National Environmental Monitoring Standard

Water Level

Water Level Field Measurement Standard

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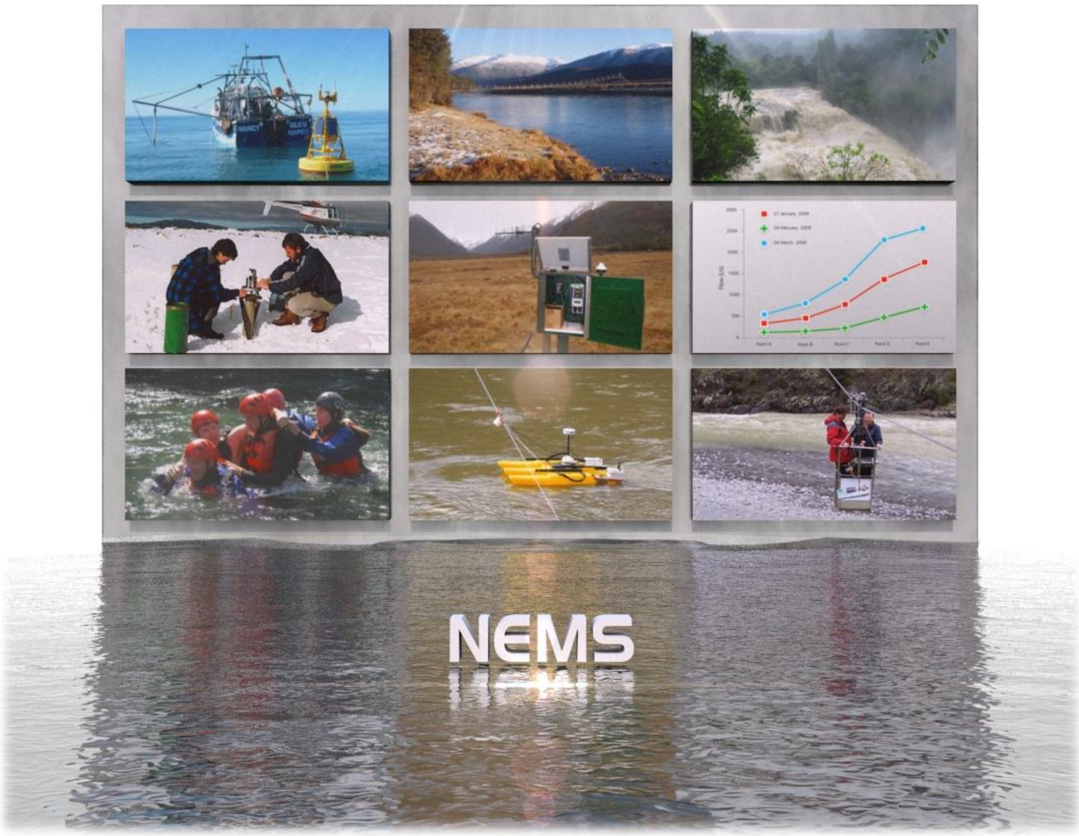

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The National Environmental Monitoring Standards

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Implementation

When implementing the Standards, current legislation relating to health and safety in New Zealand and subsequent amendments and the NEMS Codes of Practice shall be complied with.

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.

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

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Development

The National Environmental Monitoring Standards (NEMS) Steering Group has prepared a series of environmental monitoring standards on authority from the Regional Chief Executive Officers (RCEOs) and the Ministry for the Environment (MfE). The strategy that led to the development of these Standards was established by Jeff Watson (Chairman) and Rob Christie (Project Director), and the Steering Group at the time of development of the original version of this NEMS comprised Phillip Downes, Martin Doyle, Michael Ede, Glenn Ellery, Nicholas Holwerda, Jon Marks, Charles Pearson, Jochen Schmidt, Alison Stringer, Raelene Mercer (Project Manager) and Jeff Watson. At the time of the publication of Version 3.0.0 of this NEMS, the Steering Group comprises Jeff Watson, Phillip Downes, Martin Doyle, Michael Ede, Glenn Ellery, Jon Marks, Charles Pearson, Jochen Schmidt, Dan Elder, John Forne and Raelene Mercer (Project Manager)

The development of these Standards involved consultation with regional and unitary councils across New Zealand, major electricity generation industry representatives and the National Institute for Water and Atmospheric Research Ltd (NIWA). These agencies are responsible for the majority of hydrological and continuous environmental-related measurements within New Zealand. It is recommended that these Standards are adopted throughout New Zealand and all data collected be processed and quality coded appropriately to facilitate data sharing. The degree of rigour with which the Standards and associated best practice is applied will depend on the quality of data sought.

This document has been prepared by a core working group comprising Evan Baddock (lead writer – NIWA), Paul Peters (Horizons Regional Council), Martin Doyle (Marlborough District Council), Matt Mclarin, Pete Davis, Phil Downes (Environment Canterbury), and Gareth Gray (Genesis Energy). The document has subsequently been reviewed by Evan Baddock, Paul Peters and Martin Doyle. The input of NEMS Steering Group to the development and review of this document is gratefully acknowledged.

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Review

The original version of this document was reviewed by the NEMS Steering Group in February 2018, and will be reviewed again approximately every two years. Further details on the review process can be found at www.nems.org.nz .

Control Table

Version Number	Revision Date	Section	Significant Change
1.0	June 2013		Initial release
2.0	July 2016		Definitions removed and are now contained within the NEMS Glossary
			Addition of Normative References
			Insertion of Data fit for purpose and Enduring use statements
		1.1.3 1.1.3.1 1.1.3.2	Moved to section 1.4
		1.7.2.1 (new)	Access and Legal requirements – new section
		3.9.2	Confirmation of Calibration - removed
		4.5.3	Sensor Verification and Validation – moved to section 5.6
		4.5.4	Sensor Calibration – moved to section 5.6
		4.5.4.1	Use of Portable Calibrators – moved to section 5.6
		6.2.7 6.2.7.1 6.2.7.2 6.2.7.3 6.2.7.4	Synthetic and Interpolated Data – removed
		6.4	Preservation of Record – moved to section 6.6
		Annex H	Calibrated Structures – Removed
3.0.0	July 2019		References to data processing removed (will be covered by the Processing of Time-series Data NEMS)
			Minor text changes throughout
			List of other NEM Standards removed
		The Standard	Timing of measurements – averaging note added.
		2.3	Sensitivity – notes added
		4.2	Direct Contact with Water - New section
		4.3	Indirect Measurement of Water Level - New section
		4.8.2	Acoustic Transceiver – accuracy examples added
		5.4	On Board Processing – note altered to consider averaging.
		6.2.1	Missing, Synthesised and Modified Records – note recommending backup sensors added.
		6.4	Preservation of Record – moved to section 6.4
		6.7.2.4	Biennial inspections added
		Annex G	Removed (will be covered by the Processing Time-series Data NEMS)
		Annex I	Now Annex G

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Terms, Definitions and Symbols

Relevant definitions and descriptions of symbols used in this Standard are contained within the NEMS Glossary available at www.nems.org.nz.

Normative References

This Standard should be read in conjunction with the following references:

- ISO 4373:2008 *Hydrometry – Water level measuring devices*
- ISO 1438:2008 *Hydrometry – Open channel flow measurement using thin-plate weirs*
- ISO 772:2011 *Hydro – Vocabulary and symbols*
- Ministry of Works. (1958). *Standard specifications for automatic water level recorder installations and current meter gauging stations*.
- NEMS *Glossary*
- NEMS *Open Channel Flow*
- NEMS *Quality Code Schema*
- Sauer, V. B., and Turnipseed, D. P. (2010). Stage measurement at gaging stations. In *US Geological Survey Techniques and Methods* (Book 3, Chap. A7).

About this Standard

Introduction

Water level information is collected from a variety of water bodies and is used for a multitude of purposes. A water level record often acts as a surrogate for flow in rivers because it is difficult to continuously measure flow directly. Water level used for this purpose requires a good understanding of the relationship between level and flow, and the problems faced when maintaining that relationship.

Water level is often analysed on its own (flood levels, tide), or used in conjunction with other parameters, in particular water quality. It is important to understand the range of uses to which the data can be put, and to ensure that data collected for one purpose can be used as widely as possible in the future. Key to planning, maintaining and recording flow measurement is the understanding of, and catering for, stationarity.

Formal water level recording started in New Zealand in the 1890s. Collecting water level information to calculate flow data for hydro-electricity development and flood protection works began in the late 1920s, and irrigation investigations in the 1930s.

In 1949 the first Hydraulic Survey parties were established, and during the 1950s and 1960s many stations were built for a wide variety of purposes including flood control and soil conservation studies. The International Hydrological Decade (commencing 1964) was a notable period of growth in data collection and analysis, with the emergence of both the first truly accurate recording instruments and computers to analyse the data.

Growth in the number of recording stations continued, and by 2010 the total number of surface water level recorders reached more than 1300, with an additional 470 being deployed for the purpose of measuring groundwater.

Objective

The objective of this standard is to ensure that water level data from aquifers, lakes, reservoirs, flowing channels and the sea, is gathered to the standard and is suitable for ‘at site’ and comparative analysis.

This document is made up of two parts: the first part is the Standard, and the second part contains supporting information that practitioners are required to implement in order to achieve the Standard.

Scope

The scope of the Standard covers processes associated with:

- site selection
- equipment selection
- equipment deployment, and
- quality assurance (QA) of field stations.

Exclusions

The Standard does not address industrial applications.

Data Fit for Purpose

This Standard requires all collected data to be assigned a quality code.

Data that are collected in a verifiable and consistent manner according to this Standard can meet the highest quality code (QC 600).

Data that do not meet QC 600 shall be coded appropriately. This allows monitoring to be carried out that is 'fit for purpose', and these data can be coded as QC 500 (Fair), or QC 400 (Poor). These data are deemed acceptable for specific, often secondary, purposes that only require data of a lesser quality.

Note: Enduring use – It is important to note that data that are coded QC 500 or QC 400 may be restricted in their use for a wide range of (yet unknown) purposes sometime in the future.

The Standard – Water Level

For water level data to meet QC 600 in this Standard, the following shall be achieved:

Accuracy	Rivers and lakes	The greater of: • ± 3 mm, or • 0.2 % of effective stage.
	Sea and groundwater	The greater of: • ± 10 mm • 0.2% of effective stage.
Stationarity	Stationarity of record shall be maintained.	

Requirements

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

Units of Measurement			Express units in: • metres (m), or • millimetres (mm).
Resolution			1 mm
Timing of measurements	Maximum recording interval	Rivers and lakes	5 min
		Groundwater	15 min
		Sea	1 min
	Averaging	Rivers, lakes and groundwater	Instantaneous value *Note: Averaging must be defined and justified in the accompanied metadata stating comparison results with instantaneous and why this averaging period was used.*
		Sea	• 1 min (average), and • 1 Hz sampling interval (minimum)
	Resolution		1 s

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Timing of Measurements (con.)	Accuracy	Rivers, lakes and groundwater	± 90 s
		Sea	± 20 s
	Time Zone		Express time as New Zealand Standard Time (NZST). *Note: Do not use New Zealand Daylight Time (NZDT).*
Supplementary Measurements	Barometric Pressure		Required for unvented pressure transducers. Note: Barometric pressure data is a useful supplement for the analysis of groundwater and sea level.
	Measurement Statistics		Any supplementary data stream shall be defined in the metadata.
	Salinity		Required for pressure transducers in estuarine environments.
Validation Methods	Sensor test		Required pre-deployment.
	Primary reference measurement		Nearest 1 mm with estimate of uncertainty.
	Inspection of Recording Installations		Perform sufficient inspections to ensure the collected data, are of known and acceptable uncertainty, and free from bias, both in level and time.
Calibration	Frequency		Where relevant follow manufacturer's specifications. Annually for pressure transducers.
	Method		Where relevant follow manufacturer's specifications.
	Primary reference gauge		Reduced level of recording zero demonstrated constant over time to ± 3 mm.

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Metadata	Scope	Metadata (Annex G) shall be recorded for all measurements.
Quality Assurance		Quality assurance requirements are under development.
Processing of Data		All changes from raw record shall be documented in the metadata. All data shall be quality coded as per Quality Codes flowchart.

The following table summarises best practice and is not required for QC 600:

Archiving	Original and final records	File, archive indefinitely, and back up regularly: • raw and processed records • primary reference data • supplementary measurements • validation checks • calibration results • metadata.
Auditing		*Quality assurance requirements are under development.*

Accuracy

This Standard takes the United Stated Geological Survey (USGS) approach to determining accuracy, (except for sea level and groundwater – refer to the table above).

The USGS accuracy requirement is ± 3 mm up to an effective stage of 2 m, and above this, 0.2% of effective stage (2 m x 0.002 = 4 mm). The accuracy requirement is therefore constant at lower water levels, but lessens as levels rise. This makes allowance for water level sensors that cannot maintain accuracy over their full range, and that the fact that accuracy of staff gauge readings and sensors diminishes in rivers as velocity and surge increase.

Rating curve accuracy contributes to overall uncertainty for open channel flow sites and may be significantly impacted by uncertainty in determining high flows. The accuracy required for general water level measurement is frequently impractical for measuring water level in boreholes due to the physical restrictions and much larger ranges often encountered.

1 Site Selection

1.1.1 In this Section

This section contains information on site selection. It primarily covers the site-related variables to consider when selecting a site. Ensure that the stationarity, accuracy and operating requirements laid out in this Standard are met.

By selecting the best available site and/or installing the best available control structure, data quality will be maximised and work minimised over the period of the record.

Figure 1 – Water level station at Lake Hauroko, Fiordland.
Photographer: NIWA.

1.2 Sources of Information

The following sources of information should be used to determine the most appropriate stretch of river or shoreline (site) for deploying a station:

- topographical maps
- aerial photographs and plans (where available)
- local advice (where available) on access, stability and history
- land ownership, and
- consent information on local water takes.

1.3 Stationarity of Record

Stationarity of record:

- is maintained when variability of the parameter being measured is only caused by the natural processes associated with the parameter, and
- ceases when variability is caused or affected by other processes, moving the station, or adjusting the recording zero height of the station's reduced level.

Without stationarity, a data record cannot be analysed for changes over time (such as channel degradation, or climate change). While the accuracy of collection processes may change, it is critical that the methods and instruments used to collect water level record remain without bias over the lifetime of the record.

Because the methods of collecting continuous environmental data do change over time, an external reference should always be used against which the continuous data can be checked. In the case of water level, this is a staff gauge that is tied to a constant vertical datum, usually maintained by benchmarks.

1.4 Practical Controls

1.4.1 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.

1.4.2 Safety

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

1.4.3 Hazard Review

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

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

1.4.4 Different Water Environments

The following special features of different water environments shall be considered:

- rivers have highly variable flows (viz. floods)
  Note: Extra care should be given to ensuring the stability and security of monitoring equipment.
- stratification
  Note: Consider the sensor location in terms of both the depths of sampling when lakes and bores stratify, and the influence of any saltwater-freshwater interface.
- tidal influence
  Note: Coastal and estuarine waters may vary in salinity and water quality according to the tidal influence.
- groundwater aeration
  Note: Special measuring techniques are required for groundwaters to avoid errors caused by surface aeration within a well.

1.5 River Stations

1.5.1 Selecting a Site

A number of factors need to be considered when selecting a site, particularly if flow is also to be measured. Hydraulic properties should be carefully considered along with operational aspects such as how the site will be constructed and maintained.

1.5.2 Site Factors

1.5.2.1 Access and Legal Requirements

The following requirements shall be considered:

- safe access to the site over the full anticipated range of measurement
- the ability to position machinery and materials during construction
- safe access to the river's edge
  Note: Safe access is required for reading staff gauges and to carry out flow measurements.
- a long-term access agreement
  Note: Establish an agreement with any landowners whose land must be crossed to gain access to the site.
- environmental effects, and
- resource consent requirements.

1.5.2.2 Hydraulic Properties

The following hydraulic properties of the river reach shall be considered:

- the location of a suitable control
  Note: If flow is to be derived from water level. a suitable control in the river reach is required. For more information, see Section 2: 'Controls'.
- the availability of a section without significant turbulence
- whether sedimentation will occur around an intake or sensor
- the possibility of backwater effects, and
  Note: For more information, see Section 2: 'Controls'.
- the likelihood of degradation or aggradation
  Note: To the extent where water level cannot be measured.

If flow is to be measured, there shall be a suitable gauging reach without any inflows or outflows affecting results.

Note: This could result from tributary inflow, losses to groundwater, or water take.

1.5.2.3 Installation

The selection of a suitable stilling well location or sensor site shall consider the following factors:

- public safety and site security
- constructability and durability
  Note: Pay particular attention to protection from flood damage.
- a solid structure on which to build a stilling well or mount a sensor
- maintenance of the datum, for example:
  - the installation of suitable benchmarks, and
  - the possibility of building suitable reference gauges.
    For example, external staff gauge, or similar.
- an adequate power supply
  For example, solar, mains or other power sources.
- adequate communication for telemetry, and
- the ability to deploy a sensor or intake that will cover the full range of levels.

Note: This should ensure the largest possible flood level will be measured, as well as any possible low flow level. Ensure you have included a generous allowance for extra-large floods and future degradation of the river bed.

Note: The above considerations may result in a trade-off between accuracy and cost.

1.6 Lake Level/Reservoir Stations

Recording the water level of a lake may only be required for knowledge of the storage within the lake (as with a reservoir situation), but more significantly these data can provide a record of lake inflow and, for an uncontrolled lake, outflow.

Operating a lake or reservoir water level recorder properly requires consideration of wind effects, seiche and rating curve uncertainties.

If an unregulated lake has a stable threshold across its outlet, the outflow can be gauged and rated against lake level.

1.6.1 Site Factors

1.6.1.1 Access and Legal Requirements

The following requirements shall be considered:

- safe access to the site over the anticipated range of measurement
- the ability to position machinery and materials during construction
- safe access to the lake's or reservoir's edge
  Note: Safe access is required for reading staff gauges and to carry out flow measurements.
- a long-term access agreement
  Note: Establish an agreement with any landowners whose land must be crossed to gain access to the site.
- environmental effects, and
- resource consent requirements.

1.6.1.2 Hydraulic Properties

The following specific lake properties shall be considered:

- When outflow is required, the site should be located near to the outlet, and away from any drawdown.
- The sensitivity of the stage-flow relationship will depend upon the section control at the outlet, and possibly on the channel control downstream.
  Note: In alluvial formations, lake outlets tend to be shallow and wide, and hence insensitive. Weed growth can also be an issue at lake outlets. For more information, see Section 2: 'Controls'.
- Locations should be chosen that are sheltered from waves.
  Note: This avoids surging at the sensor, erosion, dampness and physical damage. In reservoirs, waves can cause an unmeasured loss of water over a dam that may, at times, be significant.
- How to get an intake or sensor to record the lowest possible level.
  Note: Often lakes have shallow edges and long intakes or sensor cables may be required.

1.6.1.3 Installation

Look for a suitable stilling well location or sensor site. Aspects to be considered shall include, for example:

- public safety and site security
- constructability and durability
  Note: In particular, consider protection from flood or wave damage.
- the substrate for building a stilling well on, or to mount a sensor
  Note: The substrate needs to be solid.
- how the datum will be maintained, for example:
  - Can suitable permanent benchmarks be installed?
  - Is it possible to build suitable reference gauges?
    For example, an external staff gauge or similar.
- an adequate power supply from solar, mains or other power sources
- adequate communication for telemetry
- ability to deploy a sensor or intake that will cover the full range of levels, and
- navigation issues for watercraft that may result from the installation.

1.7 Groundwater Stations

1.7.1 Selecting a Site

Monitoring groundwater levels usually requires the installation of underground sensing equipment. Often the water level to be monitored is in a narrow bore casing, often some distance below the ground.

Often there will be no choice on the location at which to monitor groundwater levels; for example, where accessing an existing bore.

For new bores, the following shall be considered:

- a location that is likely to be representative of the groundwater level of the aquifer being monitored, and
- the proximity of abstraction or reinjection wells or localised surface discharge that may affect readings.

1.7.2 Site Factors

1.7.2.1 Access and Legal Requirements

The following requirements shall also be considered:

- safe access to the site over the full anticipated range of measurement
- the ability to position machinery and materials during construction
- safe access to the station
  Note: Safe access is required for reading staff gauges and to carry out flow measurements.
- a long-term access agreement
  Note: Establish an agreement with any landowners whose land must be crossed to gain access to the site.
- environmental effects, and
- resource consent requirements.

1.7.2.2 Installation

Refer to NZS 4411:2001 *Environmental Standard for Drilling of Soil and Rock*, or any subsequent Standards.

The following factors shall be considered when installing groundwater level monitoring stations:

- constructability and durability
  Note: In particular, consider protection from well head damage.
- the full range of groundwater movement (including artesian)
  Note: Is the sensor suitable to measure this range to the desired accuracy?
- the height of the mounting
  Note: This is so the artesian head can be measured.
- construction of the bore head to allow equipment access
  Note: Allow for an external reference depth to be taken (plumb bob or similar, or pressure fitting).Where possible, install a dipper tubing to allow manual measurements, particularly if the well is equiped with a pump. This will ensure long-term data gathering without interference with the pump hose and cables.
- how level referenced to a datum will be maintained; for example:
  - Can you install suitable permanent benchmarks?
  - Is it possible to build suitable reference gauges? (external staff gauge or similar)
- adequate power supply from solar, mains or other power sources
- adequate communication for telemetry
- climatic factors such as freezing
- the ability to deploy a sensor or intake that will cover the full range of levels, and
- public safety and site security.

1.7.2.3 Bore Considerations

Consider the following aspects if a bore is being constructed for the purpose of monitoring water level:

- The bore/well is suitably constructed.
  Note: Refer to the reference above under 'Installation fitting'.
- Is the diameter of the bore sufficient for the type of sensor to be used?
- The bore head allows equipment access.
  Note: Allow for an independent reference depth to be taken (such as a dipper or pressure fitting).
- Is there sufficient access to the water table?
  Note: A straight pipe at least 30 mm diameter leading from the top of the bore casing to below the water table must be specified.
- Will the bore cover the full range of water levels expected?
  Note: Including artesian levels and that it is deep enough to allow for siltation.
- Avoid the screening of multiple intervals if possible as it can potentially enable the connection between otherwise separate aquifers.

1.7.2.4 Required Metadata

Where practicable, the following metadata shall be recorded:

- location of the selected site shall be recorded using GPS coordinates and WGS84 datum
- location and reduced level of the bore components
- photographs
- relevant water extraction data
- a geological well log that also records the following:
  - the driller's name, date and method
  - screening type and depth
  - depths, type and diameter(s) of casings
  - hydraulic properties at the time of construction
    For example, transmissivity and storativity.
- and well use.
  For example, production or monitoring.

1.8 Sea Level Stations

The type of sea level gauge will often be determined by what can be installed. Although a stilling well with a float and counterweight-driven encoder is perhaps the most reliable and accurate, the dynamics of a site will often make this option untenable. In addition to the float-operated encoder, the more usual choices of gauge include radar, immersed pressure transducer, and dry transducer using a gas-bubbler system.

Note: Of these, the gas-bubbler is the most versatile in where it can be placed, followed by the immersed pressure transducer.

1.8.1 Site Factors

1.8.1.1 Location

Site positioning, where practicable, shall consider the following:

- environmental effects

  Note: Sea level measurements should ideally be accompanied by observations of atmospheric pressure and wind, which are of direct relevance to sea level analysis. Consider whether and how these variables will be monitored when selecting the site's location.
- resource consent requirements
- supplementary measurements
- protection from waves

  Note: Large waves carry an enormous amount of energy, and so the site should be protected from waves as much as possible.
- tidal range attenuation, and

  Note: When measuring open sea level, there must be no attenuation of the tidal range.

  Note: If the sea level gauge is situated inside a harbour, and the harbour mouth is small in relation to the harbour size, then the sea level recorded inside the harbour may be attenuated. This occurs because the harbour mean water level lags behind the tide level outside the harbour. The greatest lag occurs at about half-tide or just before, and is usually indicated by a visible current in the harbour mouth. If this current is > 0.1 m/s (approximately), then the harbour is probably not suitable for a sea level gauge.
- tidal dynamics.

  Note: When measuring in a harbour consider the tidal dynamics.

  Note: If silting and harbour changes occur, consider if these give a false impression of changing tide levels. A small deep, wide-mouthed harbour without a river flowing into it should be a good option.

1.8.1.2 Access

Site access shall consider the following:

- site access
  Note: Site access shall be safe when site visits are likely.
- access agreement, and
  Note: Establish an agreement with any landowners whose land must be crossed to gain access to the site.
- sensors are to be installed significantly below lowest spring tide level.
  Note: However, you will need to access the sensor safely in the majority of sea conditions.

1.8.1.3 Installation

Site equipment installation shall consider:

- a solid structure on which to mount both sensors and logger housing for the gauge
  Note: Where relevant, the type of rock should be considered. If it is easily weathered then it will not be suitable in the long term, while hard rock provides a much more secure substrate.
  Note: Rock crevices in which to install sensors (in the case of pressure transducers and gas bubblers) give some protection, but they also magnify surging and are not desirable in this respect.
- whether the sensor or stilling-well intake covers the full range of levels; that is:
  - the greatest tidal range at the location
  - the extra rise or fall due to barometric pressure
    Note: This could be as much as ± 800 mm.
  - how large the wave action is, and
    Note: Ensure the sensor is not exposed during large wave troughs at spring-low tides.
  - tsunami effects in terms of level, recording interval and instrument range.
- the instrument housing is above the maximum levels expected from wave run-up, storm surge, or tsunami level.
- sufficient sunlight for solar charging, or mains power source
- adequate communication for telemetry
- navigation issues for watercraft as a result of piles driven
- public safety, and
- site security and the potential for vandalism.

1.8.1.4 Other Considerations

Other aspects to consider that may affect sea level measurement include:

- instrument selection
  For example, radar, bubblers, stilling wells and pressure transducers.
- the effect of salt incrustation and corrosion
  For example, on electric plumb bobs, floats and float tape.
- density of seawater corrections for bubblers and pressure transducers
  Note: This correction is slight, but becomes significant if high tidal ranges exist in that location.
- gas-bubblers that have an outlet bell
  Note: Bubbling gas systems are unable to measure sudden rates of rise, and require the use of a suitable outlet 'bell' to counteract the effect of waves.
- the use of sacrificial anodes, and
- bio-fouling.

1.8.1.5 Datum

Site datum is crucial at sea level stations and shall be maintained by:

- installing suitable benchmarks, and
- where practicable, installing a reference gauge (staff gauge or similar).

2 Controls

2.1.1 In this Section

This section contains information on the requirements for controls at a site. The control is the physical properties of a channel, natural and artificial, that determine the relationship between stage height and discharge at a location in the channel.

Section 2 should be read in conjunction with NEMS *Rating Curves*.

When selecting a site, the channel's physical characteristics (at the gauge location and downstream of the gauge) shall be used to assess the suitability of the site as a control. These characteristics are:

- stability, and
- sensitivity.

Note: To achieve the Standard, controls need to be considered in order to minimise uncertainty. The nature, configuration, and vegetal cover of the streambed and banks influence the stability and sensitivity, which in turn affects the relationship between discharge and stage.

The sensitivity of the site's control has a large effect on discharge derivation, especially at low flows. For more information, see section 2.3: 'Sensitivity'.

2.2 Stability

2.2.1 Stable Features

Where practicable, one or more of the following features that are relatively resistant to erosion shall be present as a control:

- exposed bedrock
- armoured rapids
- sharp bends
- waterfalls
- a constriction in the channel between non-erodible banks
- large boulders (which are unlikely to move), and/or
- man-made substitute; for example, a weir, grade control or bridge.

Note: Many of these features provide a downstream steepening of the slope of the water surface, which suggests that the feature is relatively resistant to erosion. These features may be considered permanent or semi-permanent. Unless a control is composed entirely of bedrock, its stability is extremely difficult to determine visually. Even though a control is stable, it may be altered by (say) flood debris becoming caught, such as on bridge pier. This may alter the rating, not just at the time of the flood, but over a period afterwards as gravel builds up behind the obstructions.

With a stable control, a station's rating may hold for a number of years, but an unstable one may alter a rating numerous times per year.

2.2.2 Unstable Features

Where practicable, the following features shall be avoided:

- diverging reaches
- sand bars
- gravel bars, and
- dunes.

Note: Bed changes that are caused by high velocities can alter controls. The finer the material, the more likely it is to shift. Silt, sand and fine gravel move easily during floods, and may even do so in periods of moderate to low flows. Dunes of fine material indicate active bed material movement. In very active beds, aggradation may occur during lower flows and be followed by a short period of degradation during a flood.

2.2.3 Vegetal Growth

Where practicable, a control that is likely to be affected by vegetal growth on the beds and banks shall be avoided, or its effects mitigated by weed control measures.

Note: Vegetal growth on the bed and banks can cause gradual and usually seasonal rating changes. The normal remedy is either to visit frequently and clear weed before the change *becomes significant, or to frequently file rating changes that merge over long periods. Neither tends to be satisfactory, so reaches with significant weed are best avoided. Algal growth on weirs can cause small but significant rating changes; frequent cleaning with a brush is the usual remedy.*

2.2.4 Human Interference

Where practicable, a control that is likely to be affected by human interference shall be avoided.

Note: River works, ranging from major earthworks for bridge construction or river protection, down to minor gravel extraction or even the use of a ford can affect a section or channel sufficiently to alter ratings. Children's summer pastimes can often include building weirs to enhance a swimming hole; having a site in such a locality can be a problem.

2.3 Sensitivity

The stage height measured at the recorder should be sensitive to changes in discharge in the river. High sensitivity improves resolution of the stage discharge rating, thus improving accuracy of the flow record.

The shape of a control's cross-section governs sensitivity. This term can be explained with reference to a simple V-notch weir. A very shallow angled V-notch (almost flat) would provide a small change in stage height for a considerable change in flow and would be considered insensitive. A more acute angled V-notch (say 90°) would give a greater change in stage height for the same change in flow and would thus be more sensitive. Similarly a narrow cross-section in a natural river control provides greater sensitivity than a wide shallow cross section. The degree of sensitivity of the control(s) is indicated by the slope and shape of the rating curve, as depicted in Figure 2.

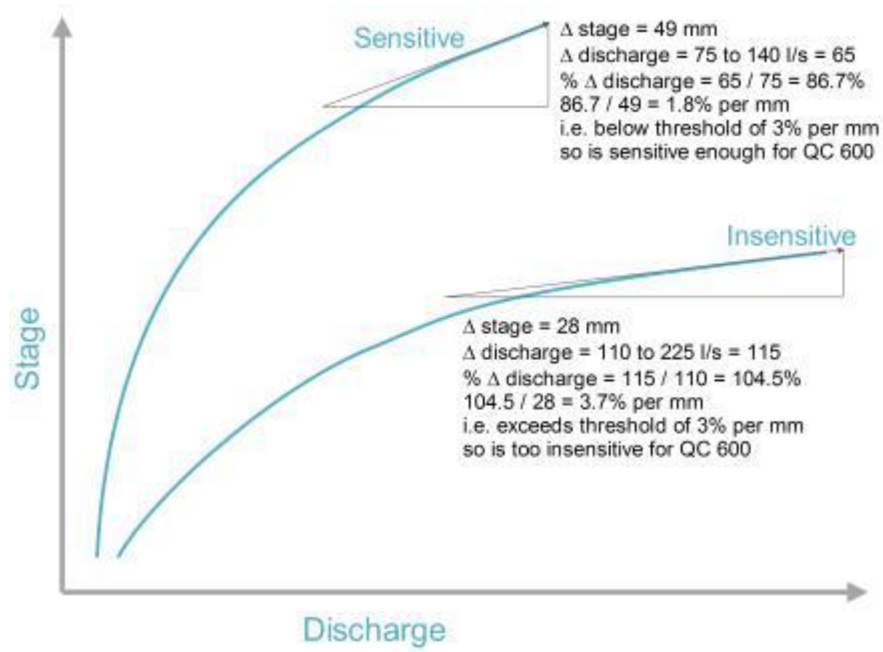


Figure 2 – Rating shapes for sensitive and insensitive controls & stage–discharge rating curves

Note: Sensitivity is usually considered during site selection, and further assessed during station design.

Refer to the Rating NEMS document for further explanation of the sensitivity of the Rating Curve.

2.4 Natural and Artificial Controls

2.4.1 Natural Controls

Satisfactory natural controls are often difficult to find because of topography, geology, and the range and frequency of flows. For instance, gorges cut through bedrock invariably provide better control sites than riverbeds on alluvial plains.

2.4.2 Artificial Controls

Purpose-built artificial controls can often provide a stable rating, albeit at some cost in construction. They can be classified as either:

- pre-calibrated structures, or
- bed controls.

For more detailed information, see NEMS *Rating Curves*.

Pre-calibrated structures are weirs or flumes which, when built accurately to standard designs, have a mathematically derived rating which may or may not hold true in practice, depending on a range of factors including:

- approach velocities
- exit conditions
- flood deposited debris
- sediment load and deposition, and
- weed and algae growth.

Where practicable, an existing natural or artificial control can be altered to improve its sensitivity or stability. The means of doing this will vary according to the site and other factors.

Note: Culvert pipes can provide a useful control if kept clean, but are prone to blockage, and because of this, the rating will vary.

2.4.3 Siting Artificial Controls

Siting a structure requires careful consideration and a balancing of conflicting requirements. The structure should:

- present a minimum obstruction to the flow for:
  - stability
  - passage of debris
  - sediment
  - fish passage
  - avoiding erosion and scouring downstream, and yet
  - give a sensitive rating, and
- have sufficient fall between the upstream water level and the tail water.

Note: Sufficient fall is required to ensure the structure continues to operate as a control. If the structure is 'drowned out', a different feature downstream may start acting as the control. However, the fall should be minimised to:

- *prevent washout by the force of the flow, and*
- *to minimise the tendency for a deep scour hole to develop downstream.*

2.5 Backwater Effects

Even if a suitable control exists for a site, downstream effects can sometimes overwhelm that control and affect the rating. Examples of this are:

- tidal levels moving upstream towards a site
- a large tributary inflow from a stream entering just downstream of the recorder, and
- civil works in the riverbed occurring downstream.

Note: A stream or river that has a low gradient is especially vulnerable to this problem.

As a general guide, when a rapid exists downstream of the recorder, a backwater effect should not propagate up through this, provided the rapid is not drowned out; for example, by flood or the downstream effect.

Knowledge of backwater effects is important when drawing rating curves and selecting a site. If a backwater effect does occur, the only possible way to keep continuous flow records may be to utilise an instrument that measures river velocity or river slope continuously.

3 Deployment

Once a site has been selected, the design and construction of the installation type and deployment of equipment follows.

3.1.1 In this Section

This section contains information on:

- acceptable installation types and components
- deployment of equipment and instruments to measure water level, and
- basic accuracy requirements.

It primarily covers two factors that influence deployment. These are:

- the site-related variables that determine the type and installation of equipment, and
- the degree to which the equipment is:
  - fit for purpose, and
  - operated to minimise errors and maximise accuracy.

3.1.2 Functional Requirement

All equipment used to measure water level must be deployed and maintained to ensure:

- stationarity of record
- appropriate resolution of time and recorded stage, and
- the overall accuracy of water level data.

3.2 Station Planning

Planning a station requires consideration of a number of factors that can affect the quality, availability and long-term usefulness of the data that are collected.

These factors are:

- site access
- materials
- design, and
- construction method.

Note: Where practicable any construction work shall be preceded by a site survey.

3.2.1 Site Access

Safe and convenient access to recording stations is crucial for data collection.

Permission shall be obtained for access over and installation of equipment on land, whether private, local authority, corporate or government owned.

Construction work on a site shall begin with work on the access itself, including foot tracks and steps to the work site.

3.2.2 Site Survey

It may be useful to precede construction work with a site survey for the purposes of design. At the least, a Station History Form should be filled out for the site as soon as records begin, updated following changes, and checked during the annual site inspection.

3.2.3 Materials

All materials used in installations shall be of adequate strength, thickness and durability for the purpose, and conform to the New Zealand Building Code and Regulations.

Note: Remember that many temporary works can become permanent, or be re-used for another purpose.

Generally:

- timber should be treated against rot to an appropriate specification (or better)
- exposed and structural steelwork should be hot-dip galvanised or stainless steel
- wire ropes shall be galvanised, and
- bolts and nuts shall be galvanised or made of stainless steel.

3.2.4 Design

The design, deployment and installation of systems shall comply with the relevant clauses of the:

- New Zealand Building Code and Regulations, and
- Health and Safety Act and Regulations.

3.2.4.1 Signage

Where relevant, signage shall be installed to warn of any hazards.

A sign that briefly explains who operates the station, contact details and its purpose, is recommended.

3.2.4.2 Security

Where relevant, security gates or systems shall be installed for the safety of anyone who visits the vicinity, and to protect the station from vandalism. Protect installations where practicable from interference and damage, including deterioration resulting from the presence of flora and fauna.

3.2.5 Construction Method

3.2.5.1 Rivers and Lakes

Where used, concrete footings shall be built in accordance with the New Zealand Building Code to ensure the stability of hydrological structures.

Generally, recorder stilling wells require concrete foundations to:

- key them to bedrock, or
- to form a broad and substantial footing in alluvium to prevent subsidence or movement.

Generally, weirs require deep cut-off walls to prevent:

- leakage, and
- overturning of the structure.

Cleaning and preparation of the foundation is essential.

Note: Rock bolts can be a useful method of fastening equipment to bedrock, large rocks or concrete structures. These can range from substantial bolts grouted into holes drilled in bedrock by a compressor-powered drill, to masonry fasteners driven into holes in concrete.

3.2.5.2 Groundwater

Generally groundwater sites are mounted on a sturdy steel bore pipe. If this is not the case, ensure that the datum will remain stable and structural strength is adequate by using suitable construction methods and materials. Allow for easy access to recording equipment.

3.2.5.3 Sea Level

Because of the coastal location of sea level sites, the following should be considered:

- the use of Grade 316 stainless steel components
- time construction around the low cycle of a 'king' tide
- the use of an epoxy that sets underwater, and
- the use of battery-powered tools when working around salt water.

3.3 Station Documentation

3.3.1 Site Identifier Allocation

All stations shall be allocated a unique identifier such as a site number or name.

Note: It is the responsibility of the recording agency to catalogue and register the site ID.

The index to hydrological recording sites in New Zealand can be used to allocate site identifiers.

Note: New Zealand has a system of water level recording station numbers based on river numbers. NIWA, some regional and district councils, and various other companies use this system. Stations are listed in a site index publication (Refer to Walter, K., (200). Index to hydrological recording sites in New Zealand *(NIWA Technical Report 73).*

3.3.2 Station History

3.3.2.1 Station History Record

As a minimum, a station history record shall be established for all water level stations as the main part of their metadata and be:

- filled out for the site as soon as records begin
- checked and updated during the periodic site surveys
- updated whenever there are changes to site parameters
- updated whenever there are changes to what is recorded on the form, and

Any updates of an existing record should be in the form of an additional record rather than an overwrite. This will ensure that the station history is maintained.

Note: The Station History Form provides a record of, for example, installations, equipment types, data collected, benchmarks and levels, location, the sites initial purpose (for example, low flow and flood) ownership of land and history for each station. For more information, see Annex C – Hydrological Station History Form'.

3.4 Reference Levels

Section 3.4 should be read in conjunction with the NEMS Code of Practice *Site Surveys.*

3.4.1 Vertical Datum

Stage height data shall be referenced to a consistent vertical datum throughout the life of the installation. This datum should be an established survey datum but may be assumed if impractical to survey this in.

3.4.2 Benchmarks

To ensure that the stations can be checked for movement and re-established (if moved or damaged), the datum of the measuring equipment shall:

- be related to a set of permanent benchmarks, or
- a particular datum above mean sea level.

A minimum of three benchmarks shall be installed (or located, if in the vicinity) and the reduced levels of the following shall be measured and recorded in the station history record and metadata.

The levels at a site that should be related to the known datum are the:

- staff gauge zero (for each staff gauge)
- internal plumb bob zero
- reference point for distance meters
- beam source and recording zero for radar and ultrasonic sensors
- the invert of all intake pipes, bubbler orifice or submersible transducer elements
- the underside of recorder house floor/stilling well ceiling,
- cross- and long-sections, and
- stage for zero flow.
  Note: That is, the lowest point of the control or reach below which the river stops flowing.

Where practicable, benchmarks shall be stainless steel pins anchored in an immovable firm concrete or rock base.

3.4.3 Reference Gauges

The reference gauge is the means by which an instrument is referenced to the recording zero. At least one reference gauge shall be installed at each site.

The reference gauge shall be:

- referenced to benchmarks
- of robust and stable construction
- readable to within 1 mm, and
- cover the full range of anticipated stage.

3.5 Primary Reference

3.5.1 Local Datum

Any water level measurement shall be referenced using a local datum that is established on site using at least three benchmarks (BMs).

Note: Three benchmarks are essential to resolve the cause of any discrepancy in levels that may occur over time, by the movement of one or more parts of the installation.

A survey grade GPS can be used to establish the approximate level of a primary benchmark. However, the vertical accuracy is unlikely to be adequate for levelling between benchmarks and staff gauge(s).

All components shall be levelled in from the primary datum, using traditional survey methods.

3.5.2 Assumed Datum

When establishing an assumed datum, an assumed level shall be conferred, e.g. 100.000 metres to the most immovable of the site's benchmarks, and level in the other benchmarks and installations to this.

100.000 metres is a useful assumed level to choose unless the site is at a comparable elevation above mean sea level (MSL), in which case it may at some time be confused with MSL datum, and thus an alternative value should be used.

Note: An assumed datum may be used instead of one established to a proper surveyed datum, as in many cases stage height is measured only to determine flow and the level itself is not the information required. A common exception to this is the case of reservoirs or groundwater stations where levels may be well defined in terms of a local or regional datum.

3.5.3 Adopting a Recording Zero

The recording zero of a station shall:

- be placed below the lowest level to which the water surface will fall, and
- take into account possible degradation at the site that may lower the water level below the recording zero.

When adopting the recording zero, choose one that is:

- a sensible number where possible, e.g. 100.000 metres, and
- below the anticipated minimum water level.

Note: An important factor is that the water level will not be likely to fall to negative values over the life of the station.

3.5.4 Equipment for Reference and Measuring

3.5.4.1 Basic Requirements for Collecting Water Level Data

The collection of water level data, either manually or automatically, requires a range of instruments, or components, to be deployed at a site.

For water level data to be useful, a permanent datum shall be maintained and specified accuracy limits shall be met. These details are documented in the station history file and metadata for individual sites.

3.5.4.2 Primary Reference Gauges

The primary reference gauge and the measured water levels are used to determine the stage height. The following are examples of primary reference gauges:

- staff gauge
- sloping staff gauge
- electric plumb bob
- electronic water level indicators
  For example, a groundwater probe.

3.5.4.3 Equipment Selection

Any of the following devices may be used to measure water level:

- shaft encoder
- pressure transducer
- gas purge sensor
- acoustic transceiver
- radar

When establishing a station, the sensing device and data logger shall, where practicable, be selected to meet:

- the accuracies and resolution required by this Standard
- the full range required
- any present and future (anticipated) data needs, and
- the time interval required to measure the fluctuations occurring at the station.

3.6 Staff Gauges

A staff gauge:

- is a graduated staff that is mounted either vertically or inclined, and
- provides an inexpensive, simple, robust and absolute method of determining water level.

At a site equipped with an automatic recorder, the staff gauge provides an independent check on recorded water levels.

Generally, with a stilling well, this external staff gauge is an essential check on whether the intake pipe is blocked by silt.

Generally, with a transducer or gas bubbler orifice directly in the river, the staff gauge is the only easy direct check on its performance.

Where the range of water levels exceeds the capacity of a single vertical gauge, other gauges shall be installed, as much as practicable in line with the recorder cross-section.

The scales on a series of stepped staff gauges should overlap by not less than 15 cm.

3.6.1 Usage

A staff gauge shall only be used for spot measurements and shall include an estimate of uncertainty.

Note: It can be difficult to obtain readings in the field with a true resolution better than ± 3 mm. Floods cause surges and standing waves which can introduce a bias.

3.6.2 Vertical Staff

The most common form of gauge is the vertical staff. It normally consists of a series of 1-metre-long plastic plates that are graduated at 10 mm and 1 dm (100 mm) intervals and fixed to a secure mount; for example, to a treated timber board or concrete wall.

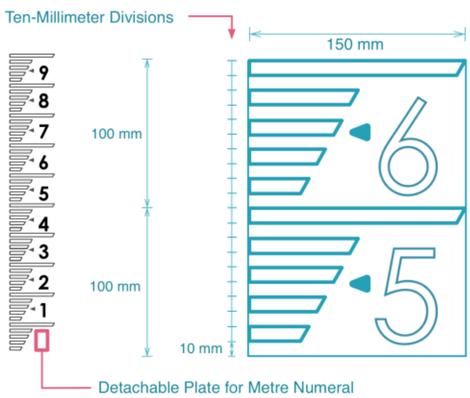


Figure 3 – Staff gauge plates

Illustration: Chris Heath.

3.6.3 Sloping Staff

Sloping staff gauges can be used where:

- there are no suitable anchorages for vertical staff gauges
- vertical staff gauges are too prone to be damaged by high velocities and debris, or
- a better resolution is required.

Note: A sloping gauge will achieve a better resolution than a vertical staff gauge because distance up the slope is greater than corresponding vertical height.

Gauges, e.g. a plank or concrete pad (Figure 4), shall be set at a known angle.
30˚ is recommended, as staff plates exist for this angle.

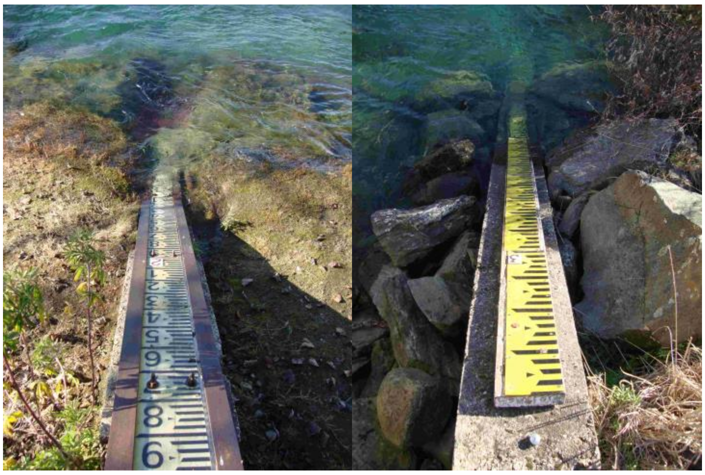


Figure 4 – 30° Sloping staff gauge
Photographer: Evan Baddock.

If standard vertical plates are used at 30˚, the values read off the sloping staff gauge can be halved to obtain the actual water level.

Note: At 30˚, the slope distance is twice the vertical height.

3.6.4 Installation

Staff gauges shall be installed so that:

- the zero of each gauge is at the recording zero
  Note: The reduced level (RL) level should be below the lowest possible water level, given that the bed may degrade significantly over the life of the station.
- there is overlap between the top of the one gauge and the bottom of the next
- the staff gauge mounts are immovable and not prone to settling
- the method of fastening the timber to the mount is positive
  Note: Friction should not be relied on to prevent slippage.
- the water level is easily and accurately read at any time
- the gauges are protected from high velocities, but
  - if high velocities are unavoidable, keep the gauges short and have more of them, or glue plates to a concrete face.
- the gauges are on the same river cross-section as the intake pipes or sensor orifice.
  Note: Especially with low flow gauges, staff gauges should be as close to the intake pipe or orifice as possible.

3.7 Electric Plumb Bob

3.7.1 Introduction

The electric plumb bob (EPB) is a non-recording gauge that is normally used to measure the water level in a stilling well.

Note: It gives an independent check on the internal water level and therefore provides a check on the recorder.

It consists of a plumb bob connected to a graduated steel tape, wound on a brass reel (Figure 5). This forms part of a low voltage electrical circuit that is completed when the plumb bob is wound down to, and touches, the water surface. The contact is registered on a milliammeter, or buzzer/light, and thus the plumb bob can be raised or lowered so that it is only just touching the water surface, and a reading taken from the tape graduations.

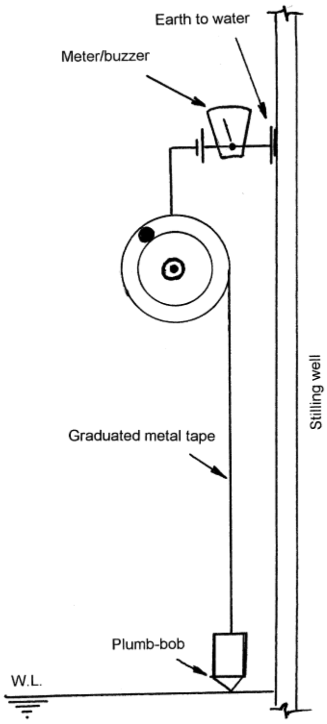


Figure 5 – Electric plumb bob schematic diagram

Source: ISO 4375 (2008) Hydrometry – Water Level Measuring Devices.

In groundwater applications, electronic water level indicators are used. These consist of a spool of dual conductor wire with a probe attached to the end as an indicator. When the probe comes in contact with the water, the circuit is closed and the meter light and/or buzzer will signal contact. Measurements should be made and recorded to the nearest 10mm.

For details on the installation and set-up of an EPB, see Annex B – Procedures'.

3.7.2 Usage

An EPB shall be used to provide an accurate indication of water level in situations where access and visibility are impaired; that is, within a stilling well or a borehole.

An EPB can provide acceptable accuracy when the distance to the water surface is of the order of tens of metres.

Note: EPBs may not work in waters of very low conductivity.

Due to their accuracy, EPBs are generally used as the primary reference check at stations where they are installed. Although they are the best check of the instruments in a stilling well, they are prone to the same intake silting. Each EPB reading should be paired with an external staff gauge reading to identify possible silting.

3.7.3 Mounting

EPBs shall be mounted in a manner that prevents vertical movement. Any vertical movement will shift the gauge zero with respect to the recording zero.

3.7.4 Precision

Fixed pointers shall be installed to ensure that readings can be taken to 1 mm precision.

3.7.5 Deployment

An EPB shall be installed at each stilling well site.

Note: Discrepancies between the recorder and the EPB will sometimes occur. For more information, see Annex B – Procedures'.

3.8 Calibrated Structures

The installation of a weir or flume can, in theory, enable flow measurements to be reduced to the simple measurement of stage, and the insertion of this value into the formula for that design.

The location of the water level recorder and staff gauge shall be at a distance away from the calibrated structure that is at least three times the maximum head to avoid any drawdown caused by flow over the crest.

The approach channel should be straight with a uniform cross-section and be free from obstructions (such as boulders).

Flow in the approach channel should be uniform and steady. The velocity distribution should approximate that found in long, smooth-sided and straight channels.

Note: Baffles and flow straighteners can be used to simulate normal velocity distributions, but their location with respect to the weir should be no closer than approximately 10 times the width of the nappe at maximum head.

Note: For more information on weirs and flumes, see the relevant section in the NEMS Rating Curves*.*

4 Sensing Devices, Wells and Recording Requirements

4.1.1 In this Section

This section contains information on devices that:

- have direct contact with the water, or
- take an indirect measurement of water level

It also provides information relevant to the selection and maintenance of stilling wells and recorder housings and instruments.

4.2 Direct Contact with Water

Devices that have direct contact with water include:

- shaft encoders
- pressure transducers, and
- gas purge sensors.

4.3 Indirect Measurement of Water Level

Devices that indirectly measure water level include:

- acoustic instruments with sound path in air
- acoustic instruments with sound path in water, and
- radar instruments.

Note: Each of these direct and indirect methods have differing accuracies, and in choosing a sensor, the appropriateness to the site must be considered. There are other sensing devices available; some of these don't meet the Standard. Price may also be a consideration.

4.4 Sensor Selection

Selecting a sensor can be complex; however, to assist in the correct sensor being selected, consideration should be given to:

- whether it is fit purpose, and
- compatibility.

4.4.1 Fit for Purpose

To be fit for purpose, the sensor shall cater for the following, where required:

- alignment with this Standard, and
- client requirements.

4.4.2 Compatibility

The sensor shall also:

- be easily interfaced with existing hardware, and
- have common industrial output protocols.

4.4.3 Site Characteristics

Every water level site is unique.

The maximum and minimum measuring range at the site shall be determined. This will ensure the sensor covers the full range and hence no loss of data results.

When selecting the appropriate sensor, the site characteristics shall be considered in conjunction with the following factors:

- seasonal conditions
- environmental conditions, and
- power budget assessment.

4.4.3.1 Seasonal Conditions

Examples of seasonal conditions that can influence or damage the sensor include:

- heat
- weed and algal blooms
- frost and ice
- recreational activity
- sediment flushes
- floods, and
- flood debris build up.

4.4.3.2 Environmental Conditions

Examples of environmental conditions that can influence the performance of the sensor include:

- wind
- waves
- bank stability
- movement of bed materials
- river works
- water turbulence, and
- migrating channels.

4.4.3.3 Power Budget

When used with a particular logger and telemetry system, the power budget and maximum demand shall be considered to cover mains power outages.

Items to consider include:

- low solar charge
  For example, during winter periods.
- temperature conditions at the site, and
  For example, below freezing-over periods.
- battery capacity.
  For example, will this sustain the power requirements through the worst conditions?

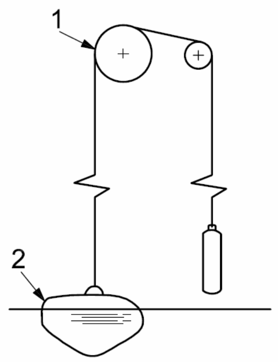
Note: Backup systems and equipment isolation (separate backup data-logger batteries) also need to be considered.

4.5 Shaft Encoders

A shaft encoder:

- is an electro-mechanical float and counterweight gauge
- consists of a pulley rotated by the float and counter-weight system
- converts pulley rotation to millimetres of rise and fall, and
- records the stage, or relative rise or fall from a start point.

Shaft encoders are precise measuring devices that usually have a resolution of ±1 mm, but with some models this can be ±0.1 mm.



Key: 1 driven pulley
2 float

Figure 6 – Float and counterweight configuration
Source: ISO 4375 (2008) Hydrometry – Water Level Measuring Devices.

Used on its own, a float gauge can provide a direct readout of stage height without requiring an external energy source. However, most encoders are now electronic, link to a separate data logger, and require constant power to operate. It provides almost uniform resolution throughout the range and good accuracy at low stage.

Note: A float gauge is a mechanical device and is therefore subject to errors from change in temperature, hysteresis and friction. It requires a stilling well, which can be expensive to construct and maintain.

4.6 Submersible Pressure Transducers

4.6.1.1 Theory

Pressure transducers convert the pressure acting on a sensing element into an electrical signal. The signal varies in proportion to the pressure.

The pressure transducer will measure the pressure head of the system but in most cases will report to an equivalent head of water. It is important to understand this relationship and the effects that it will have on given measuring situations. The relationship is:

$$h = P/(\rho . g)$$

where: P = pressure

g = gravitation constant, and

ρ = density.

The international standards used in deriving the equivalent head of water are:

$g = 9.80665$ m/sec^2

$\rho = 1000$ kg/m^3 derived at 4 °C

This relationship needs to be considered when comparing the pressure transducer against a body of water. In most situations the error involved is small and proportional to the head of water over the sensor.

Note: For groundwater systems and deep lakes, the ability to effectively validate a system is dependent on these factors, and especially the temperature of the water because this will determine the density.

For artesian groundwater systems, the temperature effect can be further influenced with exposure of inspection tubes to radiant heating. Purging the tube prior to inspection or direct comparison to another pressure reference is required in these systems.

When verifying the performance of the pressure transducer, a direct pressure comparison is preferable because this will check the sensor independent of gravity and density variations that are found with water measurements. The system can be validated against external references to monitor the overall site performance.

There are two main categories of pressure transducer used in the measurement of water level: submersible and gas purge.

4.6.1.2 Submersible Pressure Tranducers

Submersible pressure transducers are mounted directly in the water and can have vented (open to atmosphere) or non-vented cable to provide a gauge reading. They can be used in a range of applications from surface water and lakes to deep groundwater and can be used with well-head adaptors to measure artesian groundwater systems.

Note: Vent tubes must be kept clear or measurements will be affected by barometric changes. Non-vented transducers are available and have their advantages; however, measurements from these require compensation for barometric pressure. Even if barometric pressure is measured in conjunction with water level, compensation rarely produces results that meet the accuracy required of this Standard.

Submersible pressure transducers require a relatively simple installation, hence lower costs, due to no stilling well being required.

Note: It is not normally possible to set the sensor at the recording zero, so an offset is usually needed. It must be recorded in the logbook at the time of installation and applied to the record either in the logger or when processed. In any case, transducers must be checked frequently for drift; an offset or change in offset may subsequently be required.

4.7 Gas Purge Sensors

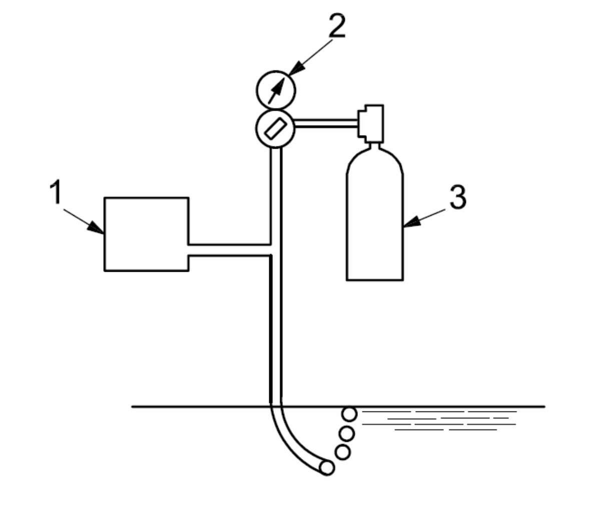
Gas purge sensors differ from a submersible pressure transducer by having the transducer located well above water level, normally within the recorder housing.

The transducer senses water level at an underwater orifice that is connected to the transducer by small diameter tubing. This in turn has a small feed of gas from a cylinder bubbling out through the orifice. The backpressure in the tubing is proportional to the water pressure over the orifice and hence the water level.

When measuring groundwater levels, there may not be sufficient space to install a pressure transducer, or the risks of not being able to retrieve it may be high. In this case, gas purge sensors are frequently used.

Note: In some situations there are considerable advantages in having only small diameter tubing exposed to the stream rather than an expensive transducer. There is, however, additional cost associated with the use of the gas purge system.

These systems must be installed correctly, with regard to manufacturer's instructions on bubble tube length, avoidance of dips in the bubble line, and a suitable orifice system that prevents under-reading in surging waters and will enable the measurement of a fast rate of rise or fall.



Key: 1 pressure sensor
2 regulator
3 compressed gas

Figure 7 – Gas purge system

Source: ISO 4375 (2008) Hydrometry – Water Level Measuring Devices.

4.7.1 Accuracy Requirement for Pressure Transducers

The accuracy requirement for water level measurement follows the USGS framework for sensor and site accuracy.

The sensor shall have an accuracy of ± 3mm or 0.2% of effective stage, whichever is greatest.

Note: This gives a high degree of accuracy at low levels with a proportional decrease over the sensor range.

Manufacturers state sensor accuracy in differing formats and can include linearity and temperature errors. The total error should be considered when selecting a pressure transducer.

Accuracy may be in terms of full-scale error (% FS), which states error as a percentage of maximum sensor range, or as a percentage of measured value, which gives a proportional error over sensor range.

For example, a sensor with a range of 10mH_2O and accuracy of 0.1% FS has an error of 10 mm over the entire 10-m range whereas a sensor of the same range and accuracy of 0.1% of value has an error of 10 mm at full range but only 5 mm at half range.

A sensor with a stated accuracy of 0.1% FS can be used if the calibration relationship is known and falls within the accuracy tolerance of ± 3 mm or 0.1% of effective stage; this can be requested on purchase or can be determined and scaled with a portable calibrator.

For sensors with an error greater than 0.1% FS then the range of the instrument must be selected to ensure that the error does not exceed 3 mm; that is, for a 0.2% FS sensor, the maximum range is 1.5 metres.

A calibration certificate showing the relationship of the sensor to a traceable reference shall be supplied on purchase detailing the sensor's accuracy

4.7.2 Installation and Commissioning

The most important component of installing a pressure transducer system is applying the correction to gauge zero. This requires an offset to be derived and applied to the raw signal on the data logger.

Note: The sensor output may require additional scaling to return the correct engineering units for the water level measurement; this is most important for voltage and milliamp outputs but can be important for digital signals as well.

Where possible the orifice or sensor mount should be surveyed to the datum to provide the offset, and monitored for stability over time.

Alternatively the sensor can be set to a suitable primary reference gauge. It is important to adequately record the offset information and ensure that the reference gauges are correctly aligned to recording zero.

4.8 Acoustic Instruments

Acoustic instruments offer a simple deployment method for measuring water bodies and reduce the need for complex and costly installations for mounting sensors directly into river systems.

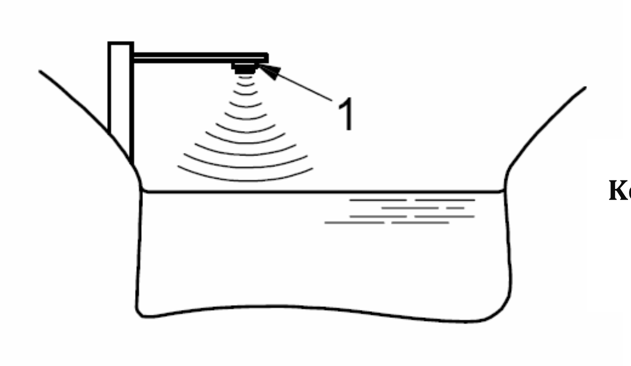
However, they generally have a lower accuracy standard than other methods and care should be taken when choosing a sensor to ensure the required level of accuracy is met for the purpose of the site.

4.8.1 Acoustic Transceiver – Sound Path in Air

The sound-path-in-air acoustic transceiver:

- consists of an acoustic transmitter/receiver
- measures the time elapsed between transmission of the pulse and reception of the echo from the water/air interface, and
- converts this time to distance, and
- is more accessible than a sound-path-in-water transceiver.

The sound-path-in-air acoustic transceiver's accuracy is typically ± 10 mm over the range.



Key: 1 transceiver mounted above flood levels

Figure 8 – Air path ultrasonic level sensing

Source: ISO 4375 (2008) Hydrometry – Water Level Measuring Devices.

To avoid contact with the water surface, but retain accuracy, the transceiver shall be mounted above the channel's maximum flood level, but as close as possible to the water level.

Either the air temperature shall be measured directly, or a reference bar shall be located at a known distance below the transducer.

Note: The velocity of sound in air is strongly proportional to temperature, and a technique for compensating for this effect is required.

The transceiver shall be mounted:

- offset from the side of the channel so it remains over an open water surface at all times, and
- so that the instrument is robust and unable to move.
  Note: This is to prevent vertical movement which will change the recording zero of the instrument.

Note: If mounted flush with the side of a channel, the acoustic beam will have difficulty focusing on the water surface. The temperature sensor only measures temperature in one place. Temperature gradients over the length of the ultrasonic beam give rise to errors.

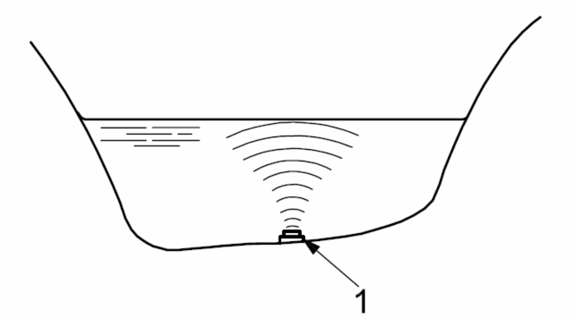
4.8.2 Acoustic Transceiver – Sound Path in Water

The sound-path-in-water acoustic transceiver:

- consists of an acoustic transmitter/receiver
- measures the time elapsed between transmission of the pulse and reception of the echo from the water/air interface, and
- converts this time to distance, and
- is less accessible than a sound-path-in-air transceiver.

Accuracies higher than the general standard of ± 3 mm or 0.2% of effective stage can also be achieved. An example specification would be:

Range: 0.3 m to 22 m, ±3.0mm accuracy, -40ºC to +80ºC operation



Key: 1 = transceiver

Figure 9 – Water path ultrasonic level sensing
Source: ISO 4375 (2008) Hydrometry – Water Level Measuring Devices.

4.8.3 Usage

The instrument operates without a stilling well.

The transceiver shall be:

- installed in a straight section of channel, avoiding any curves and abrupt changes in elevation
- mounted in a robust manner so the instrument is unable to move and is level, and
- mounted where the instrument can measure the full range of level and velocity.

Note: The velocity of sound in water is strongly proportional to temperature and a technique for compensating for this effect is required.

Either the water temperature shall be measured directly, or a reference bar shall be located at a known distance above the transceiver.

Note: Because the transceiver is fully submerged it:

- *does not intrude visually*
- *is less susceptible to vandalism, and*
- *experiences less temperature variation.*

Care shall be taken to ensure that there is no risk of reflection from channel edges at higher water levels.

The transducer is used as a transmitter and receiver. There is usually a minimum time after transmitting before receiving is possible. This results in a requirement for a minimum depth of water (refer to the manufacturer's specifications).

Note: The upwards-facing transducer is prone to sediment settling on it, particularly if it is placed on or near the bed in an attempt to overcome the minimum depth limitation.

4.9 Radar Instruments

4.9.1 Echo-Location

A downward-looking radar unit (Figure 8) is able to determine the relative position of a water surface. The value returned relates to the area covered by the beam.

4.9.1.1 Usage

An 'echolocation' instrument operates without a stilling well and has a typical absolute accuracy ± 3 mm for 15-m to 30-m range sensors.

4.9.1.2 Design and Deployment

When designing and deploying radar instruments:

- the 'echolocation' instrument shall be mounted in air where it is accessible for maintenance
- the mounting of the instrument must be robust and unable to move so as to ensure the datum of the instrument does not change
- the radar instrument must be level, and
- the radar may be mounted on an arm extending over the flow.

  Note: The arm shall be long enough to ensure that the conical beam does not strike channel walls. Alternately, it may be mounted on a bridge span beyond interference from abutments, piers and other structural features.

4.10 Stilling Wells

4.10.1 Usage

Stilling wells shall be used to:

- dampen the fluctuations present in open water
- protect the sensors, e.g. float and counterweight sensors, and
- provide, within the well, an accurate representation of the water level in the channel.

4.10.2 Stilling Well Design

Stilling wells are generally made either of spiral-welded pipe or standard rolled sections 1200 mm in length.

A steel recorder housing bolts to the flange of the top section.

The following diagram shows one design that consists of a number of sections, each section being 600 mm in diameter and 1200 mm in length.

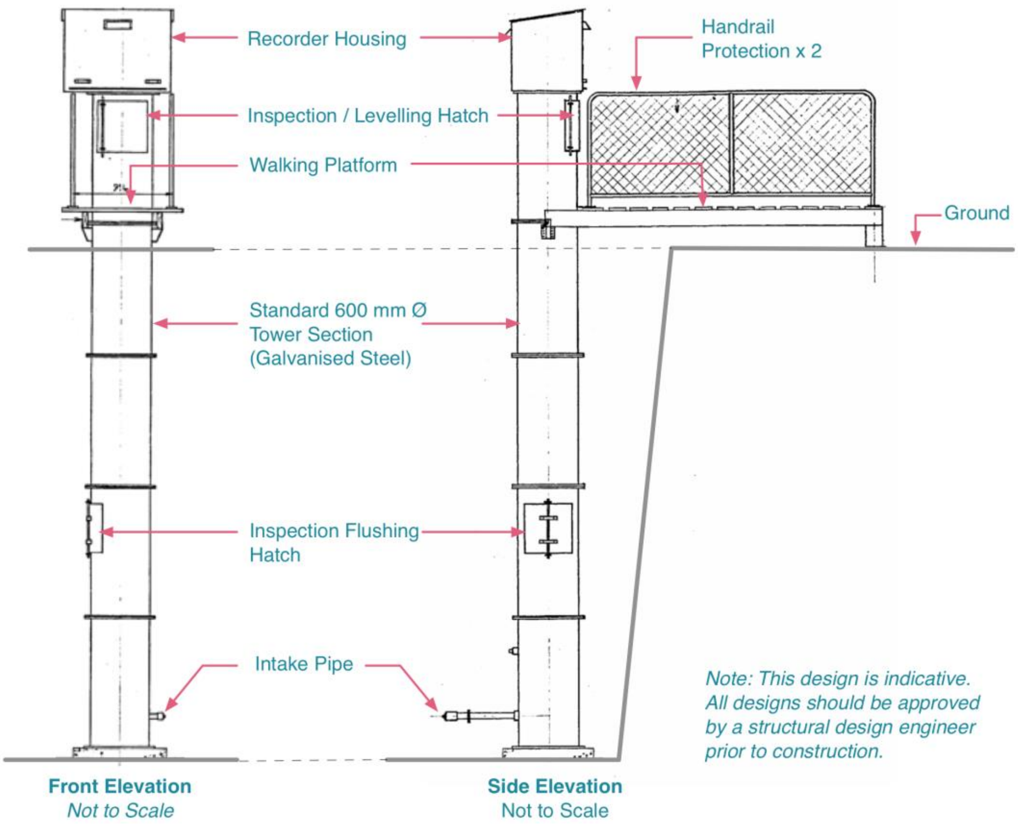


Figure 10 – Typical stilling well and housing setup

Source: NIWA Field Manual.

Note: Other designs and materials may be as good or better in certain situations. Alternatives include pipes of concrete, plastic (PVC), spiral-welded steel, fibreglass and corrugated culvert pipes.

4.10.3 Connection to Open Water

The well shall be connected to the lake or river by means of suitably sized intake pipes.

Where velocity past the river end of the intake is at times high (i.e. above 1.5 m/s) drawdown of the water level in the well may occur. To reduce this, a capped and perforated static tube shall be attached, oriented parallel to the direction of flow (± 10°).

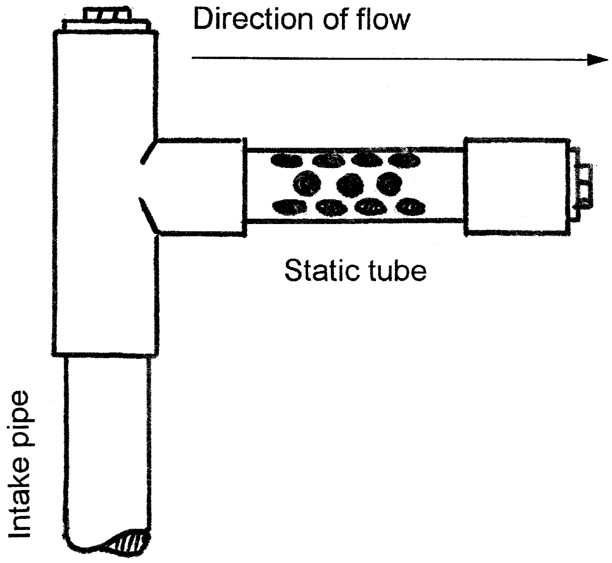


Figure 10 – Typical static tube setup
Source: NIWA Field Manual.

4.10.4 Cross-Sectional Area

The cross-sectional area of an intake pipe shall be large enough relative to the diameter of the well to follow rapid changes in the external water level without significant lag.

For more information, see Annex G – Intake Pipe Dimensions’.

4.10.5 Site Requirements

4.10.5.1 Intake Pipes

Intake pipes shall be laid:

- on firm material that will not subside, and
- at a constant gradient; normally horizontal.

The lowest intake pipe shall be at least 150 mm below the lowest anticipated water level (but considerably further if degradation of the bed is possible).

Note: This is a very important decision that may impact considerably on the usefulness of the structure over time.

The lower intake pipe shall be at least 300 mm and preferably 1 m above the bottom of the stilling well, to avoid blockage by sediment.

The intake pipes' diameters shall be large enough to keep lag within acceptable limits, but not overly large so that surging is not damped.

For more information, see Annex G – Intake Pipe Dimensions'.

Figure 11 – Example of intake and static pipe
Photographer: Evan Baddock.

4.10.5.2 Stilling Well Construction

The stilling well shall:

- be vertical within practicable limits
- not allow the float and counter-weight systems to come in contact with the walls
- have sufficient height and depth to allow the float to freely travel up and down the full range of water levels, and
- be firmly founded so that subsidence will not occur.
  Note: Foundations that sit directly on bedrock are preferable, otherwise a substantial concrete mass poured into hard alluvium is required.

All construction joints of the well and intake pipes shall be watertight.

Note: Watertight joints ensure that water can only enter and leave through the intake.

A means of access to the well and intakes for cleaning and other maintenance reasons shall be provided.

4.10.6 Silting Management

Sites with known sediment problems shall be carefully checked at each visit, and if there are any indications of a siltation problem, the stilling well must be flushed as soon as possible.

Note: Indications of a blocked or partially blocked stilling well are usually apparent on the recorded hydrograph. It may show up as uncharacteristically flat or stepped recessions, rounded peaks or a slow response to changes in external water levels.

For more information on flushing techniques for cleaning silt from stilling wells, and methods for checking the amount of silt in a stilling well or intake pipes, see Annex F – De-Silting Stilling Wells

’.

Figure 13 – Water level station showing multiple sections and housing
Photographer: Evan Baddock.

4.11 Recorder Housing

The recorder housing shall:

- be installed above maximum possible water level
- fully protect the equipment from:
  - all inclement weather
  - spray
  - condensation
  - insects
  - vermin, and
  - the general public
- provide sufficient room for:
  - equipment
  - field books
  - telemetry equipment (if applicable), and
  - downloading loggers
- be clean and dry on the inside, and
- have an exterior appearance that blends in with the landscape as much as possible.
  Note: The appearance can protect the recorder and associated equipment from the elements and from interference by the public and wildlife.

All equipment within the housing shall be installed in a secure and orderly manner.

Note: For example, wires, cables, pulleys must not interfere with operation and servicing.

4.11.1.1 Walk-in Types

A 'walk-in' housing may be:

- a small shed, or
- the top of a large diameter concrete stilling well that is mounted:
  - above a stilling well, or
  - separately on the ground nearby.

4.11.1.2 Chest Height Types

A 'chest height' recorder housing may be a smaller design mounted:

- at chest height on the recorder stilling well, or
- if the sensor is connected only by cable or tubing, in a suitably protected location.

Note: Exposed cabling and tubing also requires protection from the elements and interference.

Figure 12 – Typical stilling well housing design
Photographer: Evan Baddock.

4.12 Recording Instruments

4.12.1 Electronic Data Loggers

An electronic data logger shall be able to store at least the equivalent of four digits per reading. Where a data logger includes the sensing device, the resolution and uncertainty shall relate to the stored value.

There are many data loggers on the world market with a large range of price and capability. Generally they all have the capability to interface to several different types of sensors, vary the recording interval and output the data in various electronic formats to computers.

Chart recorders shall not be used.

The main capabilities and factors to consider when choosing a data logger are the:

- ability to interface to relevant sensors
- digital resolution (how many bits) and accuracy
- telemetry capability and compatibility
- adequacy of set-up and downloading software
  Note: With digital devices, there can be poor on-site access to the data without specialised equipment or software.
- the ability to average and record other statistical information such as standard deviation
- recording of data at some distance from the sensor
- reliability, compactness, and cost
- power requirement
  Note: The power requirement should be low.
- storage capacity
- clock accuracy, and
- scan rate.
  Note: This is the frequency a data logger is able to measure and process signals then receive data.

4.13 Site and Station Maintenance

All stations shall be maintained in good order so that they are:

- reliable and operate effectively
- fit for carrying out their intended task, and
- sufficiently tidy for efficient work practice.

Note: A well-maintained station will project the impression of a professional operation.

To maintain a station and the site in good order, the following tasks shall be carried out on a regular basis:

- The recorder housing shall be kept tidy.
  Note: Bare galvanising is often acceptable, particularly once weathered.
- Hinges and locks shall be kept lubricated.
  Note: Use graphite powder on lock, not oil, but keep it away from electronic and electrical components and aluminium surfaces that may become wet. Use sparingly or it may bind locks.
- Signage relating to hazards shall be maintained.
- Access tracks shall be maintained in a safe condition, including being clear of vegetation.
- The visual effect of the station on the environment shall be minimised.

For more information, see Annex E – Schedule of Station Visits'.

5 Data Acquisition

5.1.1 In this Section

This section contains information on the standards required for data acquisition; in particular, standards associated with:

- measurement
- data retrieval and conversion at site
- timing
- on-board processing at site
- site visits, and
- instrument validation and calibration.

In hydrology, water level data are used to measure changes in lake or reservoir storage, aquifer and sea levels, flood heights, and to record flow by means of the relationships that generally exist between stage height and discharge in river channels.

5.2 Data Retrieval and Conversion

5.2.1 General

The retrieval of stage height data varies according to the type of recorder used, and to the urgency of acquiring the data. The majority of stage height data is transmitted, received, decoded and entered into local databases through various telemetry systems, such as over radio, cell-phone and satellite systems.

Data can also be retrieved from a site by manually downloading to a mobile device or laptop computer, or by extracting a data card from the data logger and downloading data from the card to a computer.

5.2.2 Data Retrieved by Manual Downloads

All data retrieved by way of manual downloads, electronic data cards and electronic downloads:

- shall be considered original stage height data, and
- should be protected against loss or damage.

5.2.3 Data Transmitted via Telemetry

Data that are transmitted via radio, cell-phone, satellite or other telemetry method shall be considered original and must be preserved as such.

5.2.4 Data from Automated Data Collection Sites

Original data from automated data-collection sites shall be:

- defined as unaltered (no changes in magnitude) data
- acquired from the primary data series as required and clearly identified (and back up data logger, as needed), and
- converted to conventional (engineering) units using a standard format.

5.2.5 Format

The various recorded data in various formats must be deciphered and converted into a format that can be easily used by data-processing systems.

5.3 Timing

Instrument timing and accuracy is crucial for good record keeping. Where timing is part of the instrument specification, the timing method used shall be clearly stated in the metadata.

The recommended recording interval shall be 5 minutes or less, and a maximum of 15 minutes is required.

Note: Some specialised sites such as sea level require short period intervals such as 1 minute.

The uncertainty of digital timing devices used in water level measuring devices shall be within ± 90 seconds of New Zealand Standard Time.

5.4 On-Board Processing

Modern data loggers have the ability to store not just data from sensors, but also apply programs and processing to that data for storage or output to other devices; for example, flow levels for gate settings.

Note: The value archived shall be the instantaneous value recorded on the logging interval or an averaged value over this period as defined in this Standard and recorded in the metadata.

All other supplementary measurements may be stored and shall be described in the site metadata; for example, flow or further averaged data.

Note: Sub-interval averages, medians, standard deviations are useful extra data, and collection of these is recommended. When they are archived they need to be described and used properly. Issues such as induced hysteresis and phase shift can occur from using averaged data.

5.5 Verification Checks during Site Visits

Verification checks need to be carried out during visits to the station. The visits shall be at intervals sufficient to ensure that the data collected are free of error and bias, both in level and time. For a schedule of station visits and checks, see Annex E – Schedule of Station Visits'.

The extent of possible error and bias can depend on:

- the nature of the installation and instrumentation
- whether telemetry and site visit checks are carried out, and
- the presence of backup instruments.

5.5.1 Site Inspection Intervals

Site inspection intervals will vary depending on the individual site requirements and so there is no set standard as to how often a site should be inspected. However, resourcing must be adequate under normal circumstances to ensure stations are visited often enough to ensure quality of the data collected.

Note: Maximum intervals of one visit every three months are suggested, and one visit per month is recommended as a minimum for troublesome sites. For example, these may be sites with unstable ratings or sites where the bubbler system needs more attention than others.

As a minimum, an inspection record for water level should contain:

- the site name or number
- the date and time of the logger and reference time
- reference readings with uncertainties, and
- a concurrent instantaneous logger/sensor value.

5.5.1.1 Proximity to Logged Value Time Stamp

The inspection shall be completed as close to the logged value time stamp as possible and filled out at that time.

Note: Noting the logged value on the inspection record is good practice. This means that an inspection can be carried out at any time in the logging interval as verification of the logged values. This is especially useful when you have rapidly changing stage values or noisy data and if the logger only displays the value without an associated time. If the reference is situated a long way from the logger it may be useful to have two people on site to synchronise the readings. However, bear in mind some data loggers do not update their display at every scan.

5.5.1.2 Uncertainty

The reference level shall always be accompanied by an uncertainty; for example, 756 mm ± 5 mm. For an electric plumb bob the uncertainty is assumed to be ± 1 mm unless otherwise noted.

The observations collected and the uncertainty carry a lot of meaning when the data is processed and shall be carried out with utmost diligence.

Note: It is recommended the reference is read before the logger value.

5.5.2 Resetting a Logger after a Fault

When resetting a logger after a fault, the value from the primary site reference is the value that the logger is reset to. If this is done during times of varying stage, an inspection is needed soon after, during a period of relatively stable water level, to confirm the data logger was correctly set.

5.6 Instrument Validation and Calibration

5.6.1 Performance

All sensors shall be regularly validated and calibrated to ensure they perform to their specification and that measurements, taken over the life of the data series, are accurate.

This includes not only deployed sensors but those about to be used from storage, because the length of storage may be beyond the recommended calibration interval.

It is expected that any purchased instruments be delivered with a calibration certificate that is less than 12 months old.

Note: The value of the sensor record is of upmost importance here, as the sensor is producing the final archive record, so we need to ensure that the sensor is checked appropriately and is performing to its own specifications and the site's requirements.

5.6.1.1 Validation Method

Validation is a field check of the sensor's ability to conform to its specifications. Where practicable, the validation method shall be consistent with the manufacturer's instructions.

Where field validation is not possible, then proceed straight to a calibration process, potentially by swapping a new calibrated sensor for the current questionable sensor.

5.6.1.2 When to Validate

Validation shall be performed when the operator determines that the sensor is not providing an accurate record of the measured variable; for example, any time two consecutive verification readings are outside the defined tolerance for that sensor.

Sensor devices shall be validated:

- at least annually
- as a result of observed fault or major discrepancy at any site inspection indicating that the instrument requires checking
- if consecutive site inspections identify a trend in verification readings outside tolerance for that sensor, or the data collected between inspections contain evidence that the instrument requires checking, and/or
- if at any two consecutive visits the difference between recorder water level and verification readings from one or more reference gauges is outside the defined tolerance for that sensor.

5.6.1.3 Use of Portable Calibrators

A range of portable calibrators is available on the market and these provide a cost-effective means of managing deployed pressure transducers.

The calibrator should be selected with a suitable accuracy and measuring range with the required inputs to test all deployed sensors.

The calibrator shall be annually tested at an accredited laboratory.

The portable calibrator consists of three main components and may be incorporated into a signal unit or modular depending on the manufacturer and model. The key elements are a:

- high accuracy pressure element to provide the reference
- pump for applying the pressure, and
- display unit with sensor inputs.

5.6.2 Calibration of Sensors

All items of equipment used for measurements shall be calibrated to the manufacturer's specifications, and their calibration dates recorded in a suitable register.

A calibration may involve the physical adjustment of the device.

5.6.2.1 How and When to Calibrate

All sensors shall be regularly calibrated, and their calibration dates recorded in the site metadata. Calibration results shall be retained indefinitely as part of the station history records.

Sensors shall be calibrated in accordance with the methodology recommended by the manufacturer or servicing agency:

- when the instrument validation check has failed to conform with the specifications
- when field validation is not possible, and
- at the frequency recommended by the manufacturer.

Note: Pre-calibration data can be used to help reconstruct problem data record.

5.6.2.2 Where to Calibrate

Sensors shall be calibrated in a:

- controlled laboratory environment, or
- suitable office or workshop.

Note: The controlled laboratory is the preferred environment for calibrating sensors.

If an instrument requires repair, pre- and post-repair calibration results shall be requested and obtained from the service agent.

Note: Pre-repair calibration results can be used to repair compromised logged data.

5.6.2.3 Who Shall Calibrate

Calibration shall be undertaken by a recognised service provider who can comply with the manufacturer's specifications.

6 Data Handling and Preservation

6.1.1 In this Section

This section contains information on the handling of data in the field, in its original and recorded form, before being transferred to the office for data processing and editing, to final archiving.

It defines the standards relating to:

- the quality coding of data
- preservation of record
- metadata and comments, and
- quality assurance.

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

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

6.2 Quality Coding

6.2.1 Performance

All data shall be quality coded in accordance with the National Quality Coding Schema.

Note: The National Quality Coding Schema permits valid comparisons within a data series and across multiple data series.

6.2.2 Missing, Synthesised and Modified Records

Even with the best of equipment and field practices it is inevitable that some corrections will be required and some missing records will occur.

If the gaps in the record are not filled, then future analyses of the record becomes difficult, and the data can be of limited value.

Note: Having a backup sensor and logger at a station is highly recommended if possible. Both primary and secondary (backup) recorders must be reliable.

6.2.2.1 Level and Time Corrections

Equipment shall, whenever possible, be corrected for:

- level when it falls outside the standard as determined from one or more references, or
- time as measured by an accurate timepiece.

Any changes to the raw record shall be documented in the metadata.

Note: This may be achieved by quality codes or other data tags, or by time-stamped comment file entries, or a combination of these; best practice is for quality coding and/or data tags to cater for repetitive detailed point-to-point changes and comment file entries to provide broader explanation of method and action on part or all of a data set.

6.2.2.2 Modifications to Data

Any modification to onsite data shall be:

- conservative
- traceable
- documented
- performed or approved by experienced personnel
- described in a time-bounded time-stamped comment, and
- quality coded appropriately.

6.2.2.3 Traceability and Data Integrity

The modification of any field logged data shall be accompanied by evidence, explanations of the methodology applied, and comments that ensure traceability and data integrity. All such evidence, explanations, quality codes and comments shall be permanently stored as part of the station records.

6.2.2.4 Scientifically Defensible Assumptions

All assumptions on which any modifications are made shall be defensible and recorded.

6.2.2.5 Modifications Explained

Any assumption or explanation of any modification shall be:

- recorded on or attached to the original data or field log notes and is held in the site file, and
- electronically recorded by a comment in the metadata.

6.2.3 Percentage of Record Required

The goal shall be zero missing record, and it is recommended that the site be built and maintained with the goal of reducing missing record to less than five days in only one year out of two consecutive years.

Note: This may require the use of both primary and secondary (backup) recorders, both of which must be reliable.

6.2.4 When and How to Fill Gaps

Future analyses of the record become difficult and the data is of lesser value if the gaps in the record are not filled.

The following documents should be referred to in conjunction with the guidelines in this section when filling in gaps in the record:

WMO-No.1044; Volume 2 – Computation of Discharge (2010)

NIWA Client Report: CHC2010-002; January 2010 - Standard procedures for creating and describing synthetic hydrological record.

6.2.4.1 Who Synthesises Records

The agency and staff that collect the data shall wherever possible fill any gaps (missing record) that occur in the data.

6.2.5 Archiving Filled-In Data

Any data used to fill gaps in primary record shall be:

merged appropriately with the record in a controlled manner

clearly distinguished from the primary data, and

- *For example, assign an appropriate quality code.*

described comprehensively in metadata.

- *Include an assessment of uncertainty.*

Any recipient of record, or analysis containing or comprising filled-in data shall be:

alerted to its presence

informed of the uncertainty involved, and supplied with any other documentation required for interpretation of that information.

Note: Quality coding and metadata can be used to express uncertainty.

Note: Other documentation required for interpretation may include, for example, copies of procedures, explanation of codes applied.

6.2.6 Marking Gaps

Gaps shall be filled, whenever possible, to achieve a continuous record. If this is not possible, an explanation shall be provided in the metadata, e.g., comment file, for each period, as to what methods have been attempted and why they have failed.

Note: Future methods, technology or data may permit gaps to be filled at a later date and such guidance will be valuable.

Methods used to fill gaps shall be one of, in decreasing order of preference:

- backup data from site
- interpolated data at site
- adjacent station data that has been checked for suitability
- hydrological or hydraulically modelled, correlated, estimated by other means

Metadata shall include comprehensive details of:

- period
- method
- other sites and data used
- description of models
- statistical confidence, and
- expected reliability of filled-in record.

6.3 Telemetry Data

Telemetry is a means of communication with a remote field station for retrieval of data from the station data logger back to a base or office system. This is achieved by various methods such as radio, cell-phone and satellite systems.

A telemetry system offers the opportunity to remotely monitor many functions of a recorder station. It is possible to detect very quickly:

- instrument failures
- electrical problems
- substantial or probable changes in the channel control, and
- sedimentation problems; for example, orifice burial or silting of the stilling well.

Note: The system should be used to its maximum capabilities in this respect as it can save on missing record and minimise expensive return trips to repair faulty equipment by identifying a fault early and then getting to the site quickly.

Remote station configurations may also be changed via telemetry. New sampling programs may be uploaded to the remote data logger from the office. Sensor scaling and offsets may be applied at the telemetry base, or a combination of both. Systems may have automatic update capabilities; for example, remote clock synchronisation with base.

Note: It is good field practice to routinely download the data logger.

The following conditions apply to telemetered data:

- The data shall be coded as QC 200 (raw) until verified.
- Implemented automatic features must be described, and changes to those features controlled and tracked in the station history and metadata.
- Performance of automatic features shall be checked regularly; for example, confirming each field station time is correct during daily system checks.
- Ad hoc changes applied at or initiated from base, e.g. rescaling a sensor or changing a sampling method, must be controlled and documented in a manner equivalent to making the change on-site.

Note: An 'office' logbook kept by the telemetry base is useful for this purpose.

Note: There could be multipliers in the data at the base or field station which need to be documented and carefully controlled.

6.4 Preservation of Record

6.4.1 Storage

The following data shall be archived and retained indefinitely:

- Final checked and verified data
- Unedited raw primary and backup data
- Associated metadata, including;
  - data comments
  - site details
  - recording accuracy and resolution
  - station history inspections and surveys of references
  - equipment calibration history, and
  - any other factors affecting data quality.

All original records, annotations and supporting data 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.*

6.5 Metadata and Comments

Metadata describes the type of data, where it has been measured, length of record and other information relevant to the data being recorded at the site.

Comments are very useful to explain unusual features or events in the record that users of the data should be aware of. In addition, routine comments are required for key information.

Comments should describe in time-stamped text format and include but not be limited to:

- information about the site, station and characteristics of the data
- alerts and supporting information intended for end users of the data, and
- aspects not easily quality coded or otherwise quantified in point detail.

Note: Current software packages provide several ways to build a database of comments. Comments can be entered into an unstructured file of text. If the comments are entered into an ODBC (Open Database Connectivity) database, they can be accessed by any ODBC compliant software. Therefore this method is recommended.

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

- the site details:
  - site purpose
  - recording agency/ies
  - site location in coordinate system supported by Land Information NZ
  - site name and past and present aliases
  - names and/or indices of relevant environmental features (river, lake, coast)

    Note: Latitude/longitude coordinates, e.g. NZTM2000, must be expressed to a minimum of 6 decimal places.
- the start and end date of site and record

  Note: Recorded using New Zealand Standard Time (NZST).
- related sites and records
- reference to the Standard and version used
- sensor and recorder details including media; for example, specifications of:
  - chart
  - tape
  - data logger
  - memory capacity
  - storage card, and
  - telemetry capability.

Note: Use the terms and references defined and the types as described in these Standards rather than brand names, models or serial numbers so future users need only refer to this Standard to interpret the comment.

- instrument relocation dates
- data capture and/or retrieval method; for example:
  - digitised
  - manual CSV import, or
  - telemetered
- calibration results

  Note: It is preferable to use an agency instrument/asset management system.
- information about:
  - legal requirements
  - confidentiality agreements,
  - intellectual property, and
  - any other restrictions related to data access.

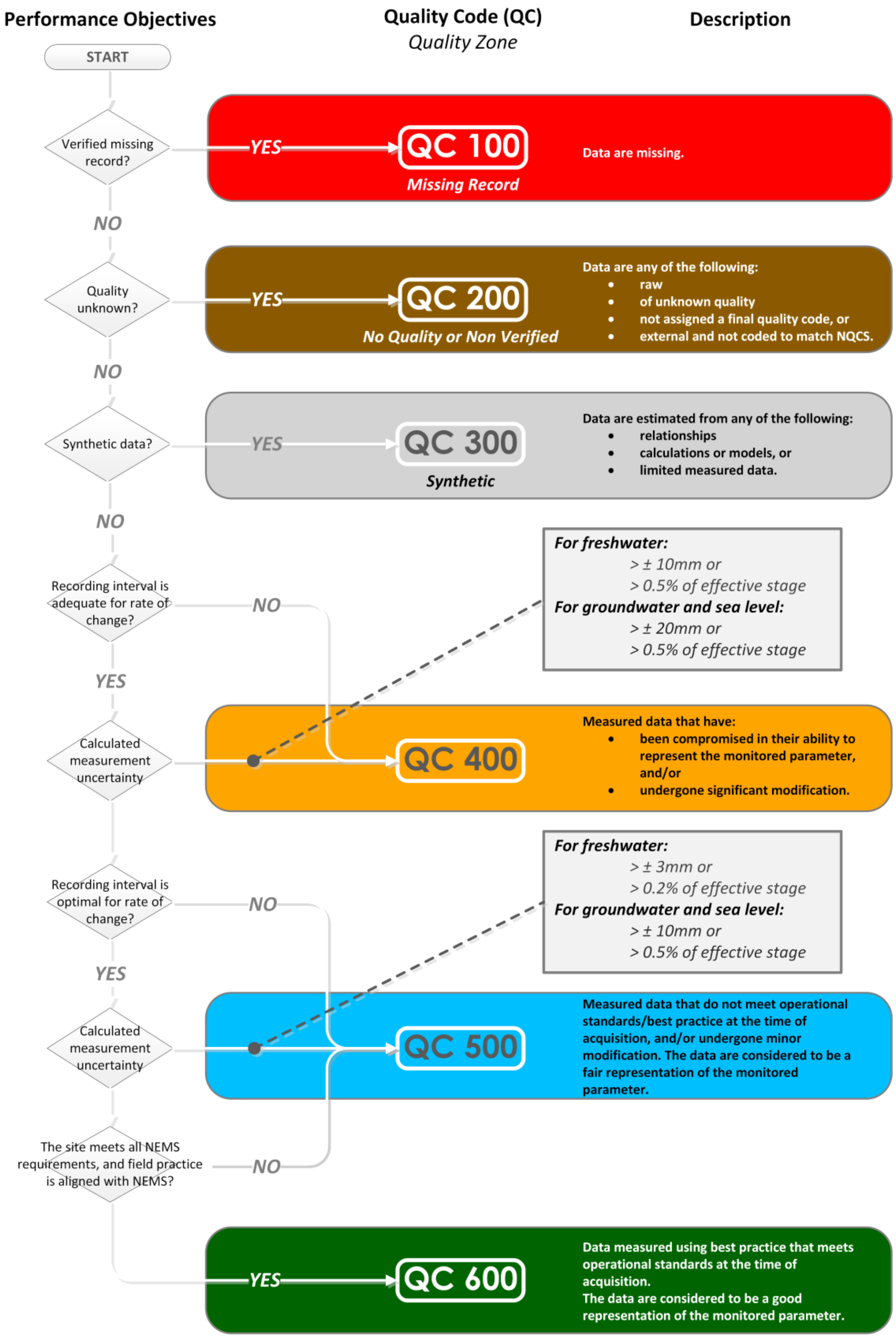
Comments relating to gaps, missing record, synthetic record and time-related events that affect the data from the field are also required in a standard format (refer to Data Processing NEMS).

All metadata or comments shall be time-stamped at the start of the interval to which they apply; for example, a gap or synthetic data comment will be filed one recording interval after the last actual data collected, so the event comment is then filed at the time of the event.

Comments covering the accuracy of data from the field and gaps in records should be informative, coherent and identify the period(s) for which the data are suspect or missing. For examples of these refer to the Data Processing NEMS document.

6.6 Quality Codes – Water Level

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



6.7 Quality Assurance

All agencies shall implement a standard methodology for field site audit and review.

Note: This is to ensure the calibration of equipment and data logging methods are "fit for purpose" whenever possible, therefore enabling meaningful analyses and comparison of water level data within regions, across regions and nationally.

6.7.1 Audit Cycle

Quality assurance processes shall include at a minimum, an audit of the field station:

- at a frequency appropriate to the organisation's and users' needs, or
- as defined by an organisation's quality management systems documentation.

This work shall be undertaken by a suitably qualified and experienced practitioner.

Unaudited data that are released for use shall be identified as being unaudited.

Note: Stations other than those under review may be included in the audit to help with comparisons. Where available, reliable records from stations operated by other agencies may be used.

6.7.2 Minimum Audit Report Requirements

As a minimum, analyses and information required for an audit report for water level stations shall cover:

- site and deployment metadata details, including catchment (if applicable) and site details
- comments and quality coding attached to data leaving the field station
- data tabulations, plots and comparisons, and
- annual station inspections.

6.7.2.1 Catchment and Site Details

The following two items shall be included in the audit report:

- a site details summary, and
- a location map, with all relevant station locations identified.

The site details summary shall:

- identify the catchment or region
- include associated rainfall stations if available, and any stations used for comparisons, and
- for each station, identify:
  - the period of record covered
    Note: Recorded using New Zealand Standard Time (NZST).
  - the station name and number
  - map reference
  - altitude, and
  - sensor type.

6.7.2.2 Tabulations

The following tabulations shall be included in the audit report:

- Listing of gaps
  Note: This should be compared with the listing of comments.
- Listing of comments
- Extremes - of stage height for the full period.

6.7.2.3 Data Plots

The following data plots shall be included in the audit report:

- Station Plots
  - For period under review plus the year prior.
  - Full scale of data recorded
  - Partial range to permit inspection of low to medium levels (usually sufficient to trim range at upper quartile of stage recorded)
  - For decade i.e. period under review plus previous years to make ten in total; full scale and partial range
- Decade Stage Height Plots
  Note: Include both full range and a partial range, and with the previous years to make 10 years.
- Comparative Plots
  Note: it is left to the review compiler's discretion to choose and present a method of comparing against at least one other station (flow, rainfall, gate openings) to demonstrate that there are no obvious anomalies in the record. Statistical techniques such as double mass curves, direct comparisons of parameters, or relationships between parameters (e.g. addition, subtraction, correlation) may be employed.

6.7.2.4 Annual or Biennial Station Inspections

Annual or biennial station inspection results that cover the period under review shall be included. Where applicable, the most recent results, and the most recently prior results shall also be included.

6.7.3 Other Requirements

6.7.3.1 Outputs

Recommended report outputs include:

- an optional hard copy report
- a mandatory electronic report, or
- an electronic document that only identifies which periods of record have passed audit.

6.7.3.2 Audit Certification

The completed audit shall contain the name and signature of the auditor and the date that the audit was completed.

Annex A – List of Referenced Documents

International Organization for Standardization (ISO). (2008). *Hydrometry – Water level measuring devices*. (ISO 4373:2008). Geneva, Switzerland: Author.

International Organization for Standardization (ISO). (2008). *Hydrometry – Open channel flow measurement using thin-plate weirs* (ISO 1438:2008). Geneva, Switzerland: Author.

International Organization for Standardization (ISO). (2011). *Hydro – Vocabulary and symbols* (ISO 772:2011). Geneva, Switzerland: Author.

Ministry of Works. (1958). *Standard specifications for automatic water level recorder installations and current meter gauging stations*. Wellington, New Zealand: Author.

National Environmental Monitoring Standards (NEMS). (2013). *Open channel flow measurement – Measurement, processing and archiving of open channel flow data* (A National Environmental Monitoring Standard). Wellington, New Zealand: Ministry for the Environment. Available from http://www.lawa.org.nz/media/16578/nems-open-channel-flow-measurement-2013-06.pdf

National Institute of Water and Atmospheric Research (NIWA). (2012). Design guide for timber footbridges. In *Hydrometric structures* (Part A). Wellington, New Zealand: Author.

Standards New Zealand. (2001). *Environmental standard for drilling of soil and rock* (NZS 4411:2001). Wellington, New Zealand: Author.

Sauer, V. B., & Turnipseed, D. P. (2010). Stage measurement at gaging stations. In *US Geological Survey Techniques and Methods* (Book 3, Chap. A7). Reston, VA: US Geological Survey. Retrieved from http://pubs.usgs.gov/tm/tm3-a7/

Walter, K. (2000). *Index to hydrological recording sites in New Zealand* (NIWA Technical Report 73). Wellington, New Zealand: National Institute of Water and Atmospheric Research (NIWA).

Annex B – Procedures

Installing an Electric Plumb Bob

Although a simple device, the installation of a plumb bob requires some thought and care.

Before You Begin

Before installing an electric plumb bob, ensure that you have sufficient tape to measure the amount of siltation at the bottom of the well.

To install an electric plumb bob:

1. **Mount the reel assembly.**

   Mount the reel assembly over the stilling well where it will not touch the recorder float, pipes or the side of the well. It should also be in a position that can be easily reached and where the meter and index point can be easily read. A good approach is to screw it to a piece of 150 x 25 mm timber that has been bolted across the back wall of the housing.

2. **Mount the battery.**

   Use a suitable power source.

3. **Attach the battery.**

   Attach the battery with the positive side to the milliammeter via the switch, and the negative connected to a good earth.

   Note: Either use the stilling well or the bolts connecting the housing floor to it or, in the case of concrete or fibreglass stilling wells, a ladder, pipe or purpose-built earth (perhaps a weighted length of copper wire).

4. **Fix the zero (or −1 m) end to the reel.**

   Ensure this stage height value is at least 0.5 m below the lowest intake pipe and preferably at or below the bottom of the well. This will enable sounding of sediment levels as described above.
   If not, add in a length of strong plastic-coated wire or similar, marked every 10 cm.

5. **Temporarily fix the plumb bob to the other end of the tape**

   Ensure the adjusting screw is at its approximate mid-point. Check the electric plumb bob to ensure it is working.

6. **Set up a level.**

   Set it up in a position where the plumb bob can be sighted through a hatch or inside the recorder housing.

7. **Take the backsights.**

   Take a backsight on a benchmark, an intermediate on the well or river water level and calculate the reduced level of the height of instrument (HI).

   Calculate the reduced level (HI) by adding the staff reading to the benchmark's RL. Use a water level shot as a check.

8. **Convert the HI to a stage height equivalent.**

   Subtract the recording zero (noted in the Station History) from the HI reduced level.

9. **Take an electric plumb bob reading.**
   Take the reading with the bottom of the plumb bob at the cross hairs of the level.
   This will require one person observing through the level with another person operating the electric plumb bob.
10. **Subtract the stage height equivalent of the HI from the electric plumb bob reading.**
   Result: This will give the length of tape that must be cut off.
11. **Using the graduations on the tape, measure back this length and cut off the tape.**
12. **Remount the plumb bob at this point.**
13. **Observe the tip of the plumb bob.**
   Observe through the level and use the electric plumb bob adjusting screw for fine adjustment to bring the tip of the plumb bob to the tip of the cross hairs.
14. **Tighten the locknut firmly.**

What's Next

Check the electric plumb bob reading of water level against the staff gauge and the levelled values.

Troubleshooting

Problem	Possible Cause	Resolution
No Power	Battery may be flat.	Check the battery and replace if flat.
No Power	Wires may be loose.	Check that the wires in the circuit are not loose or corroded. Reconnect wires if loose or no longer connected. Replace wiring if corroded.
Electric plumb bob not working	Earth connection has corroded. *Note: The earth connection always seems to corrode, sometimes just by leaving the battery connected, notwithstanding that the operating switch is left off.*	Test by touching the disconnected earth wire across the electric plumb bob tape with the operating switch closed. However, this needs to be done very briefly as it will put a lot of current through the milliammeter. If there is trouble getting a good earth, install a weighted length of copper wire down into the well. If the needle on the meter deflects in the wrong direction, reverse the battery polarity.
Poor electric plumb bob reading	Corrosion may form on the tip of the plumb bob.	Scrape or sand any corrosion off the plumb bob.
Electric plumb bob reading is lower than expected	The insulating sleeve around the plumb bob has slipped down, creating an air pocket that will give a low reading.	Check the insulating sleeve, reposition and fix back in place. Could also be removed if needed.
Electric plumb bob always reading on	The steel tape may have shorted against the recorder floor. Damp timber floors can cause shorting.	Install a plastic guide ring.
Other electric plumb bob problems?	If the axle of the reel is lubricated with oil, this may insulate the reel.	Do not lubricate with oil or graphite. If having problems, the fibre washer in the clutch can be removed and this will improve the electrical connection.

Annex C – Hydrological Station History Form

The following is an example of a hydrological Station History Form.

Site No.......................................   Form SH 100721

HYDROLOGICAL STATION HISTORY

Station .... River, at ....

Map reference(s): .... Catchment area: .... km^2

Recording authority: .... Client: ....

____
_

Section 1: RECORDS COLLECTED

Primary, Backup, Telemetry Logger/Sensor Type	Date Commenced	Date Ended	Remarks

Earlier SH or 16 forms held:
....

Section 2: BENCHMARKS

BM No.	Date Placed	Provisional R.L.	Datum	Final R.L.				Level Bk
				R.L.	Datum	Origin	Date adopted	

BENCHMARK ALTERATIONS

BM No.	Date Altered	From (RL)	To (RL)	Reason and Remarks	Level Book	Updated by: Initials	Date

Section 3: STAFF GAUGES

Type	Location	Range	RL Zero m	Date Established and Level Bk No.	Updated by: Initials	Date

Section 4: RECORDING INSTRUMENT

Type and Make.	Date Installed	Date Removed	Range m	Interval Resolution	RL Zero m	Remarks	Updated by: Initials	Date

Section 5: RECORDER STRUCTURE

Type and Description	Date Constructed	Date Removed	Date Updated Initials	Date

LEVELS:

RL invert lower inlet pipe .... RL invert top inlet pipe ....

RL invert stilling well .... RL underside recorder floor ....

Transducer: Standard RL of sensor head .... Standard offset ....

Section 6: LEVELLING CHECKS

Date	Team	Level Bk/Pg	Items checked – list results (BM's, EPB, ESG)	Remarks and Results

Section 7: REACH

Nature of Control:
....
....
....

Gaugings - Cableway/Slackline cableway/Wading/Jet Boat/Dilution/Bridge/Other ....

Slope-Area Reach:

X-Sect. No.	BM No. to BM No.	Dist. between X-S's	Remarks

Section 8: SITE PLANS

Site Plan 1 As at Drawn by / /

(Show all BMs, staff gauges, rec. installations, details of reach, cross-sections, distances, etc.)

Site Plan 2 As at Drawn by / /

(Use for significantly different change in installations, reach, benchmarks, etc.)

Annex D – Annual Station Inspection

Checklist for Annual Station Inspection

☐ Form Heading

Provide, for example, the site number, current inspection date, agency and party, and date of last inspection.

☐ Findings from Last Inspection

Review results of the last inspection before departing. Note any changes made at the time, unresolved issues, and required work or safety hazards identified.

On site, confirm actions taken last inspection and check if those issues, work and hazards have been addressed. Note any work still not done and hazards and other issues still present. Note any new issues those actions may have created

☐ Levelling Check

Give the date and all level book details of this levelling check, along with the start benchmark (BM). State name and reduced level (RL) of the start BM to the survey datum used.

Ensure when levelling that all benchmarks, staff gauges, electric plumb bob, stilling well reference points (see below), etc. are change points, or measured twice if read as intermediates. Reduce and calculate the close on site. It must be within ± 3 mm.

☐ Benchmarks

List the differences between the RLs measured and those on the Station History Form. Record the datum used; if assumed, state which BM is assigned the nominal value. Indicate whether each BM's measured value is correct to within ± 3 mm and give explanatory comments if not.

☐ Staff Gauge Zero

Determine and list the differences between the zeros measured and those on the Station History Form. Indicate whether each zero is correct to within ± 3 mm. Give explanatory comments if not, including proposed remedies.

☐ Internal (Electric Plumb Bob) Gauge and Zero

Record (with the staff gauge data) the internal plumb bob zero determined from the levelling and any difference with the value on the Station History Form. Check that the electric plumb bob has a clear and stable index mark and the connection to earth is reliable. Clean the plumb bob and ensure it is secure.

☐ Recording Zero

State what the primary reference is for the site (normally the electric plumb bob for wells and the staff gauge for transducers). Determine and list the difference between current logger and primary reference readings.

Note: Provided the primary reference zero is correctly set at recording zero for the station, this check will identify if the recorder is correctly set. Measurements from the primary reference are used at regular station visits to check logged data and to control any necessary adjustment of data.

☐ Instrument Details

Record the details of make, type, serial number of all sensors, loggers and other instruments and equipment used to collect or transmit data. Include sensor range (nominal and possible) and scan rates, logger sampling, averaging and recording intervals, and transmit/download frequency.

Note: Nominal range refers to the sensor as specified. Possible range refers to the sensor as installed; for example, by raising a float through its full operating range.

☐ Stilling Wells and Sensors

Record whether the installation is generally adequate, and whether the station as a whole promotes a professional organisation.

Check that the stilling well reference points (underside recorder floor, well invert, invert of upper and lower intake pipes) are unchanged.

Check the intake pipes for damage and sediment and any detrimental effect on the record. Determine if the flushing frequency, techniques and facilities are effective.

Ensure sensors are clear of sediment and debris, protected from likely damage, and mountings are secure, and that the sensor tube or cable is protected from damage by stock, vandals, floodwater and subsidence.

If the gas purge pressure sensor shows a discrepancy with the staff gauge, carry out a purge cycle and recheck.

Check the bubble rate is adequate. Inspect lines and fittings for leaks.

Check vented wet transducers are fitted with dry-boxes or bottles that are regularly serviced and currently functioning. Ensure gas supply systems, e.g. compressors, are drained and/or dry.

Check the transceiver surfaces of any non-contact instrument are clean and undamaged, signal paths are clear, and their mountings are secure.

☐ Safety

Consider whether access to the site and installations is safe.

Check the safety of the gauging location, bridges for flood and traffic hazards, cableways and taglines for navigation hazard, wading and other gauging sections for general safety of use.

Check the safety of gauging structures; bridges for soundness of decking, handrails; cableways and taglines for soundness of cable and winch, supports and anchors; and current operating certificate if required.

Check condition of power supply equipment, particularly mains power connections.

Note any new hazards.

☐ Recorder Operation

For both the backup and main recorders, note whether they are accurate, securely mounted and easy to service.

Ensure encoder pulleys are operating freely and the float tape or wire sits properly on the drive pulley

Review the logbooks; they should be filled in properly and be legible.

Check whether the sensor calibrations are up to date.

☐ Power Supply

Consider whether adequate. Test the voltage during a reading and check the wiring for tidiness, corroded terminals, unsoldered connections, undue tension and potential breaks.

Batteries should be marked with date of entry into service, as well as having a record of charging, discharge testing, conditioning, etc., as appropriate. Check and test any solar panel, generator, lightning protection, etc.

☐ Float Systems

Raise the float and check it for leaks, growth and obstructions, that the connections are secure, and that the tape or wire is free of kinks and damage. Check that the float will travel through its full range without striking obstructions, and that the float tape is undamaged. Ensure that the data logger resumes its correct reading, and beware of setting off alarms. Sound the depth of sediment in the well.

☐ Weir or Flume

Check the structure is clean, undamaged and there is no evidence or suggestion of leakage. Look for sedimentation and backwater effects that may be altering the rating.

☐ Gauging Reach

Check whether the gauging reach has relatively laminar flow, uniform depth, parallel flow lines, etc., and absence of weed growth, vegetation and other obstructions.

Check whether the gauging distance markings are clear if applicable, and if the gauging distances can be reliably referenced between gaugings to provide a record of river bed movement in the gauging cross-section.

☐ Photographs

Digitally photograph all components of the installation, and recording and gauging reaches including site controls (views upstream, downstream and across). Photos must be date-stamped and properly indexed and archived as part of the Station History.

☐ Records

Comment on the likely accuracy of the stage record, the stability of the control(s), and any other factors not so far covered that have a bearing on the accuracy of data since last inspection.

☐ Reporting and Filing

Transfer any safety issues and new hazards to the agency's hazard management system.

Update the Station History with results from the inspection. Update instrument records, checking calibrations where required are current for instruments on site.

Alert staff processing the data to any identified issues of record quality.

Incorporate works or repairs required to agency's work programme; for example, by non-conformance under quality management system, team meeting or budget planning process.

File the completed Annual Station Inspection form appropriately as a permanent record of the effectiveness of the station and the integrity of its data.

A manager should ensure that:

- the inspection has been carried out correctly
- any work required is done or is in the team's work programme
- the completion of the work required is noted on the inspection form, and
- the completed form is filed.

☐ Certify Correct

Certify that the Annual Station Inspection is complete, and that the data from this site is being collected according to the required standards and procedures, unless otherwise noted on the Inspection form.

Annex E – Schedule of Station Visits

Routine Station Visits and Checks

Stations will be visited according to the need for instrument checks and calibration, clearing of weed and biological growth on and around the installations, frequency or evidence of changes to controls, maintenance of power supplies, communications and access, data recovery, and other servicing necessary to ensure complete data collection and keep the site in good operational order.

Visits should include the following checks, as applicable:

☐ Check Telemetered Data

In the office, check the telemetered data for any apparent problems related to communication performance, gaps or spikes in data, and any trends that may be due to impaired sensor performance, rating change, or any other possible problems.

☐ Arrange Access

Make any arrangements required for access, such as keys, notifications, and vehicle and equipment bookings. Check the weather forecast.

☐ Observe

Go to the site, and on arrival observe any issues with growth, debris, damage, etc. Take a photograph of anything significant. Read the staff gauge or reference level pins. If no suitable reference exists survey the current water level.

☐ Clear the Site or the control

Clear any growth or debris, clean the staff gauge plates and weir crest, and note any change to the staff gauge reading. Enter details of what was done and all readings in the logbook.

☐ Connect data logger

Connect to the data logger and/or key through the display to check the following:

- Logged stage readings agree with the staff gauge reading to within the tolerance defined for the sensor and range.
  Note: If a difference occurs, a reason for that difference should be sought. It is essential to first check the reference itself is correct, and prudent to confirm any trend in differences over two or three subsequent visits before making any adjustment.
- Velocity measurements are sensible, and/or agree approximately with a current meter spot measurement (see below).

- All other parameters in the data logger, including time, appear accurate and sensible.
- If not telemetered, download the logged data, taking a backup on separate media (memory stick) then inspect the data for evidence of problems that might be fixed or further diagnosed while on site.

☐ Carry Out Gauging

As required to either define rating shape, confirm that it is stable, or track a change in the control and thereby establish a new rating, carry out a gauging.

Note. Weed growing between the recorder and control sections may ultimately become the control. Clearing this weed will cause a rating change and should be followed by gauging, but backwater effect created by the weed may take some time to drain. You may need to delay gauging several hours, or into the next day to ensure you are gauging in stable hydraulic conditions.

☐ Check Bubbler Gas Pressure

Ensure there is sufficient gas supply (chamber pressure gauge; for example, gauge on bottle if stored supply). Ensure regulated pressure to the bubbler (feed pressure gauge between regulator and bubble unit) is set at the manufacturer's recommended pressure for correct operation of the sensor. Note gauge readings in the logbook.

Note: When using industrial gas bottles the pressure (gauge closest to the cylinder) should be in the range 0 kPa (empty) to 20,000 kPa (full) and the regulated pressure to the bubbler (gauge furthest from the cylinder) should be at 400 ± 20kPa.

☐ Measure Battery Power

Measure the battery power supply voltage with a multi-meter and read the charge voltage if applicable. Note these in the logbook.

☐ Check Instrument Housing

Check the instrument housing for damage, leaks, insects, vermin and birds.

Clean and repair as necessary, including solar panels and aerials if fitted.

Similarly, check all cabling, gas lines and their protection and change dry-boxes/bottles if installed.

Check wells for evidence of habitation; for example, nests, eels. Note any requirements for the next visit on the logbook page.

☐ Carry Out Non-Routine Tasks

Carry out any non-routine tasks as required, taking care to follow the required procedures:

- Change Bottled Gas Supply
  Replace the gas cylinder once cylinder pressure is below 3000 kPa. Using the gas bottle spanner, close the cylinder valve, remove the regulator, and swap bottles. First, use the spanner on the new one to 'crack' the valve open momentarily, giving a squirt of gas to clear any dirt. Then connect the regulator, taking care to seat the connection properly. Tighten the nut firmly, but not over-tight. Turn on the cylinder valve, listen for leaks, and check both pressure gauges. If leaks are suspected, use a small brush to apply detergent mixed with a small amount of water to the connections and look for bubbles.

- Flush Stilling Wells
  Flush if it is suspected that the well or pipes may be blocked with silt and continue until the pipes run clear. See Annex F – 'De-Silting Stilling Wells' for a detailed procedure.

- Reprogram the Logger
  If the logger is to be re-programmed, before making the change ensure that either the telemetered record is fully up to date (contact the office and ask for a data retrieval) or download the most recent data to a laptop, taking a backup on separate media (memory stick).

- Purge Gas Bubbler
  If there is discrepancy between logged stage and reference reading, purge the bubbler system. This ensures the gas line is not obstructed.
  AVOID SENSOR DAMAGE
  Avoid sensor damage by ensuring the valves are operated in the correct sequence when purging, otherwise the pressure sensor may be damaged.

Follow these steps to safely purge:

1. **Close the valve to the pressure transducer**.
2. **Open the purge valve (often the red knob at top).**
   Note: This will send high pressure down the gas line to the orifice, where there should be strong bubbling that should be readily visible in all but high flows. No bubbling may mean that the gas line is well blocked or you have wrongly operated the valves.
3. **Once you have observed it purging, turn off the red valve**.
4. **Wait for at least 30 seconds.**
   Note: This allows time for the line pressure to normalise.
5. **Turn on the valve to the pressure transducer.**

☐ Observe and Record After Changes

After any maintenance or changes at the site, read the references and check logger values again before departing. Record details of any instrument changes. Photograph significant changes to installation, site, controls and surroundings. Photos must be date-stamped and properly indexed and archived as part of the Station History.

☐ Record Comments

Comment on accuracy and reliability of the record since last inspection, stability of the control(s) including evidence of any recent activity at or near the control, and any other factor not so far covered that has a bearing on the accuracy of data.

☐ Store Logbook Page

Before leaving, remove and safely store the logbook page, and/or electronic file, for delivery to the office.

Annex F – De-Silting Stilling Wells

Stilling wells and intake pipes can be subject to deposition of sediment within them that prevents free flow of water between the river and well, causing well water level to be different from that in the river. Excessive build-up may block pipes completely and stop water from entering or leaving the well, and may eventually interfere with the float and counterweight.

Silting of intakes and wells can be a significant cause of substandard data. A planned programme of detection and prevention is essential. An investment in effective flushing systems and equipment is likely to be most worthwhile.

Prevention

The most effective prevention is by design, so when siting and building a stilling well:

- The lower intake pipe shall be at least 200 mm and preferably 500 mm above the bottom of the stilling well.
- Use a ratio of 1:12 between intake pipe and stilling well diameters (this is a nominal ratio, because it will be greatly influenced by the number of intakes and their length. for more information, see Annex I – 'Intake Pipe Dimensions'.
- All construction joints of the well and intake pipes shall be watertight.
- A convenient flushing system should be designed, incorporating a means of closing off the static pipe at the stilling well end.

Detecting Silting

Effort shall be applied to detect silting before it becomes evident in the record. Once evident in the record, the period affected will not meet the QC 600 Standard.

Detect silting by:

- using a device such as a crowbar on a length of rope to sound the depth of sediment in the well
- routinely using the electric plumb bob to sound the depth of sediment in the well, and
  Note: In the instrument housing, display the stage height equivalent of the bottom of the well and the invert of the lower intake pipe, so depth of silt and the 'freeboard' left can be estimated.
- observing the amount of surge if it is a characteristic of the site.
  Note: This is usually most obvious during high-flow events when the river may be surging; however, even at low flow some surging may be observed due to turbulence, or seiche on a lake or pond. If the logger stage is slowly moving, even within 1mm, then the intakes can be assumed to be clear.

Sediment checks of the well and intake pipes shall be carried out as part of routine station visits, and after high flows that may have deposited sediment.

Flushing

This process is an important part of operating a water level recording station equipped with a stilling well. All such stations on rivers should be flushed at least annually as preventive maintenance, and more frequently if on rivers that carry a lot of suspended sediment.

Well and intake pipes may be flushed together; however, as the intake pipes are the most important but the hardest to inspect, these may be done separately and more regularly.

The various methods are:

- installed flushing systems
- modified flushing systems, and
- portable or manual flushing systems.

Installed Flushing Systems

Valve and pipe systems fed by header tanks can be fitted into some recorder stilling wells.

The system consists of a valve on each intake pipe at the stilling well end, usually capable of operation from the top, which will close off the intake pipe from the well. On the river side of the valve, a pipe tee connects in a header tank. In operation, the valve or valves are closed, the header tank is filled, and then the water released into the intake pipe(s) to flush them.

Although the volume of water in the internal tanks is relatively small, an augmented supply (e.g. from an external tank fed from a hut roof or spring) may assist, and frequent use will ensure that intake pipes are kept clear. Flushing of the well will need to be carried out separately.

Modified Flushing Systems

Where installed systems are fitted but do not prove efficient, it may be better to replace the header tank with a convenient connection for a pump. This will enable considerable pressure and a large volume to be applied to the intake pipes to flush them effectively. Towards the end of the flushing, the valves could be opened with the pump still operating to also clean them of silt.

Note: Re-plumbing of the ex-header tank pipe could be done in galvanised pipe or a suitable plastic pressure hose, and it could terminate inside or outside the stilling well. Using a quick release coupling for the pump hose such as a 'Camlock' brand fitting will be convenient.

Portable or Manual Flushing Systems

Connecting a Pump to the Static Tube

This can also be an efficient means of flushing the intake pipes, although it requires the stage to be low enough to get to the static pipe.

If the pump outlet hose has a 'free' end (i.e. no fitting on the end), then a very quick and simple method is to remove the static tube and crease the end of the hose so that it can be inserted into the intake pipe for about 200 mm (this will only work for a 50-mm intake and pump hose, but these are the most common sizes). Once the pump is started, water pressure will expand the hose against the side of the intake pipe and thus produce a good seal. The benefit of this method is that the full pressure head of the pump is applied to the intake, and pumping for only a few minutes is all that is required. The disadvantage is that silt will be flushed into the stilling well. If two intake pipes are available, then the top intake is usually pumped and the overflow will emerge from the lower intake. Pumping should be continued until clear water is emerging from the lower intake.

Flushing the Well

The bottom of the stilling well operates as a reservoir for silt, which shall not be allowed to approach the elevation of the lowest intake pipe. Silt shall be regularly removed to prevent this.

The most straight-forward method is to pump water into the well at a high flow rate so that the silt is stirred up into suspension and the mixture flows out of the intake pipe, finally flushing this also.

With larger quantities or heavier particles this does not work well and alternatives can include:

- one pump delivering water in and stirring up the sediment as another pumps it out
- alternating pumping water in and then out, particularly if the intake pipes are blocked
- using compressed air to stir up the silt into suspension while the mixture is pumped out, or
- with the intake pipes blocked off, using a suitable pump, e.g. a diaphragm pump, to remove the thick silt and water mixture directly.
  Note: Centrifugal pumps and most impeller pumps will not pump a thick mixture of sediment without damage to the seals or impeller. Diaphragm pumps can usually handle this. The pump manufacturer's specifications should be consulted to avoid high repair costs.
- entering the well and scooping out sediment directly, such as with a bucket on a rope
  Note: This is a 'last-resort' method after all other alternatives have been considered and/or attempted. It can be effective but often laborious. Health and Safety regulations with respect to entry of confined spaces must be followed (e.g,

harness, recovery winch, gas meter, etc.) and a hazard management plan must be devised and implemented, including an alternative to lifting bucketfuls by rope over a person down a well, which is unacceptably dangerous.

Annex G – Intake Pipe Dimensions

The intake pipe diameter shall be large enough to prevent lag, but not overly large so that surging is not damped. A ratio of 1:12 between intake pipe and stilling well diameters can be used as a guideline.

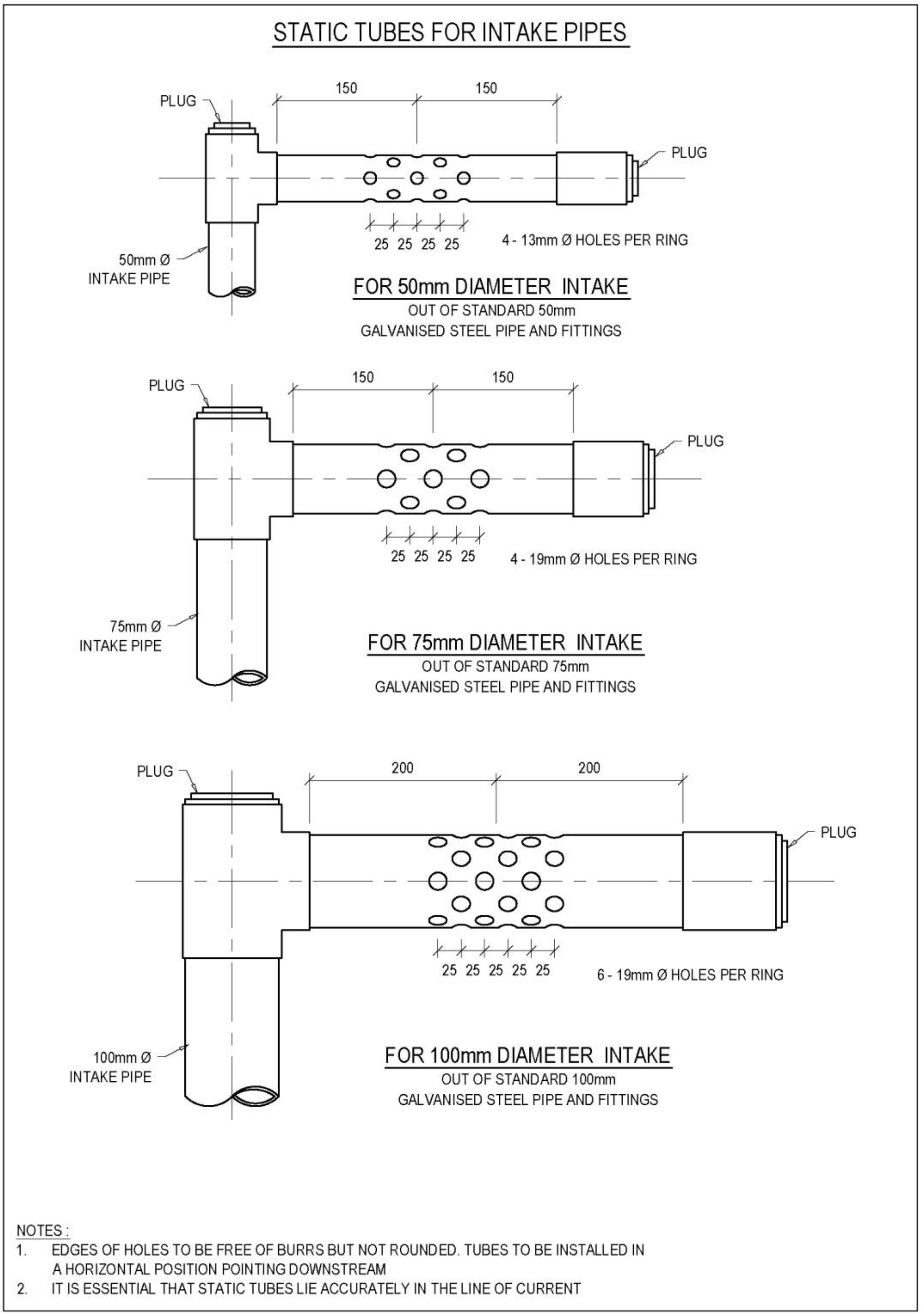


Figure 16 – Static Tubes for Intake Pipes

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The following relationship may be used to determine the lag for an intake pipe for a given rate of change of stage:

$$\Delta h = 0.01/g \times L/D\ (Aw/Ap)^2 \times (dh/dt)^2$$

where: Δh = lag, in meters

g= acceleration of gravity, in m/s^2

L= intake length, in m

D = intake diameter, in m

Aw = area of stilling well, in m^2

Ap = area of intake pipe, in m^2, and

dh/dt = rate of change of stage, in m/s.

Smith, Hanson, and Cruff (1965) have studied intake lag in stilling-well systems, relating it to the rate of change of stage of the stream and to the various types and sizes of components which are used in the stilling-well intake system.


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