A' and 'Type B' evaluations. In most measurement situations, uncertainty evaluations of both types are needed.

- ***Type A evaluations*** - uncertainty estimates using statistics (usually from repeated readings)
- ***Type B evaluations*** - uncertainty estimates from any other information. This could be information from past experience of the measurements, from calibration certificates, manufacturer's specifications, from calculations, from published information, and from common sense.

Calculating standard uncertainty for a Type A evaluation

When a set of several repeated readings has been taken (for a Type A estimate of uncertainty), the mean and estimated standard deviation, (*s)* can be calculated. From these, the estimated standard uncertainty, (*u*) of the mean is calculated from:

$$u = \frac{s}{\sqrt{n}}$$

(*n)* is the number of measurements in the set.

Calculating standard uncertainty for a Type B evaluation
Where information is scarce (in some Type B estimates) it is often only possible to estimate the upper and lower limits of uncertainty. You may then have to assume the value is equally likely to fall anywhere in between, i.e. a rectangular or uniform distribution. The standard uncertainty for a rectangular distribution is found from:

$$\frac{a}{\sqrt{3}}$$

where (*a)* is the semi-range (or half-width) between the upper and lower limits.

Rectangular or uniform distributions occur quite commonly, but if there is good reason to expect another distribution, then the calculation should be based on that. For example, it can be assumed that uncertainties 'imported' from the calibration certificate for a measuring instrument are normally distributed.

Combining standard uncertainties
Finally the individual uncertainties when expressed in the same units and confidence levels, can be combined to give an overall figure (combined standard uncertainty). It can be found using the root-sum-squares method:

$$u_C = \sqrt{(u_1{}^2 + u_2{}^2 + u_3{}^2 \ldots \text{etc.})}$$

(where u_C is the combined standard uncertainty, and u_1, u_2, u_3, etc. are the component standard uncertainties).

Expanded uncertainty
Having scaled the components of uncertainty consistently to find the combined standard uncertainty is then necessary to re-scale the result. The combined standard uncertainty is equivalent to 'one standard deviation', but often an overall uncertainty is required stated at another level of confidence, i.e. 95 percent. This re-scaling is done using a coverage factor. Multiplying the combined standard uncertainty (u_c) by a coverage factor (k) gives a result which is called the expanded uncertainty (U) i.e.

$$U = ku_c$$

A particular value of coverage factor gives a particular confidence level for the expanded uncertainty. If the combined uncertainty is normally distributed a coverage factor k = 1.96 should be used to give a confidence level of 95 percent and for a uniform distribution k = 1.732. Other, less common, shapes of distribution have different coverage factors.

Conversely, wherever an expanded uncertainty is quoted with a given coverage factor, you can find the standard uncertainty by the reverse process, i.e. by dividing by the appropriate coverage factor. This means that expanded uncertainties given on calibration certificates, if properly expressed, can be 'decoded' into standard uncertainties.

How to express the answer
It is important to express the answer so that a reader can use the information. The main considerations are:

- The measurement result, together with the uncertainty figure, i.e. the reference meter measurement was 32.5l /s ±0.9l/s
- The level of confidence and the coverage factor used
- How the uncertainty was estimated

Example Showing Determination of Compliance

(Note: this example is for an open channel system, but applies to full pipe systems as well, the difference being the permissible uncertainties)

Open channel water measurement system (thus, maximum permitted uncertainty of ±10% of reading, at 95% level of confidence)

Average measurement from the installed system = 18.2 L/s.
Average reference measurement = 20.1 L/s.

- Current meter certified with uncertainty of ± 1.5% of reading at 95% level of confidence (k=1.96). Expressing the uncertainty in terms of standard uncertainty:

$$\frac{1.5\% \times 20.1\text{L/s}}{1.96} = 0.154\text{L/s}$$

- Identified 3 sources of uncertainty, with estimated uncertainties which when converted have equivalent individual standard uncertainties of ± 0.130 L/s, ± 0.202 L/s, and ± 0.311 L/s.

  All sources of uncertainty are independent of each other.

- Combined standard uncertainty,

$$u_c = \sqrt{(0.154^2 + 0.130^2 + 0.202^2 + 0.311^2)} = 0.422\text{L/s}$$

  To give a level of confidence of 95% (k=1.96),

  Expanded uncertainty $= 0.422\text{L/s} \times 1.96 = 0.827\text{L/s}$

- Therefore, the reference measurement is 20.1 ± 0.8 L/s.

  With a maximum permitted uncertainty of ±10% of reading at 95% level of confidence, the measurement from the installed water measurement system is 18.2 L/s ± 1.8L/s at 95% level of confidence.

  The uncertainty intervals overlap, i.e. 18.2L/s is within 20.1L/s ± 2.6L/s (1.8 + 0.8), thus the water measurement system is not identified as non-compliant.

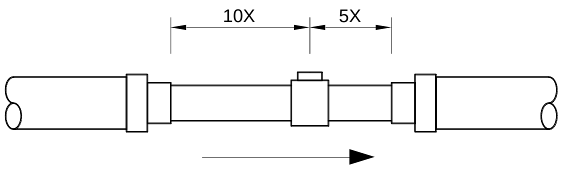
Appendix G

Recommended Configurations for Installation of Water Meters in Closed Pipes

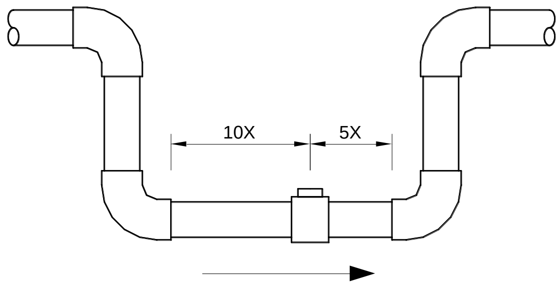
Straight Pipe Recommendations

(X = Pipe Diameter)

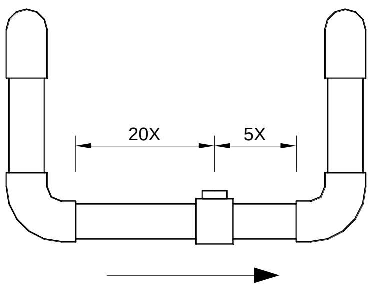
Reduced Pipe



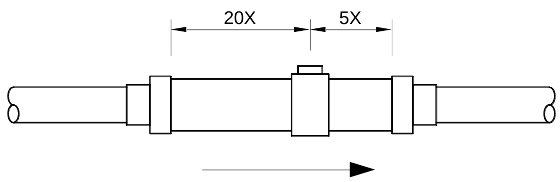
Two Elbows in Plane



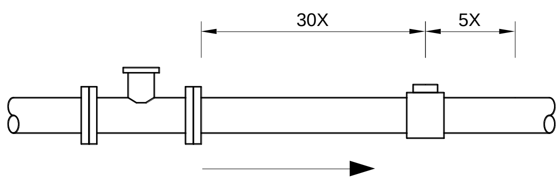
Two Elbows, Out of Plane



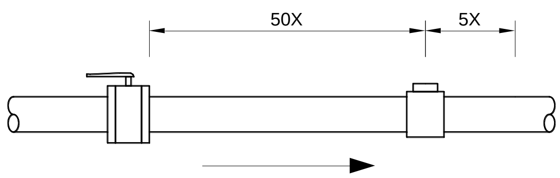
Expanded Pipe



Sprial Flow



Swirling Flow



Appendix H

Installation & Commissioning Form Template for Full Pipe Systems

Name of Permit Holder: ____

Permit Number: ____

Location of meter: ____

GPS Coordinates for meter: Northing ________________ Easting _________________ **NZMG**

Date of Installation: ______/______/______

Date of Commissioning: ______/______/______

Water Meter / Water Measuring Device Details:

Make: ____

Meter size (mm diameter): ____

Model: ____

Pulse output: **Yes / No**

Serial number: ____

Volume per Pulse _______________________ **m³ / pulse**

Meter Reading Volume: __________________ **m³** (*state units if different*)

Data Logger Details:

Installed: **Yes / No**

Make: ____

Model: ____

Serial number: ____

Telemetry installed for compliance: **Yes / No**

Data hosted by: ____

Installation Details:

Pipe internal diameter: __________________________**mm**

Pipe wall thickness: ____________________________**mm**

Pipe material: ____

Is there a straight unobstructed accessible pipe in the system of at least 15 diameters length to verify the flow with a clamp-on flow meter? **YES / NO**

Please sketch the system showing location of meter, unobstructed pipe length upstream and downstream of meter, and any specific features to allow for verification (length of pipe for clamp on meter or testing tee). Please write dimensions on the sketch including unobstructed pipe lengths, pipe diameter etc.

Figure 1: Installation diagram - Please mark any disturbances upstream of the meter e.g. pipe size reduction, gate valves, pipe bends; dimensions and any specific features for verification.

***Insertion meters only*:**

Encountered K-factor in the flow meter: ____

***Ultrasonic meters only*:**

Transducer size encountered Transducer spacing: _______________________________________

Transducer mounting type, please circle one: **V / Z** (V = Reflect, Z = Direct)

Accuracy Details:

Do you have a wet calibration certificate? **Yes / No**

(*If yes, then please submit the certificate*.)

Has the meter been verified? **Yes / No**

(*If yes please ensure verification report has been completed, if no please arrange for the meter to be verified*)

Installed by: ____

Signed (by installer): ____

Company: ____

Date: ______/______/_______

Attached:

- As-builts of system
- Photo of set-up
- Verification report (optional, some regional councils may request this at this point)

Appendix I

Installation Commissioning Report Template for Open Channel Systems

Permit holder's name: __________________
Water permit number: __________________
Serial number provided by regional council (if any): ______________

Location description: ____
GPS coordinates: ____
Commissioning completion date: ____/_____/_______ (DD/MM/YYYY)

Brief system description: (including channel type and material, type of sensor(s), control section type and dimensions, other notable features, etc.)
____
____
____
____
Channel material: _______________
Channel width: _________________mm
Channel depth: ________________ mm

Distance of straight channel upstream of measuring system: ___________________mm
Distance of straight channel downstream of measuring system: _________________mm
(attach a photograph and a detailed as-built diagram of the installation configuration, including dimensions and verification facilities)

Have level references and survey benchmarks been installed? Yes/No
Does the system allow for verification? Yes / No
Brief description of verification facilities provided:
____
____
____
Has the measurement system been calibrated? Yes / No
Reading after commissioning: ________________________________m^3 (*state units if different*)

Can be fitted with electronic data logger: Yes / No
Electronic data logger installed: Yes / No
If yes,
Make: ____________________________
Model: ____________________________
Serial number: _______________________
Telemetry installed: Yes / No
If yes,
Data hosted by: ______________________

Installer's name: _____________________________
Signed (by installer): ___________________________ Date: ____/_____/_______
Company name: ______________________________
Company contact phone number: ________________
Company address:

Appendix J

Installation Commissioning Report Template for Partially Full Pipe Systems

Permit holder's name: __________________
Water permit number: __________________
Serial number provided by regional council (if any): ______________

Location description: ____
GPS coordinates: ____

Commissioning completion date: ____/_____/_______ (DD/MM/YYYY)

Brief system description: (including type of sensor(s), other notable features, etc.)
____
____
____
____
Pipe material: ________________________
Pipe outside diameter: _________________mm
Pipe wall thickness: ___________________ mm

Distance of straight pipe upstream of measuring system: ___________________mm
Distance of straight pipe downstream of measuring system: _________________mm
(attach a photograph and a detailed as-built diagram of the installation configuration, including dimensions and verification facilities)

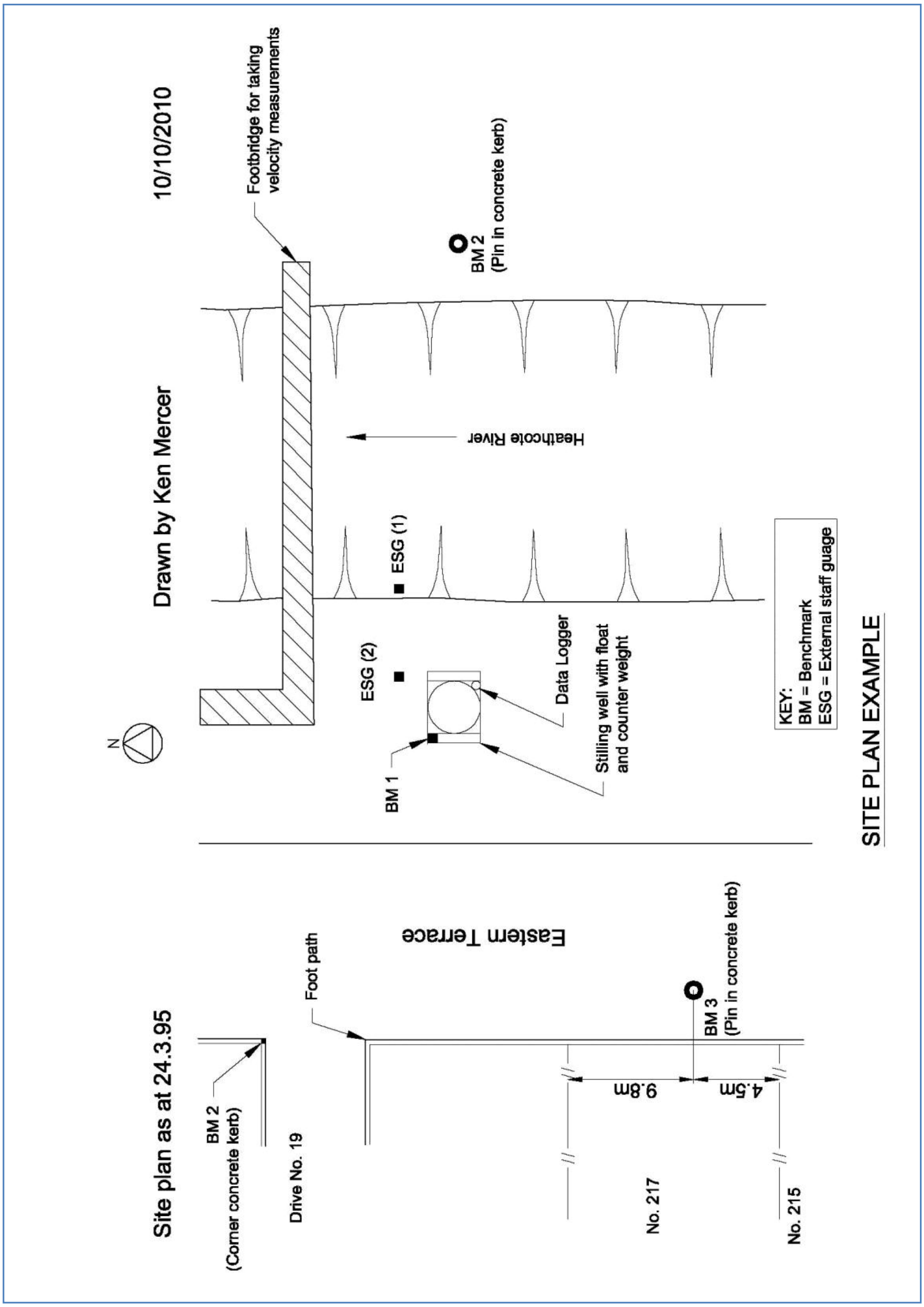
Does the system allow for verification? Yes / No
Brief description of verification facilities provided:
____
____
____
Has the measurement system been calibrated? Yes / No
Reading after commissioning: ________________________________m^3 (*state units if different*)

Can be fitted with electronic data logger: Yes / No
Electronic data logger installed: Yes / No
If yes,
Make: ____________________________
Model: ____________________________
Serial number: ______________________
Telemetry installed: Yes / No
If yes,
Data hosted by: _____________________

Installer's name: ______________________________
Signed (by installer): ___________________________ Date: ____/_____/_______
Company name: ______________________________
Company contact phone number: ________________
Company address:

Appendix K

Example of a Site Plan for an Open Channel System



Appendix L

Verification Form Template for Full Pipe Systems

Name of Permit Holder: ____

Permit Number: ____

Date of Verification: ______/______/______

Water Meter / Water Measuring Device Details:

Make: ____

Meter size (mm diameter): ____

Model: ____

Pulse output: **Yes / No**

Serial number: ____

Volume per Pulse _________________________ **m³ / pulse**

Meter Reading Volume: ____________________ **m³** (*state units if different*)

***Ultrasonic meters only*:**

Transducer size encountered Transducer spacing: _______________________________________

Transducer mounting type, please circle one: V ***/*** Z (V = Reflect, Z = Direct)

Correct **Yes / No**

Verification details:

Is a clamp-on water meter used for verification: **Yes / No**

If ***No***, *describe the method used (e.g. reservoir/time calculation, volumetric etc)*

____

____

____

Verification flow meter brand and type: ____

Verification flow meter serial number: ____

Last calibration date of the flow meter used for verification: ______/______/______

(*Calibration certificates needs to be sent to the Regulatory Authority after calibration)*

Verification parameters:

Pipe Diameter: ___________________________**mm**

Pipe Wall Thickness: ______________________**mm**

Pipe material (please circle one): ***Ductile Iron,***

Mild Steel

PVC

Polyethylene

Aluminium

Other: ________________________________

Please sketch the system showing the location of the clamp-on meter in relation to the meter being verified.

Measured flows:

Undertake at least three separate observations and record and average the results in the table below. Verification flows should be taken at or around the consented flow rate and/or the flow rate the well is usually pumped at. For ultra-sonic tests if flows don't verify within 5% +/- the reference meters uncertainty, a second clamp-on location can/should be attempted.

No. of different flow rates tested	Installed system measurement	Reference measurement			Individual accuracy requirement compliance (Y/N)
	Volume (m^3)	Volume (m^3)	Difference (%)	Uncertainty	
1					
2					
3					
4					
5					
6					
7					

Note: The number of tests should reflect the range of expected flow rates, with a minimum of 3 flow rates tested. All individual tests must be compliant for the system to be compliant.

Certification

Please circle which of the following statements applies to the verified meter:

I/we certify that the above water meter / water measuring device has been verified and the measured flow is within 5% of the verification meter
OR

I/we have found that the installed water meter / water measuring device deviates more than 5% **above / below** the verified flow.

Recommended remedial action: ____

____

____

Verified by: ____

Signed (by verifier): ____

Company name: ____

Company address: ____

Contact phone number: ____

Date: ______/______/______

Appendix M

Verification Form Template for Open Channel Systems

Permit holder's name: ____
Water permit number: ____
Serial number provided by regional council (if any): _______________

Location description: ____
GPS coordinates: ____

Verification date: ____/_____/_______ (DD/MM/YYYY)

Water Measurement System:
Brief description: (channel type and material, type of sensor(s), control section type and dimensions, data logging/telemetry, other notable features, etc.)

Channel material: __________________________
Approximate channel width: __________________mm
Approximate channel depth: _________________ mm

Reading at start of verification: _________**m^3** (*state units if different*)
Reading at end of verification: _________**m^3** (*state units if different*)

Verification details:
Verification method:

Verification equipment type/description:

Verification equipment serial number: ____________________
Verification equipment are currently calibrated and certified: Y/N
(attach calibration certificates)
Verification equipment available on request: Y/N

Sources of reference measurement uncertainty:
(attach calculations for expanded uncertainty, showing individual uncertainty values)

Verification results:
(attach record of individual measurements)

No. of different flow rates tested	Installed system measurement	Reference measurement		Individual accuracy requirement compliance (Y/N)
	Average measurement (m^3)	Average measurement (m^3)	Uncertainty (m^3)	
1				
2				
3				
4				
5				
6				
7				

Note: The number of tests should reflect the range of expected flow rates, with a minimum of 3 flow rates tested. All individual tests must be compliant for the system to be compliant.

Accuracy Requirement Compliance:
I/we have found that with regards to the accuracy requirement of the Regulations, the water measurement system is compliant/non-compliant (please strikethrough or circle one).

Recommended remedial action (if any):

General Inspection Notes and Any Recommended Actions:

Verifier's name: ___________________________________
Signed (by verifier):

Company name: ___________________________________
Company contact phone number: _____________________
Company address:

Date: ____/_____/_______ (DD/MM/YYYY)

Appendix N

Verification Form Template for Partially Full Pipe Systems

Permit holder's name: ____
Water permit number: ____
Serial number provided by regional council (if any): ________________

Location description: ____
GPS coordinates: ____

Verification date: ____/_____/_______ (DD/MM/YYYY)

Water Measurement System:
Brief description: (type of sensor(s), data logging/telemetry, other notable features, etc.)

Pipe outside diameter: __________________mm
Pipe wall thickness: ____________________mm
Pipe material: _________________________

Reading at start of verification meter
Reading at end of verification: _________**m³** (*state units if different*)

Verification details:
Brief description of verification method:

Verification equipment type/description:

Verification equipment serial number: ________________
Verification equipment are currently calibrated and certified: Y/N
(attach calibration certificates)
Verification equipment available on request: Y/N

Sources of reference measurement uncertainty:
(attach calculations for expanded uncertainty, showing individual uncertainty values)

Verification results:
(attach record of individual measurements)

No. of different flow rates tested	Installed system measurement	Reference measurement		Individual accuracy requirement compliance (Y/N)
	Average measurement (m^3)	Average measurement (m^3)	Uncertainty (m^3)	
1				
2				
3				
4				
5				
6				
7				

Note: The number of tests should reflect the range of expected flow rates, with a minimum of 3 flow rates tested. All individual tests must be compliant for the system to be compliant.

Accuracy Requirement Compliance:
I/we have found that with regards to the accuracy requirement of the Regulations, the water measurement system is compliant/non-compliant (please strikethrough or circle one).

Recommended remedial action (if any):

General Inspection Notes and Any Recommended Actions:

Verifier's name: ___________________________________
Signed (by verifier):

Company name: __________________________________
Company contact phone number: _____________________
Company address:

Date: ____/_____/_______ (DD/MM/YYYY)

Appendix O

Flow Measurement for Partially Full Pipe Systems

Electromagnetic Velocity Measurement and Level Sensor

Flow measurement can be achieved through the use of an electromagnetic measurement device that is capable of measuring flow velocity in a partially full pipe, and a level sensor (e.g. ultrasonic time-transit level sensor) that measures water level. Some electromagnetic measurement devices have a cut-off trip that stops measurement when the pipe is not full, and therefore are not suitable for this purpose.

The level sensor is connected to a central processing unit. The central processing unit continuously records the measured water level, converts the measurement to cross-sectional area of flow, and then calculates the volumetric flow rate. The central processing unit then totalises the flow rate over time to give the cumulative flow volume.

This configuration will require calibration, which will include the following:

1. Calibrating the level measurement: The level sensor will need to be calibrated with the required input parameters (e.g. specific pipe material, wall thickness, cross-section shape and area of flow, etc.).

2. Inputting the relationship between water level and cross-sectional area of flow (stage-area rating) into the central processing unit.

3. Ensuring that the central processing unit software correctly calculates flow rate from the velocity and cross-sectional area of flow.

Details of this possible solution has been excluded because the installation and calibration procedure depends on various factors such as those relating to the existing pipe-work and sensor type. Therefore, professional advice is recommended, even if the permit holder chooses to self-install.

Other Options for Partially Full Pipe Systems

Some relatively more modern electromagnetic devices can measure both average velocity and water level in partially full pipes. Currently, however, it may be difficult to achieve the required accuracy with these devices without specialist installation.

Ultrasonic measurement using Acoustic Doppler Current Profiler devices currently have the reputation of being difficult to configure and calibrate to give sufficiently accurate results.

As previously mentioned, technological advances are likely to improve these and other options, but currently, caution is advised in their use.

Appendix P

Recommended Service Interval for Open Channel Systems

This appendix provides recommended service intervals for different commonly used open channel measurement systems. There are two types of inspection required periodically for open channel systems:

- A maintenance inspection is a visual check to identify if any maintenance on the measuring system is required, for example, checking for accumulated sediment/debris behind a weir.
- A calibration check is to determine if re-calibration of the system is required.

A maintenance inspection and a calibration check may be carried out simultaneously on the same visit.

The recommended time intervals below have been established for typical sites as described based on experience within the Canterbury region. However, measurement systems in other regions may require less or more frequent intervals depending on the local conditions in the region. Furthermore, the specific site conditions and the characteristics of the measurement system will determine the frequency required. For example, if weed growth is present, more frequent servicing may be necessary.

Flow Measurement System	Frequency of Calibration Checks	Frequency of Maintenance Inspections
Automated Controlled Flume (pre-calibrated)	1-2 checks per season	1-2 inspections per season
Float and counterweight, stilling well and weir	Every 8 weeks	Every 8 weeks
Pressure transducer/bubbler/ultrasonic sensor and weir	Every 8 weeks	Every 4 – 6 weeks
Any system with a level sensor but without a control section (e.g. weir/flume)	Every 4 weeks	Every 4 – 6 weeks

Appendix Q

Example Inspection Checklist for Open Channel Systems

The following inspection checklist has been developed for the inspection of open channel measurement systems in the Canterbury region. This has been included as an example of what should be inspected routinely to identify any maintenance requirements. It may also contribute towards the verification of the measurement system.

Site: .... **at** ....

Site Number: .... **Year started:** ....

GENERAL

	Yes/No	Comments
Site access: adequate	....	....
Appearance: maintained	....	....
Inspection: Up-to-date	....	....
Levels close	....	....
Identified problems	....	....
Benchmarks: adequate	....	....
Identified	....	....
Reach and controls: OK	....	....
Stable/sensitive	....	....
Comments:	....	....

TOWER/RECORDER HOUSING

	Yes/No	Comments
Tower: condition OK	....	....
Adequate height	....	....
Structurally sound	....	....
Locks/hatches secure	....	....
Housing: Condition OK	....	....
Secure	....	....
Access: safe	....	....
Intakes: adequate	....	....
Valves fitted	....	....
Static tube fitted	....	....
Minimal surge	....	....
Clear of sediment	....	....
Silting problems	....	....
Flushing: method OK	....	....
Frequency adequate	....	....
Comments:	....	....

STAFF GAUGES/ELECTRIC PLUMB-BOB

	Yes/No	Comments
Staff gauges: cover range	....	....
Mountings: OK	....	....
Undamaged/vertical	....	....
Positions: readable	....	....
Free from surge	....	....
EPB: mounting secure	....	....
Covers range	....	....
Earthing: OK	....	....
Reading procedures: OK	....	....
Comments:	....	

RECORDER

Recorder type: .... Serial number: ....
Date last serviced: .... Recording interval: .... Range: ....
Sensor type: .... Serial number: ....
Recorder reading: .... Time: ....

	Yes/No	Comments
Recorder: site appropriate	....	....
ESG/EPB/Rec same	....	....
Free from surge	....	....
Mountings: secure	....	....
Code disks: OK	....	....
Float/float tape: OK	....	....
Pulley size: OK	....	....
Sensor: mounting OK	....	....
Condition: OK	....	....
Protection: OK..........	....	....
Free from silt	....	....
Calibration: OK	....	....
Battery: voltage OK	....	....
Service record: OK	....	....
Age: too old	....	....
Logbook: correctly used	....	....
Visit frequency: OK	....	....
Back-up recorder in use	....	....
To standard	....	....
Comments:	....	

TELEMETRY

	Yes/No	Comments
Remote/recorder wiring: OK	....	....
Connections: good condition	....	....
Remote: OK	....	....
Software version: OK	....	....
Comms test: OK	....	....
Sensor inputs: OK	....	....
Dataline level in: OK	....	....
Dataline level out: OK	....	....
Signal line voltage: OK	....	....
Awake current: OK	....	....
Asleep current: OK	....	....
Remote/radio wiring: OK	....	....
Protected	....	....
Radio housing: standard	....	....
Wiring: protected	....	....
Fuses: OK	....	....
Mountings: secure	....	....
Site signal strength: OK	....	....
Aerial: standard	....	....
Mounting: secure	....	....
Solar panel: standard	....	....
Cabling: OK	....	....
Angle suitable	....	....
Orientation OK	....	....
Blocking diode: OK	....	....
Power: adequate	....	....
Mains power: standard	....	....
Cabling: OK	....	....
O/C volts: OK	....	....
S/C current: OK	....	....
Reset time: OK	....	....
Battery: standard	....	....
Voltage: adequate	....	....
Capacity: OK	....	....
Age: OK	....	....
Lightning protection: OK	....	....
Adequate bonding	....	....
Comments:	....	
	....	
	....	
	....	

GAUGINGS

Methods used: Wading, boat, slackline, cableway, bridge, volumetric, dilution

	Yes/No	Comments
Low flow reach: adequate	....	....
Turbulent free	....	....
Weed/debris free	....	....
Access: safe	....	....
Reference marks: OK	....	....
High stage reach: adequate	....	....
Turbulent free	....	....
Weed/debris free	....	....
Access: safe	....	....
Reference marks: OK	....	....
Distance marks: OK	....	....
Cableway: safe	....	....
Backstay adequate	....	....
Maintenance done	....	....
Certificate: OK..........	....	....
Bridge: safe	....	....
Safety practices: OK	....	....
Volumetric/dilution: used	....	....
Equipment: standard	....	....
Calibrated	....	....
Methods: standard	....	....
Gauging practices: OK	....	....
Suitable method	....	....
Equipment adequate	....	....
Frequency: OK	....	....
Comments:	....	
	....	

GENERAL STATION COMMENTS

....
....
....
....
....

Inspection completed by: .... Date: ....

Appendix R

Template for Reporting Data

Water Permit Number:	002468	**Meter Identification Number:**	0357911
Permit Holders Name:	Joe Bloggs	**Date of Submission**	30/07/10
Meter Location Coordinates (NZMG):	**Northing:** 5754513	**Easting:**	2453389

Date (DD/MM/YY)	Time (00:00)	Meter Reading	Unit	Cumulative Volume (m^3)	Daily Volume[4] (m^3/d)	Comments
01/07/10	09:00	005624.23	L	5.624	-	First reading
02/07/10	09:30	008276.37	L	8.276	2.652	
03/07/10	08:45	009867.25	L	9.867	1.591	

A blank space or – denotes that an error has occurred and no value has been recorded. A zero (0) denotes that no water has been tak

Appendix S

Regional Council Approved Verification Methods

Regional Council	Approved Verification Methods
Northland Regional Council	No information supplied
Waikato Regional Council	Reference meter test rig using mag-flow or ultrasonic clamp-on. Clamp-on Ultrasonic
Auckland Council	No information supplied
Bay of Plenty Regional Council	Clamp-on Ultrasonic On-site volumetric or gravimetric
Gisborne Regional Council	Reference meter test rig, using mag-flow or ultrasonic clamp-on.
Hawkes Bay Regional Council	Reference meter test rig, using mag-flow or ultrasonic clamp- on.
Taranaki District Council	No information supplied
Horizons Regional Council	Clamp on Ultrasonic Reference meter, in-line, by-pass or test rig. On-site volumetric or gravimetric On-site electronic validation
Greater Wellington Regional Council	Clamp on Ultrasonic Reference meter, in-line, by-pass or test rig. On-site volumetric or gravimetric On-site electronic validation
Marlborough Regional Council	Reference meter test rig, using mag-flow or ultrasonic clamp-on. Clamp on Ultrasonic
Tasman District Council	Reference meter test rig, using mag-flow or ultrasonic clamp-on. Clamp-on Ultrasonic

Environment Canterbury	Clamp-on Ultrasonic Reference meter, in-line, by-pass or test rig. On-site volumetric or gravimetric On-site electronic validation
Otago Regional Council	No information supplied
Environment Southland	No information supplied

Note: Always check with the relevant Regional Council as to which verification method is suitable in the area in which you are intending to operate.