NEMS

NATIONAL ENVIRONMENTAL MONITORING STANDARDS

National Environmental Monitoring Standards

Open Channel Flow Measurement

Measurement, Processing and Archiving of
Open Channel Flow Data

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NEMS

NEMS Standards Documents

The following standards can be found at www.landandwater.co.nz.

- National Quality Coding Schema
- Safe Acquisition of Field Data In and Around Fresh Water
  Code of Practice
- Dissolved Oxygen Recording
  Measurement, Processing and Archiving of Dissolved Oxygen Data
- Open Channel Flow Measurement
  Measurement, Processing and Archiving of Open Channel Flow Data
- Rainfall Recording
  Measurement, Processing and Archiving of Rainfall Intensity Data
- Soil Water Measurement
  Measurement, Processing and Archiving of Soil Water Content Data
- Turbidity Recording
  Measurement, Processing and Archiving of Turbidity Data.
- Water Level Recording
  Measurement, Processing and Archiving of Water Level Data
- Water Meter Data
  Acquisition of Electronic Data from Water Meters for Water Resource Management
- Water Temperature Recording
  Measurement, Processing and Archiving of Water Temperature Data

To obtain copies of NEMS standards, or to enquire and comment, please visit:
www.landandwater.co.nz

Limitations

It is assumed that as a minimum the reader of these documents has undertaken industry based training and has a basic understanding of environmental monitoring techniques. Instructions for manufacturer specific instrumentation and methodologies are not included in this document and the user must refer to this information.

The compilation of information contained in these documents relies upon material and data derived from a number of third party sources.

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When implementing these standards, the following legislation shall be complied with:
- Health and Safety in Employment Act 1992
- Health and Safety in Employment Regulations 1995
- NEMS Safe Acquisition of Field Data In and Around Fresh Water, Code of Practice 2012

National Environmental Monitoring Standards (NEMS)

The National Environmental Monitoring Standards (NEMS) group has prepared the national standards listed below. The development of these standards followed discussion and consultation with all regional and unitary councils within New Zealand as well as the National Institute for Water and Atmospheric Research Ltd (NIWA). Between them, these agencies undertake the majority of flow measurement within New Zealand. NEMS recommend that these standards be adopted throughout New Zealand. The degree of rigour that the standard is applied to, will depend on data objective. All recorded data should be quality coded.

Funding

Review

This document will be reviewed by the NEMS steering group in February 2014, and thereafter once every two years.

Signatories

NEMS Project Director	NEMS Chairman	MFE	NIWA	Workgroup Leader

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Definitions

ADCP Abbreviation for Acoustic Doppler Current Profiler. An instrument that uses acoustic signalling to measure velocity, depth and boat speed.

ADV Abbreviation for Acoustic Doppler Velocimeter. A current meter that uses acoustic signalling to measure point velocity.

calibration The process of comparing the response of a measuring device with a calibrator or a measuring standard over a range.

comments file A metadata file associated with the data file. The metadata provides relevant information about the site and data.

cross-section A specified section of the stream normal to the direction of flow bounded by the wetted perimeter and the free surface.

current meter An instrument for measuring water velocity.

DGPS Abbreviation for Differential Global Positioning System. A GPS system that uses a network of fixed ground based reference stations to broadcast the difference between measured satellite ranges and actual satellite ranges to roving receivers.

depth cell or bin A truncated cone shaped volume of water at a known distance and orientation from the ADCP transducers

ensemble A single profile of the water velocity through the water column consisting of one or the mean of multiple acoustic measurements collected from an ADCP instrument

discharge The volume of liquid flowing through a cross-section in a unit of time.

discharge rating A curve, equation or table that expresses the relation between the stage height and the discharge in an open channel at a given cross-section.

effective waters edge The position on a cross-section where the water velocity is zero but there is still a depth of water, and there is no more flow between here and the physical waters edge.

gauging All of the operations necessary for the measurement of discharge. May also be used to refer to the combined result of the measurement.

metadata Information about the data that may describe the content, quality, condition, and/or other characteristics of the data and operations on or modifications to the data.

POEM Acronym for Pressure Operated Electronic Meter. A depth and velocity measuring instrument that uses a forward-facing pitot tube on the front of a streamlined weight that houses velocity and depth sensors.

propeller current meter a current meter whose rotor is a propeller rotating around an axis approximately parallel to flow.

QC Abbreviation for quality code. For example, a quality code of 600 may be referred to as QC 600

quality codes A series of defined codes attached to the data that convey information about the reliability.

rating A relationship between two variables.

reach A straight length of river channel.

resolution The smallest increment that is measurable by a particular instrument.

rotating cup current meter a current meter whose rotor is composed of a wheel fitted with cups turning on a vertical axis that is perpendicular to flow.

sounding The operation of measuring the depth from the free surface to the bed.

stage or stage height The water level (elevation of the free surface) of a stream relative to a known fixed datum.

stationarity of record The quality of a process in which the statistical parameters of the process do not change with time. Stationarity of record is maintained when variability, of the parameter being measured, is only caused by the natural processes associated with the parameter. Stationarity of record ceases when variability is caused or affected by other processes, e.g., changing the instrumentation used for measuring discharge.

transect One sweep across a water course from one bank to the opposite bank with an ADCP on a moving boat.

uncertainty A quantity defining an interval about the result of a measurement. This quantity may encompass a large fraction of the values that could contribute to the measurement. In Hydrology this shall be expressed at 95% confidence level.

validation A check to determine if the device or procedure conforms to specifications.

vertical A vertical line on a cross-section where a measurement of depth or velocity is made.

About this Standard

Introduction

Open channel flow measurements are routinely made on many rivers in New Zealand. They provide information on flow at the time of measurement, and for the development of discharge ratings used to derive continuous flow data from water-level stations. Key to planning, maintaining and recording open channel flow is understanding and catering for stationarity.

The earliest open channel flow measurements collected in NZ were from the Wairua River at Wairua Falls in May 1911. This data was collected for a hydro-electric power station that was being built at this site. The need for further flow information for rivers for hydro-electricity development began in earnest in the late 1920s and many measurements were collected for this purpose.

The establishment of the first Hydraulic Survey parties in 1949 oversaw the start of specialist flow monitoring in rivers on a national basis, and during the 1950s and 1960s many rivers were measured for a wide variety of purposes including flood control and soil conservation studies.

The majority of open channel flow measurements are made to rate a water-level station to enable derivation of continuous flow from the water-level record. By 2011, 995 stations with flow measurements associated with their data records were recorded on the national water resources database.

The most common method of measuring flow from the first measurements until recent time has been the Velocity-Area method that uses sounding devices and mechanical rotating-element current meters. Acoustic technology emerged in the 1990s implemented as current meter devices using the Velocity-Area method. By the 2010s acoustic technology had been adopted by most data collection agencies. The development of the ADCP moving boat method enabled flows to be measured efficiently in rivers and in situations that are difficult to measure with mechanical current meters.

Objective

The objective of this standard is to ensure single measurements of open channel flow made using the methods in this standard, are gathered, processed and archived in a verifiable and consistent manner over time and across New Zealand and are suitable for 'at site' and comparative analysis.

Scope

This standard covers all processes associated with:

- selection of a measurement method
- standards required
- data processing, and
- quality assurance (QA) that is undertaken prior to archiving the data.

Exclusion

Methods used to measure open channel flow by continuous methods are excluded from this standard.

The Standard – Open Channel Flow

The following shall apply for all measurements:

Stationarity	Stationarity of measurement shall be maintained.	
Metadata	Scope	Metadata shall be recorded for all measurements.
Archiving	Original and Final Records	File, archive indefinitely and back up regularly: • Raw and processed records • Supplementary measurements • Validation checks • Calibration results • Metadata
	Results database	Minimum requirements: • Stage for computed discharge • Computed discharge, at l/s resolution, or ml/s where applicable • Cross-section area (where applicable) • Mean velocity of discharge (where applicable) • Method code • Uncertainty • Quality code • Time of mean gauge height

As a means of achieving the standard (QC 600), the following requirements apply:

Units of Measurement		Discharge shall be expressed as • m^3/s to three decimal places, or • l/s, or • ml/s for very small flows where measurement uncertainty is less than ±50ml/s
Discharge Calculation	Velocity-Area Stationary method	Mean-section method
	Velocity-Area Moving Boat method	Average of the individual transect discharges *Transects with identified quality problems shall not be used in the calculation*
Uncertainty	Velocity-Area Stationary method	± 5% (expanded uncertainty, 95% confidence) *Not all flow measurement methods have an accepted form of calculating uncertainty.*
Quality Assessment	Velocity-Area Moving Boat method	Classified good under Annex D

Continued on next page

Timing of measurements	Instrument Resolution	1 Second
	Instrument Accuracy	± 90 seconds/month
	Time Zone	Express time as New Zealand standard time (NZST) Do not use New Zealand daylight time (NZDT)
	Discharge Results	Assign date and time of mean gauge height 1 minute resolution
Supplementary Instrument Measurements	Temperature	± 0.5 ˚C *Required for acoustic methods*
	Salinity	± 5 ppt (parts per thousand) *Required for acoustic methods*
	Bearing	Compass calibrated on site *Required for acoustic methods*
	Water level	Required if result is to be used for discharge rating Read at regular intervals over duration of discharge measurement
Calibration check	Frequency	Current Meter: 2 years, or 300 hours of use ADV: 5 years ADCP: 3 Years POEM: 2 Years or 100 Hours of Use
	Method	Where relevant follow manufacturers' specifications, AS3778.6.3, ISO3455 and ISO748:2007. Further details in Standard.
Validation Methods	Instrument Tests	Required pre-deployment, and post-deployment for rotating element current meters.
	Moving Bed	Test required Pre-measurement for Velocity-Area Moving Boat method

Continued on next page

Deployment	Site Selection	Use criteria within Standard, method dependent
	Sampling *Velocity-Area Stationary Method*	≥ 40s velocity measurement at ≥20 verticals, and each partial segments with <10 % of the total discharge
	Sampling *Velocity-Area Moving Boat Method*	≥ 720s total sampling time, and reciprocal transect pairs
	Width Measurement *Velocity-Area Stationary Method*	± 0.5% of total cross-section width (Velocity-Area stationary method)
	Depth Measurement *Velocity-Area Stationary Method*	≥ 22 verticals to +/- 5 mm for depths < 0.3 m, or +/- 10 mm for depths > 0.3 m

Quality Codes – Open Channel Flow

All data shall be quality coded in accordance with the National Quality Coding Schema. The schema permits valid comparisons within a data series and across multiple data series. Use the following flowchart to assign quality codes to all flow measurements.

Performance Objectives   **Quality Code (QC)**   **Description**
Quality Zone

START

Unreliable

Verified Unreliable Record? —YES→ **QC 100**

Unreliable Measurement
Note: The measurement must not be used for discharge calculation.

NO

No Quality or Non Verified

Quality Unknown? —YES→ **QC 200**

Data is any of the following:
- Raw
- Of unknown quality
- Not assigned a final quality code
- External and not coded to match NQCS

NO

Estimated

Incorrectly Determined or Incomplete Data? --YES-- **QC 300**

Result is indirectly determined, or estimated from any of the following:
- Weir or flume formulae not verified by gauging
- Hydraulic or hydrological models
- Established relationships
- Incomplete direct measurement

NO

ADCP Moving Boat Method Used ? —YES→ Code from Annex D is...

Good (600)

Fair (500)

Poor (400)

To assign a code, refer to: 'NEMS Open Channel Flow Measurement, Annex D – ADCP Moving Boat Estimation of the Quality Code'.

NO

Measurement Uncertainty Calculated? —NO→

YES

> 10% Uncertainty? —YES→ **QC 400**

Poor Quality

Measured data that has:
- been compromised in its ability to represent the monitored parameter, and/or
- undergone significant modification.

NO

Fair Quality

> 5% Uncertainty? —YES→ **QC 500**

Measured data that doesn't meet operational standards / best practices at the time of acquisition, and/or undergone minor modification. The data is considered to be a fair representation of the monitored parameter.

NO   NO

The measurement meets the NEMS Standard for the method.

Note: Uncertainty must be ≤ 5%.

YES

QC 600

Good Quality

Data measured using best practice that meets operational standards at the time of acquisition. The data is considered to be a good representation of the monitored parameter.

1   Method Selection

1.1.1   In this Section

This section contains information on methods of measuring discharge in open channels.

1.1.2   Discharge

Discharge cannot be measured directly but shall be computed from measurements of other variables that can be measured directly, such as:

- channel width
- channel depth
- channel velocity
- captured channel volume over time
- channel slope and area

The choice of discharge measurement method is determined by a combination of the following variables:

- magnitude of flow
- size of the channel
- roughness of the bed
- level of turbulence
- availability of water-level information
- access
- safety

1.1.3   Methods

The main methods are:

- Velocity-Area Stationary Meter
- Velocity-Area ADCP Moving Boat
- Volumetric
- Indirect Discharge

1.2 Velocity-Area Stationary Meter Method

1.2.1 Introduction

The Velocity-Area Stationary Meter method:
- is a widely used method.
- that uses current meters to measure velocities and sounding devices to measure depths at fixed locations on a cross-section.

1.2.2 Application

The Velocity-Area Stationary Meter method shall be used where there is relatively uniform flow and uniform channel conditions.

1.2.3 Variables Measured

Current meters shall be used to measure water velocity.

Sounding devices shall be used to measure water depth in a cross-section.

Calibrated measuring devices shall be used to measure water surface width.

1.2.4 Discharge

Discharge shall be computed as the product of area and velocity.

Note: This is a widely used technique that requires relatively uniform flow and channel conditions.

1.3   Velocity-Area ADCP Moving Boat Method

1.3.1   Introduction

The Velocity-Area ADCP (Acoustic Doppler Current Profiler) Moving Boat method:
- is a widely used method, and
- uses ADCP instruments mounted on a moving boat.

1.3.2   Application

The Velocity-Area ADCP Moving Boat method may be used where:
- discharge needs to be measured quickly
- detailed information is required
  Note: This method provides much more detailed information than the Velocity-Area Method
- unsteady, bidirectional, and non-standard flow conditions need to be measured efficiently.

This method may be limited by:
- insufficient acoustic scatterers
  Note: The water has to contain enough suspended particulate material for sufficient acoustic energy to be returned to the ADCP.
- high sediment loads in the water column
  Note: Acoustic energy returned to the ADCP can reduce to a level that the instrument cannot detect.
- high sediment loads near the streambed
  Note: An ADCP may have trouble discerning the streambed interface causing inaccuracies in depth and/or velocity measurement.
- instrument capability.
  Note: The acoustic frequency and techniques used to process the acoustic signal may limit the measurement depth and/or velocity range.

1.3.3   Variables Measured

Using ADCPs, the following variables are measured while traversing a cross-section of the channel:
- Water Depth
- Water velocity Profiles
- Moving boat velocity

Note: Measurement locations may be recorded by GPS. Distances may be measured from moving boat velocity and or GPS locations.

1.3.4   Discharge

Discharge shall be computed by summing the measured values and extrapolating across unmeasured areas.

1.4 Volumetric

1.4.1 Introduction

The volumetric method involves:
- capturing the flow into a container of known volume, and
- measuring the time taken to fill the container.

1.4.2 Application

The Volumetric method is generally used for small flows.

Avoid using this method where:
- the time taken to fill the container is less than 10 seconds
- the container size becomes unmanageable
- there is insufficient fall in the stream to enable filling of the container.

1.4.3 Variables Measured

Using a calibrated container, the following variables are measured:
- Volume
- Time

1.4.4 Discharge

Discharge shall be computed by dividing volume by time.

1.5   Indirect Discharge Method

1.5.1   Introduction

The Indirect method involves:
- measuring peak water-levels along a channel, and
- surveying cross-sections or structures after a flood event, and
- estimating hydraulic parameters for the channel or structure.

1.5.2   Application

The Indirect method is generally used for flood flows.

Avoid using this method where:
- water-level information is not available, or
- direct measurements of flow have been made.

1.5.3   Variables Measured

The following variables are measured:
- The water-level either from:
  - levels marked during a flood, or
  - high water marks left after a flood.
- Cross-sections along a channel or across a structure.

1.5.4   Discharge

Discharge shall be computed by using the appropriate discharge calculation equation.

2 Velocity-Area Stationary Meter Method

2.1.1 In this Section

This section contains information on measuring discharge in open channels using the Velocity-Area method with stationary current meters. This method has standards associated with the following:

- Site selection
- Site primary reference
- Measurement of cross-sectional area
- Measurement of velocity
- Calculation of discharge
- Uncertainty in discharge measurement

2.1.2 Functional Requirement

All equipment used to measure discharge shall be deployed and maintained to ensure:

- there is no systematic bias, and
- calibration requirements are met.

2.2   Principles

2.2.1.1   Discharge Measurement

The discharge measurement shall be made by:
- meeting site selection requirements
- subdividing a channel cross-section into segments, and then
- measurements of depth and velocity are made at the boundaries of each segment (referred to as verticals).

2.2.1.2   Discharge Computation

The discharge is then computed as the summation of the products of the segments of the cross-section and their respective velocities.

2.3 Site Selection

The selection of the measurement site is a key step and will have a large impact on the uncertainty of the discharge result.

2.3.1 Practical Controls

2.3.1.1 Site Access

Site access shall be secure and safe for the complete period of deployment.

A long term access agreement with any landowners whose land must be crossed to gain access to the site is recommended.

2.3.1.2 Safety

Hazards (for observers, the public, livestock, and wildlife) related to the location and the measurement activity shall be identified and mitigated.

2.3.1.3 Hazard Review

On selection of a final site, a hazard review shall be carried out in accordance with relevant guidelines or best practise.

The potential for human activity affecting the measurement, e.g., vandalism, shall be minimised.

2.3.2 Selection Criteria

Where practicable, the selected site shall:
- have a reach that is reasonably straight; three to five times the channel width
- have a cross-section that is uniform
- have sufficient depth of water in the cross-section for the effective immersion of the current meter
- have flow directions for all points on verticals parallel to one another
  That is, free from turbulence.
- have flow directions for all points at right angles to the measurement cross-section
- have stable bed and channel margins for the period of measurement, and
- be accessible at all times with the measurement equipment.

2.3.2.1 Sites to Avoid

Where practicable, sites showing any or all of the following characteristics shall be avoided:
- Obstructed cross-section.
  Note: The cross-section may be obstructed by, for example, trees, weeds and other obstacles.
- Vortices, reverse flow or dead water zones
- Converging or diverging flow.
- Nearby pumps, sluices or outfalls regardless of whether they are upstream or downstream.
- Reaches affected by tidal or other significant backwater effects.

These characteristics can cause unsteady flow conditions during measurement.

2.3.3 Restricted Channel Length

To have a typical velocity distribution, a reasonably straight channel with a uniform cross-section is required. If the channel length is restricted then the cross-section should normally be chosen approximately two-thirds of the way down the reach.

2.3.4   Proximity to Water-Level Station

The measurement section shall be relatively close to the water-level station (if applicable) to avoid the influence of:

- losses and gains to groundwater
- water abstractions, or discharges to the water body
- tributary inflow between the measurement section and the control, and
- channel storage between the section and control at times of changing water-level.

Note: These criteria may not be important for one-off spot measurements of flow but would be important for measurements used to derive discharge ratings for a water-level station.

2.3.5   Measurement of Flow from Bridges

Where practicable, the upstream side of the bridge shall be used for taking readings.

Note: Bridge piers cause downstream turbulence.

The effect on velocity distribution caused by turbulence from any obstructions shall be considered and noted.

2.4   Associated Water Level Reference

If the discharge measurement is to be used for establishing and maintaining a discharge rating curve, then one or more of the following water-level references, shall be installed nearby:

- Water-Level Reference Benchmark
- Staff Gauge
- Water-Level Recording Instrumentation

2.4.1   Recording Frequency and Method

The water-level shall be recorded at regular intervals during the measurement period using any one of the following methods:

- Manually measure the water-level offset from the reference mark.
- Manually read the water-level from the staff gauge or internal reference gauge.
- Automatic logging of water-level by instrumentation.

2.5 Measurement of Cross-Sectional Area

Measurement of the cross-sectional area requires measurements of:

- width, and
- depth.

These measurements shall be taken at sufficient points to establish the shape of the bed.

2.5.1 Measurement of Width

Width measurements:

- define the location of the required depth and velocity measurements across the selected cross-section, and
- provide the width parameter of each segment.

2.5.1.1 Criteria

Width measurements shall be made:

- as close as possible to right angles to the direction of flow
- along a horizontal plane in the line of the cross-section, and
- from or to a fixed reference point.
  Note: Where practicable, this reference point shall be installed permanently so that all measurements at a site have distances measured in the same terms.

2.5.1.2 Direct Physical Measurement

Width measurements by direct means shall use a graduated tape or suitable marked wire.

The graduations on tapes or wires shall be graduated to an accuracy of ± 0.5% of the total cross-section width, and have regular cumulative graduations (coded or digital).

2.5.1.3 Instrument Derived Measurement

Where the channel is too wide or impractical for direct physical means, measurements shall be made using one of the following technologies:

- Optical distance meters
- Electronic distance meters
- Differential Global Positioning System (DGPS)

Note: These technologies may not achieve an accuracy ± 0.5% of the total cross-section width requirement and in this case shall be quality coded accordingly.

2.5.1.4 Bridges and Cableways

On bridges or cableways, permanent width markings suitable for the vertical spacing or a calibrated tape or wires, shall be used. The accuracy of the permanent markings shall be within ± 0.5% of the total width.

Measurement of Depth

Depth measurements:
- define the cross-sectional area, and
- provide the basis for the current meter velocity measurements.

2.5.2.1 Criteria

Depth measurements shall be made:
- at intervals close enough to define the cross-sectional profile accurately
- with intervals between verticals not greater than $1/20^{th}$ of the width
- at 22 or more separate verticals
  Note: A vertical is defined as a measurement of depth or velocity so edge measurements are included in the required number.
- at all verticals that velocity is measured
- at a resolution of ± 5 mm for depths < 0.3 m, or ±10 mm for depths > 0.3 m, and
- with instruments calibrated to ± 0.5 % of the instrument's range.

2.5.2.2 Measurement Instruments

Depth measurements shall be made using any one of the following tools:
- Pressure Transducer
- Echo Sounder
- Acoustic Doppler Current Profiler
- Wading Rod
- Gauging Reel

Note: Wading rods are commonly used in shallow water measurements. Gauging reels in deeper unwadeable water. Pressure transducers, echo sounders and acoustic profilers are typically used in higher velocity deeper water where there may be difficulty measuring the depth with a gauging reel and sounding weight.

2.5.2.3 Pressure Transducers, Echo Sounders & Acoustic Profilers

When using pressure transducers, echo sounders or acoustic profilers at least one reading shall be taken at each vertical.

Note: Software associated with these devices typically averages many readings taken during the time taken measuring velocity at the vertical time interval.

2.5.2.4 Wading Rods and Gauging Reels

When using wading rods or gauging reels, at least two readings shall be taken at each vertical.

If the readings taken at a vertical are within 5%, their mean value shall be adopted.

If the readings taken at a vertical differ by more than 5%, two more readings shall be taken and the mean value of all four readings shall be adopted.

2.5.2.5 Depth and Velocity Measurements Made at Different Times

If depth measurements are made separately from velocity measurements and the water-level is not steady, then where practicable, the water-level shall be observed at the time of each depth measurement.

If this is not practicable, note the time of each depth measurement and take water level readings at sufficient intervals for interpolating a level for each depth.

2.5.2.6 Depth Measurements Made During Bed Profile Change

Bed profile may change appreciably during times of flood. In these cases depth measurements at a vertical shall:

- be an average over the velocity measurement, and
- in the case of current meter measurements, this shall be a measurement at the beginning and end of the velocity measurement.

2.5.2.7 Inaccuracies in Depth Soundings

Consideration shall be taken for inaccuracies in depth soundings that result from:

- departure from vertical of the sounding rod or line, particularly where the water velocities are high.
  Note: The drag effect on the sounding line may be reduced by using a streamlined lead sounding weight. A correction shall be applied to the wetted length of line if the line is not normal to the water surface (correction details in ISO748:2007, Appendix C).
- penetration of the stream bed by the sounding weight or rod.
  Note: This may be reduced by fitting a base plate to the sounding rod.
- the nature of the bed when an echo sounder is used.
  Note: A low frequency echo sounder (200 kHz or less) is often more effective at accurately defining the bed-water interface than a high frequency instrument.

2.6 Measurement of Velocity

Velocity measurements:
- define the mean velocity in a vertical
- are made at fixed points on a vertical.

2.6.1 Criteria

Velocity measurements shall be made to meet the following requirements:
- Velocity Vertical Spacing
- Exposure Time
- Sampling Technique
- Instrument Capability

2.6.2 Velocity Vertical Spacing

Velocity measurement verticals shall be made:
- at a minimum of 20 (preferably 25) verticals, and
  Note: When more than 30 verticals are measured there is little improvement in the accuracy.
- at intervals:
  - no wider than $1/15^{th}$ of the total width for a regular bed profile, or
  - no wider than $1/20^{th}$ of the total width for an irregular bed profile
- with no partial segment containing more than 10% of the total discharge, or
- as close as practically possible for channels < 1metre wide.
  Note: Current meter sampling volume limitations mean that overlap will occur as width intervals reduce. This is dependent on the size of the current meter sampling volume. For most small current meters the practical width limit is 50mm.

2.6.3 Exposure Time

The time of velocity measurement shall be:
- after the current meter has adjusted to the flow conditions
- at each selected point for a minimum of 40 seconds
  Note: ISO748 sets the minimum exposure time at 30 seconds. Historic and recommended exposure time in New Zealand and current technique with the USGS is to use a minimum of 40 seconds.

  Exception: At times of rapidly changing flow velocity observations may be reduced to 20s, these measurements shall be quality coded less than good.

2.6.4 Sampling Technique

2.6.4.1 Minimal Flow Disturbance

The sampling of velocity shall use techniques that cause minimal flow disturbance from the personnel, boat, or sounding weight

Note: For a wading gauging the person gauging shall stand at least 0.5m downstream and 0.5m to the side of the current meter.

2.6.4.2 Alignment of Current Meters

The sampling of velocity shall use correctly aligned current meters. Some current meters will align automatically to the flow angle others have to be aligned to the manufacturer's specifications.

Important: *A rotating-element current meter shall be aligned to the flow angle rather than be held normal to the cross-section, and this angle between the flow direction and perpendicular to the cross-section shall be measured and corrected for. An ADV shall always be held perpendicular to the cross-section even if the flow angle is oblique as the instrument can determine flow angle and correct for it automatically during discharge calculation.*

2.6.4.3 Pre-Deployment Test

The sampling of velocity shall have a current meter validation test completed before and after each discharge measurement.

Note: For a rotating-element current meter this is a spin test to check the meter spins freely (See the instrument's calibration certificate or manufacturer's specifications). An ADV or other current meter will have a manufacturer specific diagnostic test completed before the measurement.

2.6.4.4 Visual Examination Checks

The sampling of velocity shall include visual examination checks of the current meter during the discharge measurement, generally after each vertical is completed.

2.6.5 Instrument Capability

Current meters used to measure velocity shall be used within their specified:

- calibrated velocity range, and
  Note: Low velocities (<0.1m/s) should be avoided with a mechanical current meter as any small deviation in meter performance will cause a large percentage error in velocity.
- depth range, where no part of a rotating-element current meter shall:
  – break the surface of the water, or
  – be used where the depth at the point of measurement is less than four times the diameter of the impeller, or the body of the meter itself, whichever is the greater.
    Note: An exception to this is the case where the cross-section is very shallow at one side and this is the best available.

2.7 Instrument Validation and Calibration

2.7.1 Instrument Type

Any of the following meters may be used for measuring velocity:
- Rotating-element current meter
- ADV
- ADCP profiler used as a stationary vertical profiler
- Pressure operated electronic meter (POEM)

Current Meters shall be calibrated to meet the velocity measurement uncertainty requirements as specified in ISO748:2007 Table E.5.

Figure 1 – Examples of velocity current meters.
From left to right; Rotating-element propeller, Rotating-element cup, ADV, ADCP, POEM.
Photographer: A Willsman, NIWA.

2.7.2 Rotating-Element Current Meters

Rotating-element current meters shall be manufactured, calibrated, and maintained according to AS3778.6.3, ISO2537:2007 and ISO3455.

This shall involve recalibration after two years of use or 300 hours of service whichever is shorter. A recalibration shall be completed when a meter consistently fails a validation.

If the meter has been used in a comprised condition then:
- it shall be calibrated before and after repair,
- and any change in calibration shall be applied retrospectively to earlier gaugings.

2.7.3 ADV Current Meters

ADV current meters shall be calibrated in an approved velocity-rating tank initially, and then a calibration check every five years in an approved velocity-rating tank.

2.7.4 Pressure Operated Electronic Meters

Pressure operated electronic meters shall be calibrated in an approved velocity rating tank initially and then a calibration check every two years or 100 hours of service in an approved velocity-rating tank.

2.7.5 ADCP Instruments

See ADCP Instrument Tests section in Velocity-Area Moving Boat Method.

2.8   Determination of Mean Velocity in a Vertical

Velocity typically varies throughout a vertical in a manner that is depicted in Figure 2. However conditions such as weed growth on the bed, a non-uniform cross-section, turbulence and other factors may alter this pattern markedly.
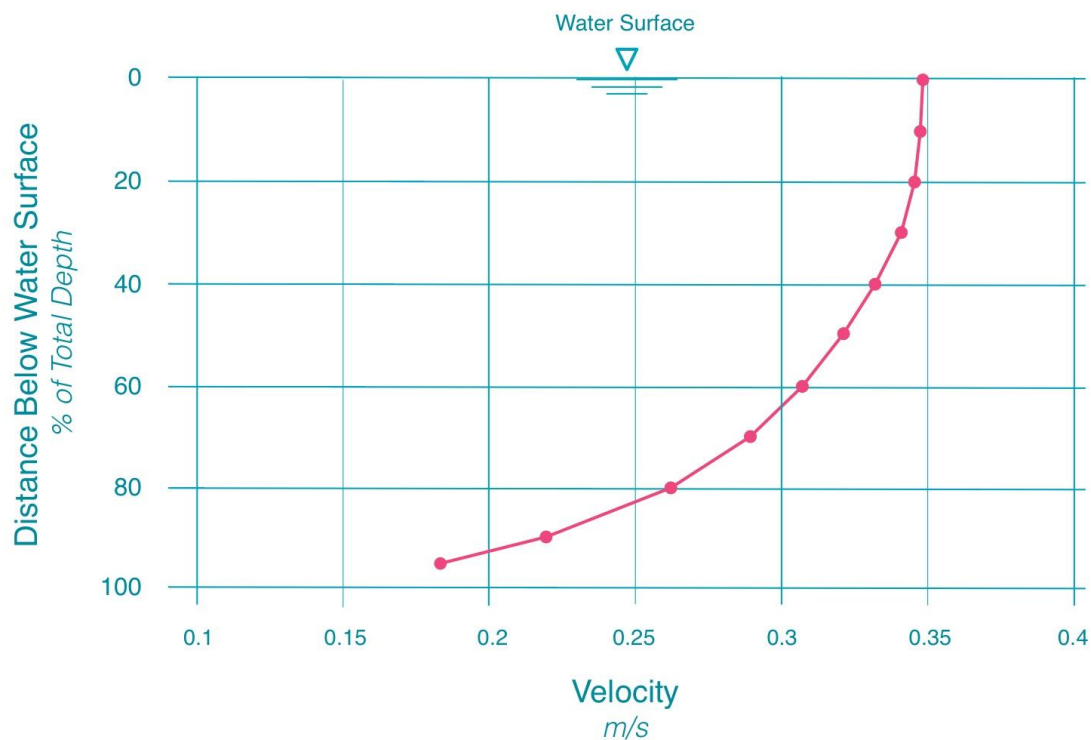

Figure 2 – Typical vertical velocity curve.
Illustrator: Chris Heath

The choice of method for determining velocity depends on a range of factors, for example:
- time available
  That is, avoiding rapidly changing stage.
- depth and width of channel
- bed conditions in the measuring section
- rate of variation of flow, and
- equipment used.

A method may be classified as a:
- point method
- integration method, or
- stationary ADCP profiling method.

Point Methods

One and two-point methods are commonly used for routine discharge measurement because they take less time than the other multi-point methods. They are, however, based on theoretical velocity profiles.

Note: For a new gauging station the accuracy of the selected point method should be assessed by comparing results from a method using 6 or more points.

Examples of reduced point methods are:
- One-point method
- Two-point method
- Three-point method
- Five-point method
- Six-point method
- Surface one-point method.

2.8.1.1 One-Point Method.

Velocity observations shall be taken on each vertical by setting the current meter at 0.6 of the depth below the surface. The observed value is taken as the mean velocity in the vertical.

Note: This method is the least accurate, and it is preferable to use two or more points in the vertical. However it is often necessary to use this method owing to depth limitations. For more information see, 'Measurement of Velocity' – 'Instrument Capability', earlier in this document.

2.8.1.2 Two-Point Method.

Velocities shall be measured at 0.2 and 0.8 of the depth below the surface, and the average of the two values is taken as the mean velocity in the vertical.

Note: This method is widely used and is recommended as the minimum standard method where depth allows.

2.8.1.3 Three-Point Method

Velocities shall be measured at 0.2, 0.6, and 0.8 of the depth below the surface and the mean velocity in the vertical shall be calculated by first averaging the 0.2 and 0.8 measurements and then averaging the result with the 0.6 value.

2.8.1.4 Five-Point Method.

Velocities shall be measured at 0.2, 0.6, and 0.8 of the depth, and as near to the surface and bed as possible. The mean velocity may be determined from a graphical plot of the velocity profile with a planimeter, or from the equation:

$$v = 0.1(v_{surface} + 3v_{0.2} + 3v_{0.6} + 2v_{0.8} + v_{bed})$$

2.8.1.5 Six-Point Method

Velocities shall be measured at 0.2, 0.4, 0.6 and 0.8 of the depth, and as near as possible to the surface and the bed as possible. The mean velocity may be determined from a graphical plot of the velocity profile with a planimeter, or from the equation:

$$v = 0.1(v_{surface} + 2v_{0.2} + 2v_{0.4} + 2v_{0.6} + 2v_{0.8} + v_{bed})$$

2.8.1.6 Surface One-Point Method

In flood or other conditions where the above methods are not feasible, velocity shall be measured at one point just below the surface. The depth of submergence of the current meter shall be uniform over all of the verticals and shall take account of the limitations related to meter rotor height; and care shall be taken to ensure that the observations are not affected by random surface or pressure waves or wind. In practice, a depth of 0.5 m or 1.0 m can be used.

Note: The "surface" velocity may be converted to the mean velocity in the vertical by multiplying it by a correction coefficient which will be specific to the vertical and to the discharge. The coefficient shall be computed for particular water-levels by correlating the "surface" velocity with the velocity at 0.6 or 0.2 and 0.8 depth. In general this coefficient varies between 0.84 and 0.9 depending on the shape of the vertical velocity profile.

2.8.2 Integration Method

In this method the current meter is lowered and raised at a uniform speed through the entire depth range of a vertical. The speed at which the meter is lowered or raised should be not more than 5% of the mean water velocity. At least 60 s of sampling shall be completed.

Note: This method:

- *shall not be used with rotating cup meters*

- *can be used with rotating-propeller current meters but is not commonly used. See ISO748:2007 section 7.1.5.4 for more details.*

A pressure operated electronic meter (POEM) is the standard instrument for this method, as it is capable of sampling velocity and depth at the front of the instrument at a very high rate. This instrument and method is best suited to flooded river measurement as the POEM is not precise at water velocities <1 m/s. The average velocity for the vertical is calculated in the POEM software by integrating the depth and velocity readings.

2.8.3   Stationary ADCP Profiling Method

Using an ADCP profiler mounted on a boat, velocity is measured in a vertical column from the surface. The ADCP is held in position on a boat at the surface and measures the velocities in the water column.

Measurements shall be taken at each vertical column.

Each water column shall be divided into depth cells and a velocity is reported at each depth cell.

Note: An ADCP also measures streambed depth continuously so is also a depth sounding device.

When measuring velocity:
- the ADCP shall be held stationary
- velocity readings shall be taken for a minimum duration of 40 seconds, and
- the flow angle between the ADCP and perpendicular to the cross-section shall be determined.

Note: An ADCP cannot measure velocity at the top of the water column because:

- *the transducers are submerged, and*

- *there is a blanking distance that corresponds to transducer and electronics recovery time.*

Note: An ADCP cannot measure velocity at the bottom of the water column because of acoustic signal side lobe interference.

2.8.3.1   Mean Vertical Velocity Calculation

The mean in vertical velocity is calculated in the ADCP software by averaging the measured velocities from the depth cells, and velocity extrapolations at the top and bottom unmeasured areas.

Velocity extrapolations in unmeasured areas shall be checked for best fit by assessing:
- with field notes that record wind and current conditions at the time, and
- using specialised velocity extrapolation checking software for representative measurements at the cross-section.

2.9	Discharge Calculation Methods

There are two common arithmetic methods for calculating discharge from velocity and depth verticals, the differences being in the way the depths and velocities are averaged.

These methods are:
- Mean-Section Method, and
  This method shall be the calculation method for this Standard
- Mid-Section Method
  This method is used in the USA. For more information, see ISO748:2007 section 8.3.2.

Two further arithmetic calculation methods are available for a unique flow condition or measurement type, these are:
- Independent Vertical Method
  This method is used for calculating rapidly changing discharge. For more infrmation, see ISO748:2007 section 8.4
- Float Measurements
  This is a calculation method used when velocity information is only available from time of travel of surface floats. For more information, see ISO748:2007 section 8.6.

Note: Either of these methods shall only be used in rapidly changing flow or flood conditions.

2.9.1 Mean-Section Method

Discharge shall be calculated as follows:
- Determine cross-sectional segments
- Calculate the discharge of each segment
- Calculate total discharge

2.9.1.1 Determine Cross-Sectional Segments

The cross-section is regarded as being made up of a number of segments, each bounded by two adjacent verticals (Figure 3)
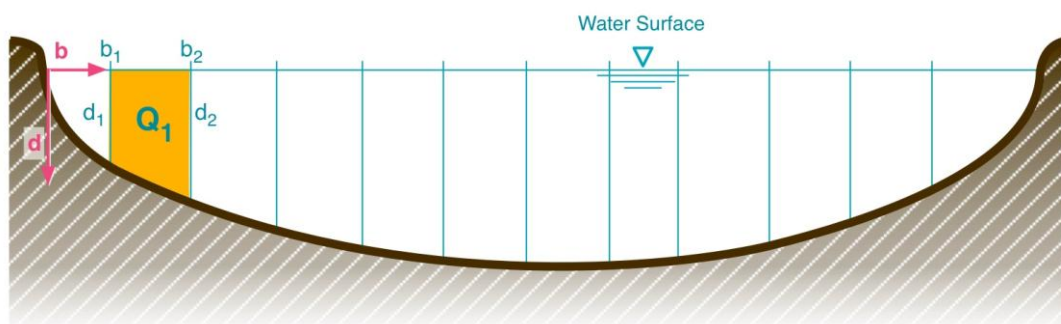

Figure 3 – Cross-Sectional Segments
Illustrator: Chris Heath

2.9.1.2 Calculate Segment Discharge

If v_1 and v_2 are the mean velocities at the first and second verticals respectively, if d_1 and d_2 are the depths measured at verticals 1 and 2 respectively, and (b_2-b_1) is the horizontal distance between the verticals, the discharge in a segment is:

```
q1 = (b₂ –b₁) x (d₁ + d₂)/2 x (v₁ + v₂)/2
```

where:

- q_1 = discharge through segment 1
- b_1 = distance from initial point to vertical 1
- b_2 = distance from initial point to vertical 2
- d_1 = depth of water at vertical 1
- d_2 = depth of water at vertical 2
- v_1 = mean velocity in vertical 1
- v_2 = mean velocity in vertical 2
  Note: The additional discharge in the segments between the effective waters edge and the first vertical, and between the last vertical and the other effective waters edge can be estimated as a proportion of the velocity at the adjoining velocity vertical.

2.9.1.3 Calculate Total Discharge

The total discharge is obtained by summing the discharges for all segments.

3 Velocity-Area ADCP Moving Boat Method

3.1.1 In this Section

This section covers measuring discharge with the use of boat mounted ADCPs. This method has standards associated with the following:

- Instruments
- Pre-Deployment
- Instrument Quality Assurance
- Ancillary Equipment
- Field Procedures
- Site Selection

3.1.2 Functional Requirement

All equipment used to measure flow shall be deployed and maintained to ensure:

- there is no systematic bias, and
- calibration requirements are met.

Principles

3.2.1.1 Discharge Measurement

The Acoustic Doppler Current Profiler (ADCP) is a device that measures discharge by using sound and the Doppler principle.

It works by:

- boat mounting an ADCP with transducers beneath the water surface, aimed downward and moving the boat across the river channel.
- emitting acoustic signals from transducers and receiving acoustic energy reflected back from small particles of sediment and other material (collectively called scatterers) that are present in the water to measure Doppler shifts .
  Note: It is assumed that the scatterers are moving at the same velocity as the water.
- converting the measured Doppler to velocities parallel to the transducer emitting and receiving the acoustic energy.
- obtaining three-dimensional velocities by the use of three or four beams pointing between 20 and 30 degrees from the vertical.
- measuring velocities over a large part of the water column beneath the ADCP continuously
- using Doppler shift bottom tracking, or an external GPS, to determine the velocity of the boat over the streambed, then converting water velocities to a fixed reference system, and
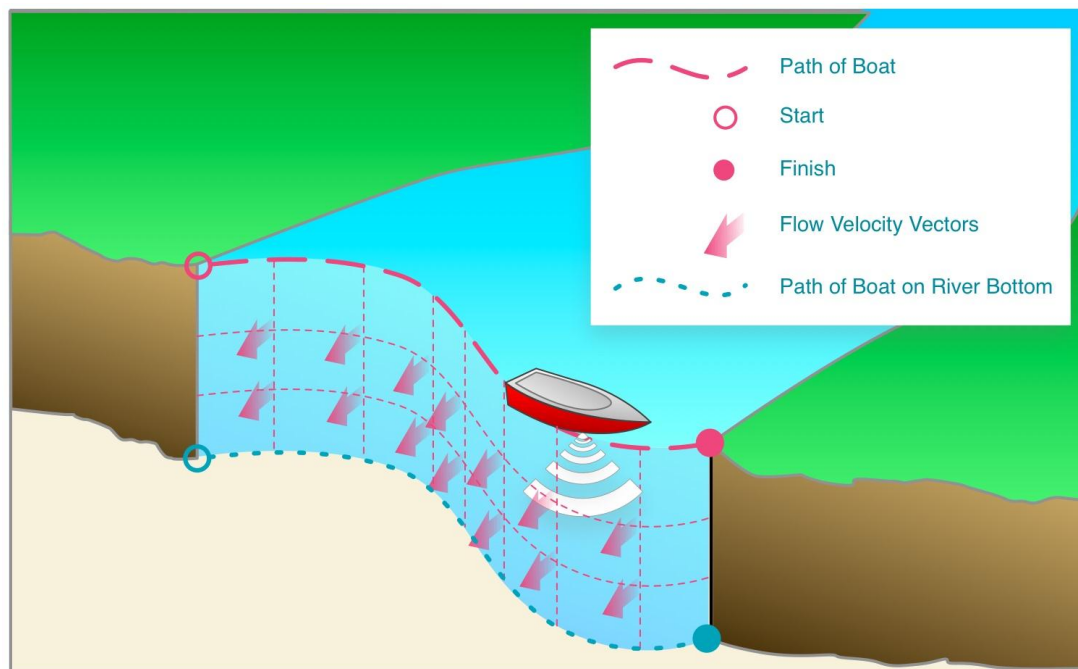- measuring depth in transducer beams, or with an echo sounder.

Figure 4 – An ADCP mounted on a boat measuring discharge of a river.
Acoustic beams are directed down into the water as it guided across a river channel.
Illustrator: Chris Heath

3.2.1.2 Speed of Sound

The velocity calculation is directly related to the speed of sound in the water, which varies with changes in:

- water temperature
- salinity
- pressure, and
- sediment concentration.

ADCPs that do not compensate for speed of sound changes shall not be used.

Note: Manufacturers of ADCP instruments measure water temperature, the most important sensitive component, near the transducer faces and apply correction factors to allow for temperature related differences in the speed of sound.

If the instrument is to be used in waters of varying salinity then independent measurements of salinity shall be taken and instrument software shall be used to correct the speed of sound.

Note: A temperature change of 5°C, or a salinity change of 12 parts per thousand, results in a speed of sound change of 1%.

3.2.1.3 Discharge Calculation

Measurements of depth, velocity profiles, distance, and direction travelled are then combined to calculate discharge.

Note: Complex calculations are involved in the discharge calculation requiring manufacturer software and a computer. Calculation details are in Mueller and Wagner (2009).

Measurement of all these parameters continuously means that:

- transects do not need to be in a straight line, or at right angles to flow
- measurements are much faster than standard Velocity-Area stationary meter methods
- many data points can be measured across the river as ADCPs measure velocities in large parts of the water column, and depths at many points, and
- non-standard velocity profiles can be measured.

3.3   Site Selection

One of the most important steps to collecting high quality data is site selection.

Many ADCP measurement problems can be solved by moving to a better measurement site.

Site selection guidelines for an ADCP measurement are very similar for the Velocity-Area stationary meter method although there are some differences.

3.3.1   Practical Controls

3.3.1.1   Site Access

Site access shall be secure and safe for the complete period of deployment.

A long term access agreement with any landowners whose land must be crossed to gain access to the site is recommended.

3.3.1.2   Safety

Hazards (for observers, the public, livestock, and wildlife) related to the location and the measurement activity shall be identified and mitigated.

3.3.1.3   Hazard Review

On selection of a final site, a hazard review shall be carried out in accordance with relevant guidelines or best practise.

The potential for human activity affecting the measurement, e.g., vandalism, shall be minimised.

3.3.2   Selection Criteria

Where practicable, the selected site shall:
- have a channel that is reasonably straight
- have a cross-section that is roughly parabolic, trapezoidal, or rectangular. Asymmetric channels and channels with abrupt changes in channel bottom slope should be avoided.
- be free from vegetation and debris
- have flow directions reasonably parallel to one another
- have stable bed and channel margins for the period of measurement, and
- be accessible at all times with the measurement equipment
- have enough depth to collect two or more depth cells at the start and stop points.
- have enough depth across the channel to collect at least two depth cells.

3.3.2.1   Flow Velocity

Where practicable, the selected site shall:
- have a cross-section with mean velocities greater than 0.1 m/s.
  Note: Measurements can be made in lower velocities but it can be difficult to keep boat speeds, particularly large manned boats, less than or equal to the water velocity in these conditions.

- not have excessive turbulence, such as standing waves, large eddies and non-uniform flow lines.

3.3.2.2 Proximity to Water-Level Station

The measurement section shall be relatively close to the water-level station (if applicable) to avoid the effect of:

- tributary inflow between the measurement section and the control, and
- channel storage between the section and control at times of changing water-level.
  Note: These criteria may not be important for one-off spot measurements of flow but would be important for measurements used to derive water-level flow ratings at a water-level station.

3.3.2.3 Sites to Avoid

Where practicable, sites showing one or more of the following characteristics shall be avoided:

- Any large steel structures nearby that may have magnetic fields that cause ADCP compass errors, and
- when using GPS avoid locations where multipath interference is possible, or GPS satellite signals may be blocked.
  Note: Large obstructions on the banks such as trees, and buildings or steep banks rising above the river may all cause problems for GPS systems. It may be possible to make successful measurements in these conditions but look for a better section first.
- Water with insufficient acoustic scatterers as the amount of acoustic energy returned to the ADCP would be too low to determine velocity.
- High sediment loads in the water column, as this can result in a reduced depth range.
- Excessive moving bed, particularly when alternative GPS reference systems are unavailable.

3.4   Pre-Measurement Checks

Before conducting field measurements, all of the following tasks shall be performed:
- Water Temperature and Salinity Measurement
- Instrument Diagnostics
- Compass Calibration
- ADCP Configuration
- Moving Bed Tests

On completion, one or more of the above tasks, e.g., moving bed test, may require you to find a more suitable site.

3.4.1   Water Temperature and Salinity Measurement

Water temperature and salinity can affect the speed of sound.

Prior to measuring discharge:
- water temperature shall be checked using a calibrated thermometer
  Note: An ADCP in-built thermometer should be with ± 2 ^{o}C of an independent check. An error of 5 ^{o}C can potentially cause a 2 % bias error in the discharge result.
- where saline water may be present salinity shall be measured using a calibrated conductivity sensor. If salinity is likely to vary over time it shall be measured for every transect.

3.4.2   Instrument Diagnostics

Prior to measuring discharge:
- the ADCP internal clock shall be checked against local standard time, and a correction made if necessary.
- internal instrument components shall be checked by running diagnostic software.
  Note: Only use the diagnostic software that was provided by the manufacturer for the ADCP model you are using. ADCP software provides a file archiving system to store diagnostic tests in each discharge data file.

3.4.3   Compass Calibration

The ADCP internal compass shall be calibrated prior to:
- completing a loop moving bed test, or
- using the GPS as the boat velocity reference
  Note: Some ADCPs do not have a compass so this calibration procedure is not required.

Compass calibration shall be completed:
- using the manufacturers software and procedure
- at the site and in the boat mount to represent the local magnetic conditions
- by minimising any ferrous material or electromagnetic sources in the immediate vicinity
- using rotation velocities specified by the manufacturer.

After calibration the total compass error should be less than 2 degrees.

3.4.4 ADCP Configuration

Prior to deploying the ADCP at any site, the following parameters shall be entered into the ADCP software:

- File names for the data files
  Note: The file names shall follow a uniform documented naming convention.
- The depth of the ADCP reference point beneath the water surface
  Note: Manufacturer documentation shall be used to determine the ADCP reference point.
- Magnetic declination if a GPS reference is to be used.
  Note: Magnetic declination values are available for NZ from http://gns.cri.nz
- Information on site characteristics such as, maximum water depth, type of bed material, and expected water and boat speeds.
  Note: Some ADCPs automatically set maximum water depth and speed as they collect data so this information will not be required at the configuration stage.
- Wind speed and direction
  Note: Some ADCPs software may not be capable of accepting this information, in these cases this information shall be documented on a gauging card.

After configuration a trial transect may be useful in determining if the appropriateness of the ADCP settings.

Note: Start and stop locations to satisfy a minimum of 2 depth cells can be determined during this trial transect.

3.4.5 Moving Bed Tests

Before making discharge measurements, a moving bed test shall be conducted.

Important: *ADCPs use bottom tracking. Bottom tracking assumes the streambed is stationary, however sediment transport on or near the streambed can affect the Doppler shift of the bottom tracking pulses. If sediment is moving, a stationary boat will appear to move upstream and will result in measured velocities and discharges that are biased low.*

There are two methods for testing for a moving bed, and procedures for measuring discharge if moving bed is present, these are the:

- Stationary Moving Bed Test
- Loop Moving Bed Test

3.4.5.1 Stationary Moving Bed Test

A stationary moving bed test, for example Figure 5 shall be completed by:

- holding the boat a stationary position on river where there is potential for moving bed and collecting data for greater than 5 minutes, this requires a tether, anchor or GPS reference to maintain position, or
- if a boat operator is trying to hold station to visual reference points at least 10 minutes of data shall be collected
- any apparent movement upstream in the boat ship track during the test shall be assessed for significance with the thresholds in Table 1,**Error! Reference source not found.** or computed using ADCP manufacturer or USGS software for this purpose.

Conduct further testing if there is any doubt about the validity of the test.
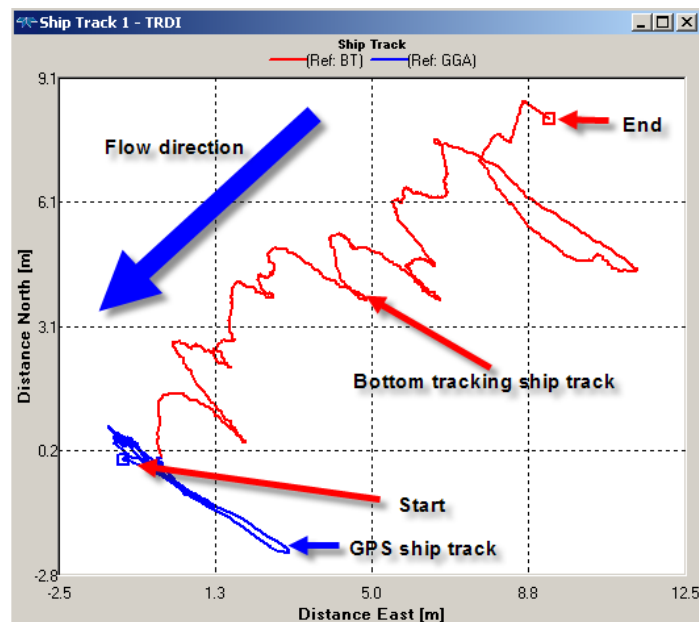More tests should be made at other parts of the cross-section.

Figure 5 – Example of a stationary moving bed test carried out on an anchored boat with a GPS.
The red ADCP bottom track has moved upstream 12 m over 10 minutes while the blue GPS ship track has not moved upstream just swung sideways over time on the anchor. Moving bed velocity = 0.017 m/s.
Illustrator: Andrew Willsman

Table 1 – Thresholds for Determining Significance of Moving Bed.

Locating Method	Assume moving bed if Vmb/Vw ratio is…
Anchored or Tethered Boat	> 0.01
Non-Anchored Boat	> 0.02
GPS Referenced Boat	> 0.01
Loop Method	> 0.01 and Vmb > 0.012 m/s

Where:

- *Vmb is the Velocity of the moving bed.*
  That is, the apparent distance moved upstream (Distance made good)/Duration in seconds

- *Vw is the mean water velocity.*

3.4.5.2 Loop Moving Bed Test

A loop moving bed test, for example Figure 6 (below), can be more representative of moving bed conditions in the whole channel although it does require an ADCP with a compass.

This test shall be carried out by:

* ensuring the compass is well calibrated at the site
* collecting data as a loop is made from a known starting point on one bank across the river and back to the exact starting point.
  Note: This method requires bottom tracking to be maintained during the test.
* visually assessing the recorded ship track. If moving bed is present then the end position of the loop will be significantly upstream of the start position.

Any apparent upstream movement in ship track shall be:

* calculated for significance against thresholds (See Table 1, Page 32), or
* computed using ADCP manufacturer or USGS software for this purpose.
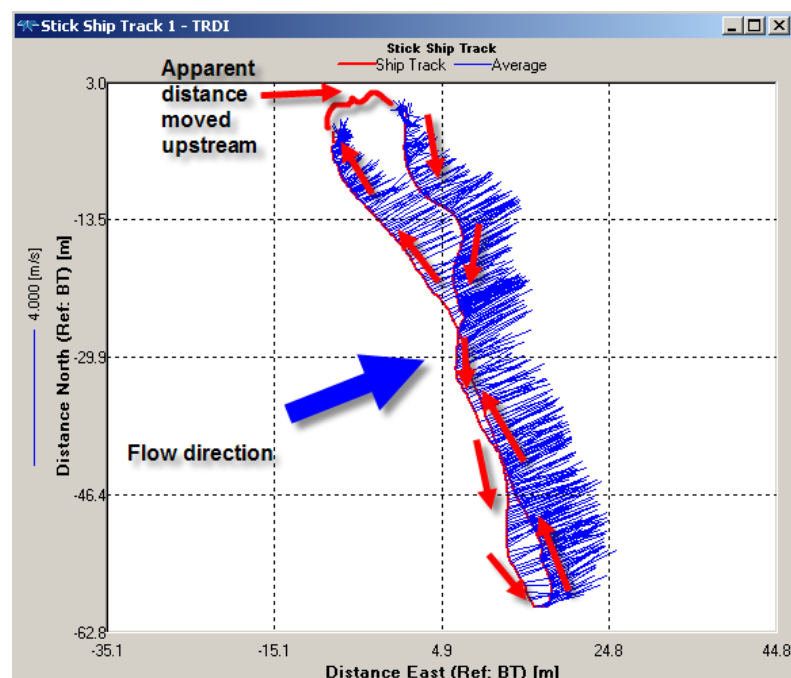

Figure 6 – Example of a loop test with a distorted ship track caused by a moving bed.
Distance moved upstream = 8.1 m, duration = 275 s, average moving bed velocity = 0.029 m/s.
Illustrator: Andrew Willsman

3.4.6 Moving Bed Alternatives

If moving bed is found to be significant and it is not possible to find an alternative site with no moving bed then one of the following methods may be used:

- GPS can be used as the reference for the boat velocity, if this is available and valid.
- The stationary ADCP profiling method can be used, as the bottom track reference is not required for this method.
- The discharge measurement can proceed and the potential error determined by the moving bed test can be applied to adjust the discharge results. The USGS and ADCP manufacturers provide software to complete this calculation, or it can be manually calculated and adjusted. For more information see 'Annex B – Moving Bed Test Correction'.

Note: No preference is implied by the order of this list as the accuracy of each alternative method will depend on the specific flow and site conditions at the time of measurement.

3.5 Discharge Measurement

When completing a discharge measurement during steady flow conditions, the following rules shall apply:

- The edge distances from the start and stop positions to the water's edge shall be measured.
- At least 10 ensembles of data shall be collected at the start and stop positions.
- An even number of transects (reciprocal pairs) shall be collected.
- The total exposure time of these shall be at least 720 seconds (12 minutes).
  Note: The total exposure time is measured as the time the ADCP is recording data. Reciprocal pairs allow for averaging of any potential directional bias.

Where practicable:

- the boat speed shall be less than the water speed
- boat operation shall be as smooth as possible
- rapid course changes shall be avoided, and
- transects with identifiable problems shall be replaced with transects in the same direction.

Note: Common identifiable problems are:

- *improper boat operation*
- *significant loss of bottom track*
- *other boats passing*
- *configuration errors, and*
- *excessive pitch and roll.*

3.6 Discharge Calculation

In steady flow conditions the discharge shall be calculated by averaging the individual transect discharges.

Note: Transect with identified quality problems shall not be included in the discharge average.

During unsteady flow conditions it may be necessary to use individual transects as discrete measurements of discharge, although it is preferable to use reciprocal pairs to reduce directional bias.

The rationale for using individual transects shall be documented and stored in the metadata associated with the measurement.

Instrument Validation & Calibration

The configuration, frequency, and techniques used to configure the ADCP may limit the depth and velocities that can be measured.

Instrument specification sheets and instrument configuration wizards shall be used to determine the limits of measurement.

ADCPs fit into a range of general categories based on the:

- quantity of transducers
- configuration of transducers.
- transducer frequency, and
- techniques that are used to configure and process the acoustic signal.

3.7.1 Configuration of Transducers

Typically four or eight transducers are used.

Figure 7 – Examples of ADCP transducer configurations.
Left: 4-beam Janus.
Centre: 8-beam dual frequency Janus with an addition echo-sounder transducer in the centre.
Right: phased-array configuration capable of generating 4 Janus beams from the flat transducer face.
Left: Photographer: A Willsman NIWA
Centre: Used with permission from Sontek YSI
Right: Used with permission from Teledyne RDI

3.7.2 Transducer Frequency

Typical frequencies used for river discharge measurements vary between:

- 600 kHz, and
- 3000 kHz.

3.7.3 Instrument Quality Assurance

Although ADCPs have no moving parts and typically require no calibration, the instruments and associated software and firmware are complex. Quality assurance procedures will help identify potential instrument issues.

Procedures shall be established for:

- software and firmware upgrades
- calibration checks, and
- changes to ancillary equipment.
    For example: depth sounder, thermometers, GPS, travelling system.

3.7.3.1 Software and Firmware Upgrades

Upgrades to software and firmware are common, and many upgrades result in minor improvements that do not substantially change the quality of the discharge result.

There is the potential for major changes that can affect the results so the following practice shall be adopted:

- An instrument history log shall be kept to track firmware changes.
- A transformation matrix check shall be made after the firmware change to ensure that the instrument specific matrix has been retained.
  Note: Details of the instruments original transformation matrix will be supplied by the manufacturer. Instrument software will output the current matrix with an instrument test command.
- The most recent version of software and firmware approved by the USGS Office of Surface Water shall be used.
  Note: The USGS provide information at the OSW hydroacoustics web page http://hydroacoustics.usgs.gov/.
- Any versions of software and firmware not approved by the USGS Office of Surface Water shall be tested by completing before using for routine data collection.
  Note: Testing shall involve making comparison discharge measurements with discharge measurements from some other source, such as a rotating-element current meter.

3.7.3.2 Calibration checks

The purpose of calibration checks is to verify that the ADCP is working to enable accurate discharge measurements.

Each instrument shall have its calibration checked:

- when the ADCP is first acquired
- after factory repair or modification
- within three years of the previous calibration check.

Calibration checks can be performed using one or more of the following methods:

- A beam alignment check in a tow-tank or against a GPS reference system.
  Note: This is recommended for a new ADCP or after a transducer repair or replacement along with a comparison measurement check. Details can be found in Mueller and Wagner (2009) Appendix D
- Compare ADCP measured discharge with rated discharge at a site with a known stable rating.
- Compare ADCP discharge results with concurrent measurements made using an independent method.
  Note: Check at different sites at periodic intervals so a range of hydrologic conditions are reflected in the tests.

The discharge obtained from the ADCP should be within 5 per cent of the known stable rating or independently measured discharge.

Note: If the ADCP measurement departs by more than 5 per cent from a discharge rating, then it is possible that the rating has shifted. Another measurement with a second ADCP or other current meter should be made to check the validity of the rating.

A consistent bias in measurements not attributable to rating change shall be investigated.

3.8   Ancillary Equipment

The ADCP is the primary equipment although ancillary equipment will help achieve an accurate measurement in a variety of conditions. Not all equipment is necessary for every measurement as this is dependent on the conditions encountered.

Ancillary equipment that is available for ADCP measurements include:
- GPS instruments
- Echo sounders
- Specialised boats
- Distance measuring equipment

3.8.1.1   GPS Requirements

Using GPS to measure boat velocity is the preferred method of data collection for a moving transect when:
- moving-bed conditions are present, and/or
- bottom tracking fails.

GPS provides two options, either of which shall be used for providing boat velocity:
- Differentiated position (GGA sentence), this requires a differential GPS correction source from a real-time kinematic (RTK) system, or a wide area correction service transmitted over satellite, radio, or cell phone systems.
- Velocity and direction sentence (VTG), this is based on Doppler shifts in the satellite signals and does not require differential corrections. This does require more complex receivers that are capable of providing accurate non filtered results. At slow boat speeds (< 0.25 m/s) and in narrow channels (< 25 m wide) considerably more variation may occur in the discharge transects.

Note: USGS OSW hydro acoustics and manufacturers can provide recommendations for GPS receivers that can output accurate VTG sentences.

3.8.1.2   Echo Sounders

Streams with high concentrations of fine sediment and sand being transported on or near the streambed may cause inaccuracies in ADCP water-depth measurements. In these conditions, using a low frequency echo sounder (approximately 200 kHz) to measure water depth may be necessary.

If an echo sounder is used it shall be calibrated as part of the pre-measurement procedure by using:
- a bar check procedure, or
  Note: A bar check involves lowering a flat plate beneath the transducer to known depths to calibrate the echo sounder. This standard procedure may be impractical at many river discharge measuring stations due to the difficulty in suspending and holding a plate in a stable position in moving water.
- by calibrating echo sounder data to an independently measured depth in a stable part of the channel.

3.8.2 Boat Requirements

Every measurement site has unique features that may determine the best type of ADCP deployment boat. Site features may include hydraulic characteristics, such as water velocity, and access considerations, such as the presence of boat ramps, bridges, or cableways.

Three common type of ADCP boats are:
- manned boats
- tethered boats, and
- remote controlled boats.

3.8.2.1 Manned Boats

An ADCP can be mounted on either side, off the bow, or in a well in the centre of the boat. There are advantages and disadvantages for each of these locations and details of these can be found in Table 4 of Mueller and Wagner (2009).

An ADCP mount on a boat shall meet the following criteria:
- be constructed of non-ferrous material, and be situated away from other ferrous material in the boat so as to not cause ADCP compass errors.
  Note: A good rule of thumb is that an ADCP should not be mounted any closer to a steel object than the largest dimension of that object.
- be situated far enough away from the engine of the boat so electromagnetic forces do not cause ADCP compass errors.
- allow the ADCP transducers to be positioned free and clear of the hull to minimise hull flow disturbance.
- hold the ADCP in a fixed vertical position so the transducers are submerged at all times.
- be adjustable for depth, and boat pitch-and-roll.
- be rigid enough to withstand the force of water caused by the combined water and boat velocity.

3.8.2.2 Tethered Boats

These are a small unmanned boat generally less than three metres long that are attached by a tether or rope that enable them to be deployed from a bridge, cableway, or temporary bank operated cableway.

Tethered boats shall meet the following requirements:
- be equipped with a mount that meets the criteria of the boat mount, and
- be deployed using a method of towing where the operator is not standing in the water upstream of the boat or standing in the water in a position close enough downstream to cause flow disturbance.
  Note: If a tethered boat is to be hand towed from in the water then a long pole shall be used to enable the operator to position himself well downstream of the boat.

3.8.2.3 Remote-Controlled Boats

These allow deployments where a manned or tethered boat may not be feasible or ideal. Mount and operational requirements are the same as manned boats. Regular maintenance of the boat and control radios is critical to ensure reliable operation.

4   Volumetric Method

4.1.1   In this Section

This section contains information on measuring discharge in open channels using the volumetric method. This method has standards associated with the following:

- Site Selection
- Measurement of Volume
- Measurement of Time
- Calculation of Discharge

4.2   Site Selection

The volumetric method is typically used on small discharges and it requires:

- sufficient fall to enable diversion of water to a container
- a structure or method of capturing all the flow

Note: Ponds or reservoirs of known volumes can be used to capture flow.

4.2.1   Practical Controls

4.2.1.1   Site Access

Site access shall be secure and safe for the complete period of deployment.

A long term access agreement with any landowners whose land must be crossed to gain access to the site is recommended.

4.2.1.2   Safety

Hazards (for observers, the public, livestock, and wildlife) related to the location and the measurement activity shall be identified and mitigated.

4.2.1.3   Hazard Review

On selection of a final site, a hazard review shall be carried out in accordance with relevant guidelines or best practise.

The potential for human activity affecting the measurement, e.g., vandalism, shall be minimised.

4.3   Measurement

4.3.1   Measurement of Volume

A container shall be used to capture the water. The container shall be:

- calibrated before use
- of a size that ensures filling times are greater than ten seconds, and
- of a size that is manageable.

Note: This method may be applied to larger flows if large reservoirs or tanks are available.

Note: As an alternative, the sample can be weighed and temperature corrected to derive the volume of water.

4.3.2   Measurement of Time

Time taken to fill the container shall be measured:

- with a stopwatch, and
- at least 10 separate filling measurements shall be made.
  The total duration of the filling measurement shall exceed 100 seconds.

The standard deviation of the time measurements shall be calculated for use in the uncertainty estimate.

4.4　Discharge Calculation

Discharge is calculated by dividing the container's volume by the time taken to fill. Multiple measurements shall be averaged for the final discharge result.

The uncertainty of the discharge result shall be calculated using the principles in ISO5168.

Quality codes shall be derived from the calculated uncertainty value.

5   Indirect Discharge Measurements

5.1.1   In this Section

This section contains information on estimating discharge in open channels using indirect methods. This method has standards associated with the following:

- Flow Conditions
- Indirect Methods
- Data Collection
- Calculation of Discharge

5.1.2   Quality Codes

All discharge results obtained by indirect methods (other than current meter) shall be assigned quality code QC 400 or less.

5.1.3   Flow Conditions

Indirect methods shall only be used for flood flows where it is:

- impossible or impractical to measure the peak discharge, or
- too dangerous to deploy current meters and sounding devices.

5.1.4   Indirect Methods

A number of different methods are available to calculate peak discharge, and these methods make use of the energy equation for computing discharge.

The following methods are available:

- Slope-Area
- Contracted-Opening

5.1.5   Data Collection

Data collected for the indirect methods include:

- surveyed high water-level locations and elevations
- cross-sections along the reach
- geometry of any structures relevant to the method, and
- selection of a roughness coefficient for the reach.
  Note: A reference for roughness of channels in New Zealand is Hicks and Mason (1998).

Discharge Determination Using the Slope Area Method

This method is one of the most commonly used techniques of indirect discharge determination. A complete description of the method is detailed in ISO1070:1992, and USGS Publication TWRI: 03-A2 (1968).

In summary, the velocity in a reach will be related to the slope of the channel and to the bed friction, which is due to the roughness of the bed material. The Manning equation derives velocity from channel parameters and slope. These values are calculated for the reach, rather than a single cross-section, with the values thus being averaged between two or more cross-sections.

The version of the Manning equation employed (Hicks and Mason, 1998) to compute the velocity is:

$$v = \frac{1}{n} R^{\frac{2}{3}} S_f^{\frac{1}{2}}$$

and, as discharge = velocity x area;

$$Q = \frac{1}{n} A R^{\frac{2}{3}} S_f^{\frac{1}{2}}$$

where:

- V is mean velocity (m/s)
- Q is discharge (m^3/s)
- R is hydraulic radius = A/P (m)
- A is mean cross-section area (m^2)
- P is wetted perimeter (m)
- n is the Manning roughness coefficient.
- S$_f$ is friction slope, where:

$$S_f = \frac{\Delta H + \Delta H_v - \Delta k(\Delta H_v)}{L}$$

where:

- ΔH is the change in elevation of the water surface between the upstream and downstream cross-sections
- ΔH$_V$ is the change in velocity head between the upstream and downstream cross-sections, where:

    H$_V$ at a cross-section = $\frac{\propto v^2}{2g}$, where α is usually assumed to be 1

    g = the acceleration due to gravity

    V = mean velocity in the cross-section (calculated from Discharge/Area)

- k is assumed to be zero for contracting reaches and 0.5 for expanding reaches.
- L is the length of the reach.

A variation of the Manning formula deals with energy gradients in diverging and contracting reaches by utilising two cross-sections. This was derived by the USGS and was simplified and applied by A C Hopkins of the Ministry of Works (circa 1969 training courses).

The conveyance of the reach is calculated using:

$$\mathrm{K} = \frac{AR^{\frac{2}{3}}}{n}$$

where:

- K is the conveyance of the reach (m^3/s)
- A is the mean of the upstream and downstream cross-sections (m^2)
- R is hydraulic radius
- n is the Manning roughness coefficient

Then discharge in a contracting reach is:

$$Q = \frac{(2gL)^{1/2} \, K \, S^{1/2}}{\sqrt{(2gL) + \left(\frac{K}{A_2}\right)^2 - \left(\frac{K}{A_1}\right)^2}}$$

Note: For a diverging reach replace (2gL) with (4gL)

where:

- Q is discharge (m^3/s)
- g the acceleration due to gravity (m/s^2)
- L is the length of reach (m)
- S is the slope (m/m)
- A_1 is the upstream cross-section area (m^2)
- A_2 is the downstream cross-section area (m^2)

5.3 Discharge Determination using the Contracted Opening Method

The contraction of a stream channel by a bridge creates an abrupt drop in the water-surface elevation between an approach section and the contracted section under the bridge.

This contracted section framed by the bridge abutments and the channel bed can be used to estimate flood flows. High water marks and the geometry of the bridge and channel are used in this method.

A complete description of this method is in Matthai (1967).

Note: this is a US paper with formulae and examples in imperial units; coefficients unless dimensionless require conversion to metric units

A variation of the formula was derived and applied in New Zealand by A C Hopkins of the Ministry of Works (circa 1969 training courses). This version removes the components which have no significant effect and so simplifies the calculation.

Flow is computed by firstly determining the velocity at the upstream cross section using:

$$V_1 = C \frac{A_2}{A_1} \sqrt{2g\left(H + \alpha\frac{V_1^2}{2g}\right)}$$

where:

- V_1 is mean velocity in the upstream cross-section (m/s)
- A_1 is the upstream cross-section area (m^2)
- A_2 is the contracted cross-section area (m^2)
- H is the draw-down between the upstream and contracted cross-section (m)
- C is the discharge coefficient (assessment in Matthai (1967))
- α is the Coriolis coefficient estimated from the conveyance and area (refer to Matthai (1967))
- g is the acceleration due to gravity (m/s^2)

then:

$$Q = V_1 A_1$$

6 Section 6 – Data Processing & Preservation

6.1.1 In this Section

This section contains information on the handling of data received from the field, in its original form, to data processing and editing, to final archiving.

It defines standards relating to:
- original records
- review of discharge measurements
- measurement quality
- quality coding
- metadata, and
- archiving records.

6.1.2 Performance

The methodology used to process and preserve data shall be documented.

Note: The methodologies applied by each agency vary depending upon the software utilised for hydrological data processing and archiving.

6.2 Original Records

Discharge measurement and supplementary data (whether electronic, or paper records) on arrival in the office shall be:

- permanently identified with site identifiers, unique measurement number, and dates and times
- entered in a register, organised by unique discharge measurement number, station name, date and time, and method code
- moved from field computers or backup media to permanent storage locations, or
- (paper records) stored in a fireproof secure location.

All original records shall be retained indefinitely by the recording agency.

Note: The original record may be required at a later date, should the archived processed data be found to be in error, corrupt, or lost.

6.3 Review of Discharge Measurements

Discharge measurement data shall be examined by the data collector and checked by a second individual in the office.

Items checked in electronic and/or paper records for all discharge measurement methods shall include all of the following:

- Site and measurement identifiers
- Date and time of measurement
- Instrument configuration values
- Instrument test results
  Note: For a rotating-element current meter this includes spin test results. An acoustic meter will have a manufacturer specific test routine that logs an electronic file.
- Instruments use within their specified range
- Location of cross-section is appropriate
- Water-level information
- Values entered during the measurement
- Correct use of instrumentation
- Computed flow
- Gauging party
- Method code
- Possibility of wind effects
- Quality coding or measurement uncertainty
- Comments

6.3.1 ADCP Measurement Review

ADCP discharge measurements have aspects that are specific to this method. The following items shall be confirmed in the data:

- Transducer offsets, edge distances, temperature and salinity match the field notes.
- A moving bed test using a proper technique has been conducted and assessed.
- If a moving bed was detected, an appropriate alternative to bottom tracking was used.
- Total exposure time is greater than 720 seconds.
- An even number of reciprocal transects has been collected.
- The average boat speed was less than the water speed.
  Note: Boat operation causing rapid course changes and excessive pitch and roll will degrade the quality of the measurement
- The number of missing or invalid ensembles (data) was not excessive.
  Note: The number of missing or invalid ensembles that will result in a poor measurement is difficult to establish because the location and clustering of the missing data is important. If 50 percent is missing but every other ensemble was valid then this would be a good measurement. However, if 10 percent of the ensembles are missing in one location where there is a significant part of the flow and neighbouring data is of poor quality then the measurement quality shall be downgraded.
- Extrapolation methods are appropriate for the wind and velocity conditions.

Note: Manufacturers and the USGS provide software for the purpose of assessing potential non-standard velocity situations. Details of this can be found on the USGS OSW hydro acoustics web page.

Further details on reviewing ADCP measurements are summarised in Appendix F of Mueller and Wagner (2009).

6.4 Measurement Quality

The quality of the discharge measurement can be assessed:
- quantitatively by calculating uncertainty, or
- qualitatively by assigning a quality code based on performance objectives

Both methods are presented and where possible shall be derived for the discharge measurement.

6.4.1 Uncertainty in Discharge Measurement

Flow measurements are only an estimate of the true value of the discharge and therefore are only complete when accompanied by a statement of the uncertainty of the result.

These uncertainties may be due to:
- systematic errors (biases) in the equipment used for calibration and measurement, or
- random scatter caused by: for example, a lack of sensitivity in the measurement equipment.

Discharge measurements are composite quantities that depend on several component quantities, so the total error of the measurement is a combination of the errors in all component quantities. Uncertainty is determined by using statistical rules for combining standard deviations and the resulting value is the standard uncertainty. In most applications a coverage factor of 2 is applied to this standard uncertainty to determine an expanded uncertainty with an approximate level of confidence of 95%.

Note: For more information see JCGM100:2008 and ISO5168:2005.

6.4.2 Uncertainty Calculation

Discharge measurement results shall have an expanded uncertainty value expressed at 95% confidence levels.

This expanded uncertainty value shall be calculated using approved techniques that are dependent on the choice of velocity current meter or measurement method.

6.4.2.1 Rotating-Element Current-Meter Measurements

The discharge uncertainty calculation is described in ISO5168:2005 and ISO748:2007 section 9.3.

Software used to calculate discharge shall use these standard algorithms.

6.4.2.2 ADV Instruments

The discharge uncertainty calculation uses ISO5168:2005 and ISO748:2007 section 9.3 with modifications by the instrument manufacturers to account for the specific uncertainty components associated with these instruments.

Manufacturer software shall be used to determine discharge uncertainty results from these instruments.

Note: Report uncertainty results using the ISO748 standards.

6.4.2.3 ADCP Profilers used in the Velocity-Area Stationary Method

The discharge uncertainty calculation is based on ISO5168:2005 and ISO748:2007 section 9.3 with modifications by the instrument manufacturers. Where available this is based on a relative standard uncertainty model (Huang, 2008).

Manufacturer software shall be used to determine discharge uncertainty results from these instruments.

6.4.2.4 ADCP Instruments used with the Velocity-Area Moving Boat Method

These instruments currently have no accepted method for the calculation of uncertainty. A matrix of quality parameters is available in 'Annex D – ADCP Moving Boat Estimation of the Quality Code', for assessing the quality of a measurement.

Note: Research on large numbers of ADCP measurements by Mueller and Oberg (2007), showed that an uncertainty of ± 5% in the measured discharge could be achieved by sampling exposure times of > 720 seconds.

6.4.2.5 POEM Instruments

POEM instruments currently have no standard method of calculating uncertainty although the principles of ISO5168:2005 and ISO748:2007 section 9.3 can be applied.

6.4.2.6 Float-Based Surface Velocity Measurements

For float based surface velocity measurements, uncertainties shall be calculated using ISO748:2007 Annex F.

6.4.2.7 Volumetric Methods

For volumetric methods, uncertainties shall be derived using the principles in ISO5168:2005.

6.4.2.8 Indirect Methods

For indirect methods, uncertainties may be derived using the principles in ISO5168:2005, although it may be difficult to get enough repeat measurements of parameters to calculate standard deviations.

6.5 Quality Coding Flow Measurements

Flow measurements shall have a quality value assigned based on qualitative and quantitative performance objectives. The following table shall be used to assign a quality code to every flow measurement.

Figure 8 – Flow Measurement Quality Codes
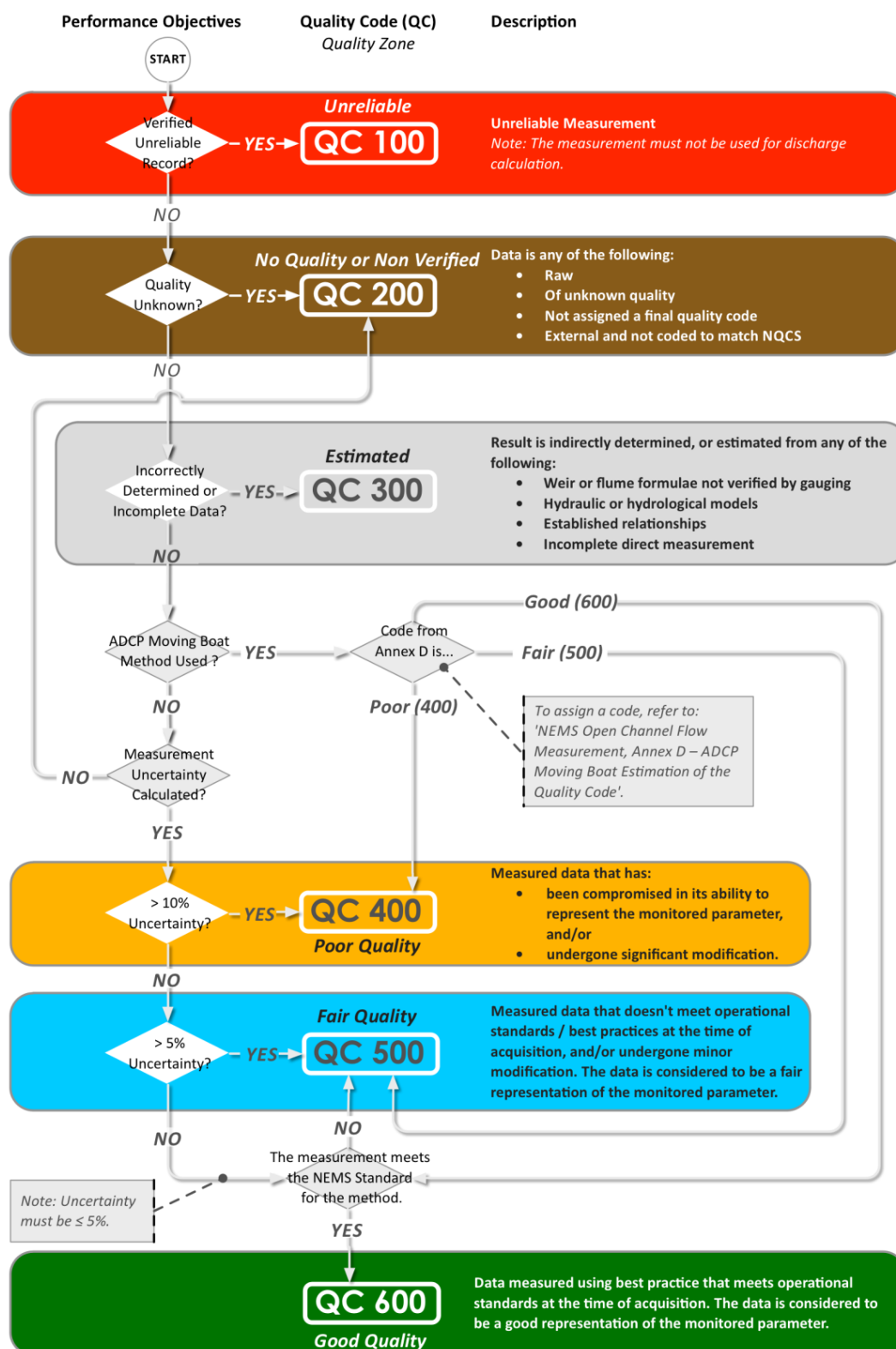
6.6 Metadata / Comments

6.6.1.1 Archiving

Adequate mechanisms shall be put in place to store all relevant metadata with, or accessible from, or indexed from, the actual discharge measurements. The metadata shall include but not be limited to:

- instrument calibration records
- instrument validation records
- the following flow measurement site details:
  - Site purpose
  - Recording agency
  - Site location in standard and documented coordinate system
  - Site name and past and present aliases
- comments.

6.6.1.2 Comments

Anything other than what is covered under the quality codes shall be commented on.

Comments are very useful to explain unusual features or events in the record of measurements at a long-term site that users of the data should be aware of. In addition, routine comments are required for key information. These should include, but not limited to:

- Site identifiers and agency
- Date and time of first and last flow measurements at site
- Related records
- Methods used to measure flow
- Items filed in the database and units
- Reference to calibration records (preferably through an instrument/asset management system)
- Any relevant comments in document vocabularies that future users will understand (e.g. define terms and refer to instrument types and not brands)
- Information about legal requirements, confidentiality agreements, intellectual property, and any other restrictions related to data access
- Comments relating to issues or problems with particular measurements. They should filed at the time of the measurements.

Preservation of Record

Performance

The following data shall be archived and retained indefinitely:
- Unedited raw instrument data (the original data as recorded)
- Field gauging cards
- Instrument validation data (pre-deployment check data)
- Reviewed final measurement data
- Calibration records
- Metadata

All original records shall be retained indefinitely by the recording agency.

Note: The original raw data may be required at a later date, should the archive data:

- *be found to be in error*
- *become corrupted or*
- *be lost.*

Discharge measurements that have been registered, and reviewed, shall be archived in a database.

Discharge measurement data items filed in the database shall include:
- time of the mean water-level height during the measurement.
  Note: If a measurement is completed over a peak or trough then the time of mean water-level height may occur at more than one time. The most appropriate time to use would be the one closest to where the larger portion of flow was measured.
- the mean value of the reference water-levels during the measurement
  Note: During times of non-linear change in water-level of more than 100mm the method in ISO748:2007 section 8.7.3 shall be used.
- a method code.

For information on method codes, see 'Annex C – Discharge Measurement Method Codes'.

Annex A – List of Referenced Documents

Dalrymple T, Benson MA (1967). Measurement of peak discharge by the slope-area method. *USGS Techniques of Water-Resource Investigation: 03-A2*
http://pubs.er.usgs.gov/publication/twri03A2

Hicks DM, Mason PD (1998). Roughness Characteristics of New Zealand Rivers. Wellington, New Zealand. DSIR Marine and Freshwater.

Huang H (2012). Uncertainty Model for In Situ Quality Control of Stationary ADCP Open-Channel Discharge Measurement. *Journal of Hydraulic Engineering, Vol. 138 (1), 4-12.*

ISO748 (2007). Hydrometry – Measurement of liquid flow in open channels using current meters or floats.

ISO1070 (1992). Liquid flow measurement in open channels – Slope-area method.

ISO2537 (2007). Hydrometry – Rotating-element current-meters.

ISO3455 (2007). Hydrometry – Calibration of current-meters in straight open tanks.

ISO5168 (2005). Measurement of fluid flow – Procedures for the evaluation of uncertainties.

JCGM100 (2008). Evaluation of measurement data – Guide to the expression of uncertainty in measurement.

Matthai HF (1967). Measurement of peak discharge at width contractions by indirect methods. *USGS Techniques of Water-Resource Investigation: 03-A4*
http://pubs.er.usgs.gov/publication/twri03-A4

Mueller DS, Wagner CR (2009). Measuring discharge with Acoustic Doppler Current Profilers from a moving boat. *U.S. Geological Survey Techniques and Methods 3-A22, 72p.*
http://pubs.usgs.gov

Oberg KA, Mueller DS (2007b). Analysis of exposure time on streamflow measurements made with acoustic Doppler current profilers: *Proceedings of the ASCE Hydraulic Measurements and Experimental Methods Conference, Lake Placid, NY, 2007, 6 p*

Annex B – Moving Bed Test Correction

The average moving bed velocity is found from

V_{mb}=Distance upstream/Duration in seconds

It is significant if:

- greater than 0.012 m/s, and
- the Vmb/Vw ratio is greater than 0.01
  Where Vw is the mean water velocity.

Then calculate the following:

- Area of Section with Moving Bed
  A_{mb} *(usually) = Total Area – Right Area – Left Area*

Note: How you calculate this will depend on the section and what you know about the flow.

Then:

$$Q_{corrected} = Q_{measured} + (V_{mb} \times A_{mb})$$

Carry out a series of normal measurements and calculate this moving bed discharge correction for each one. Alternatively in rapidly changing flows or flood situations the loop test can be sub-sectioned into two transects later in the office using the recorded edge offsets.
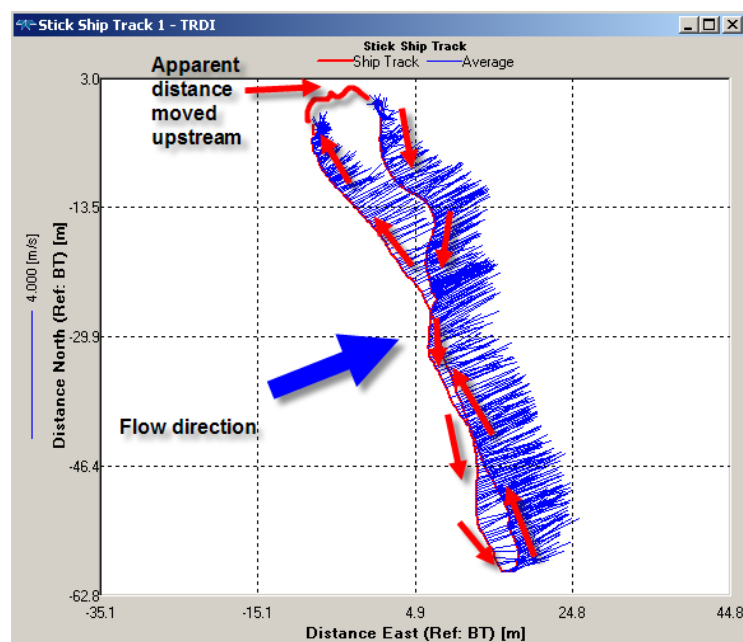

Figure 9 – Example of a loop test with a distorted ship track caused by a moving bed.
Distance moved upstream = 8.1 m, duration = 275 s, average moving bed velocity = 0.029 m/s.
Illustrator: Andrew Willsman

Annex C – Discharge Measurement Method Codes

Table 2 – Method Codes for Gauging Methods used in New Zealand.

Instrument/method	Code	Rod-Mounted	Cable-Mounted	Combination Rod & Cable
Pygmy		01	07	34
Gurley (Price AA)		02	08	35
Watts (Watts Price)		03	09	36
Amsler		04	10	37
Large Ott or Oss		05	11	38
Small Ott or Oss		06	12	39
Braystoke or other directional current meter			13	
Two different current meters	40			
Volumetric	14			
Portable weir or flume	15			
Continuous current meter	16			
Rated value (from rating curve)	17			
Velocity Head Rod	18			
Floats	19			
Slope-area	20			
Miscellaneous formula	21			
Chemical tracer velocity method	22			
Estimation	23			
Pitot tube	24			
Ripple meter	25			
Dilution gauging methods		*Constant Rate*	*Sudden injection*	
Conductivity		26	29	
Fluorometry		27	30	
Other		28	31	
Miscellaneous	32			
Miscellaneous current meter	33			

Instrument/method	Code	Rod-Mounted	Cable-Mounted	Combination Rod & Cable
Cross-section only	41			
Sediment sample only	42			
Electromagnetic	43			
ADCP (RDI) + RiverRay	44			
ADP (Sontek)	45			
ADV including Flowtracker	46			
ADCP StreamPro	47			
POEM	48			
ADCP stationary Section by Section	49			

Annex D – ADCP Moving Boat Estimation of the Quality Code

	Criteria	3 Points (Poor)	1 Points (Fair)	0 Point / NA (Good)
1	Channel Description **Visual**	Bed debris and vegetation disrupting flow and bed profile, a large amount of non-uniform and turbulent flow. Aeration of the water. ☐	Some non-uniform flow, asymmetrical channel shape, some bed debris/ vegetation causing moderate flow and channel disturbance. ☐	Uniform/ laminar flow, smooth uniform X-section profile, no large bed debris or vegetation disruption of flow within the channel profile. ☐
2	Total Exposure Time	0-8 min ☐	8-12 min ☐	>12min ☐
3	% of Q Measured	≤ 40% ☐	> 40% & < 65% ☐	≥ 65% ☐
4	Data loss, missing or lost ensembles **Visual**	Significant, large blocks located in main areas of channel flow. ☐	Some blocks randomly located across channel. ☐	No or minor instances located randomly . ☐
6	Compass Calibration	Q1-4 or not completed ☐	Sontek Q5-7 Or RDI >2 degrees ☐	Sontek Q8-9 Or RDI <2 degrees ☐
7	Moving Bed Test	Not completed ☐		Completed ☐
8	Edge Data **Visual** *All transects must have 2+ cells to be Good*	0 cells ☐	1 cell ☐	+2 cells ☐
9	Pitch **Visual**	10 deg + ☐	6 to 9 deg ☐	0 to 5 deg ☐
10	Roll **Visual**	10 deg + ☐	6 to 9 deg ☐	0 to 5 deg ☐
11	Moving bed Track Reference *(If moving bed present, what method used)*	Bottom Track- no loop correction. ☐	Bottom Track- loop correction. ☐	GPS-RTK/ GPS-VTG Or N/A ☐
12	Max GPS HDOP's **Visual** *Only if GPS used as a reference*	> 6 ☐	3 to 5 ☐	< 2 ☐
	TOTAL POINTS	☐	☐	☐

Final Quality Code

Poor (400) = >12
Fair (500)   = 4-12   **GRAND TOTAL**   ☐
Good (600) = <4

If three or more criteria are selected in the Poor column the gauging is considered to be Poor.