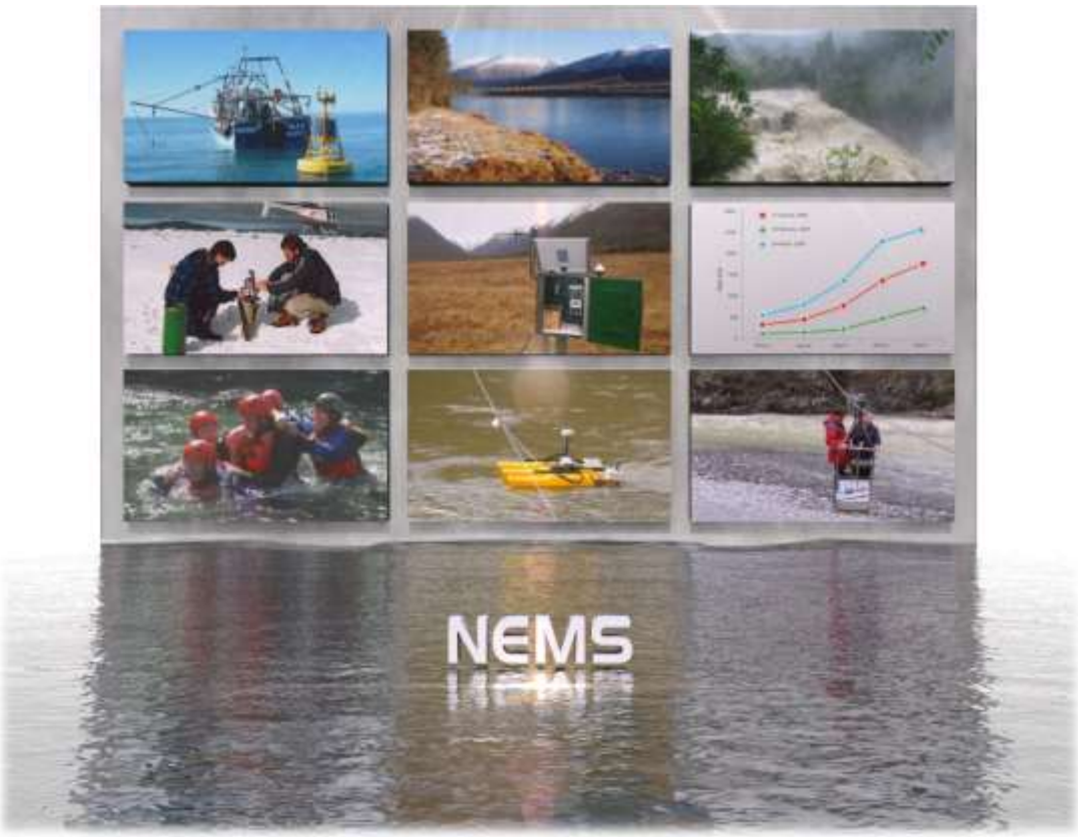
National Environmental Monitoring Standard

Rainfall Recording

Measurement of Rainfall Data for Hydrological Purposes

Version: 2.0

Date of Issue: March 2017



The National Environmental Monitoring Standards

The current suite of National Environmental Monitoring Standards (NEMS) documents, Best Practice Guidelines, *Glossary* and *Quality Code Schema* can be found at www.NEMS.org.nz.

Implementation

When implementing the Standards, current legislation relating to health and safety in New Zealand and subsequent amendments and the NEMS Best Practice Guidelines 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.

The documents do not relieve the user (or a person on whose behalf it is used) of any obligation or duty that might arise under any legislation, and any regulations and rules under those Acts, covering the activities to which this document has been or is to be applied.

The information in this document is provided voluntarily and for information purposes only. Neither NEMS nor any organisation involved in the compilation of this document guarantee that the information is complete, current or correct and accepts no responsibility for unsuitable or inaccurate material that may be encountered.

Neither the NEMS Steering Group, nor any employee or agent of the Crown, nor any author of or contributor to this document shall be responsible or liable for any loss, damage, personal injury or death howsoever caused.

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 NEMS initiative has been led and supported by the Local Authority Environmental Monitoring Group (LAEMG), to assist in ensuring the consistency in the application of work practices specific to environmental monitoring and data acquisition throughout New Zealand.

The strategy that led to the development of these Standards was established by Jeff Watson (Chair) and Rob Christie (Project Manager), and the current Steering Group comprises Phillip Downes, Martin Doyle, Michael Ede, Glenn Ellery, Nicholas Holwerda, Jon Marks, Charles Pearson, Jochen Schmidt, Alison Stringer and Raelene Mercer (Project Manager).

The development of this Standard involved consultation with regional and unitary councils across New Zealand, 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 may be applied will depend on the quality of data sought.

This document has been prepared by Micah Dodge of Horizons Regional Council, Nicholas Holwerda of Auckland Council, Matthew McLarin of Tasman District Council, and Blair Sowman of The University of Auckland. The input of NEMS members into the development of this document is gratefully acknowledged; in particular, the review undertaken by the NEMS Steering Group.

Funding

The project was funded by the following organisations:

- Auckland Council
- Bay of Plenty Regional Council
- Contact Energy
- Environment Canterbury Regional Council
- Environment Southland
- Genesis Energy
- Greater Wellington Regional Council
- Hawke's Bay Regional Council
- Horizons Regional Council
- Marlborough District Council
- Meridian Energy
- Mighty River Power
- Ministry for the Environment
- Ministry of Business, Innovation and Employment – Science and Innovation Group
- National Institute of Water and Atmospheric Research Ltd (NIWA)
- Northland Regional Council
- Otago Regional Council
- Taranaki Regional Council
- Tasman District Council
- Waikato Regional Council
- West Coast Regional Council

Review

The original version of this document was reviewed by the NEMS Steering Group in October 2016, and will be reviewed thereafter once every two years. Further details on the review process can be found at www.NEMS.org.nz.

TABLE OF CONTENTS

National Environmental Monitoring Standard 1
Rainfall 1
The National Environmental Monitoring Standards ii
Development iii
Terms, Definitions and Symbols vii
About this Standard viii
The Standard – Rainfall x
Quality Codes – Rainfall xii

1 Metadata and Stationarity 1
1.1 Metadata 1
1.2 Stationarity 1

2 Site Selection 3
2.1 Topography 3
2.2 Exposure 3
2.3 Obstructed Horizon 4

3 Deployment 5
3.1 Required Gauges 5
3.2 Distance Between Gauges 5
3.3 Primary Reference Gauges 5
3.4 Intensity Gauges 6
3.5 Backup Intensity gauges 7
3.6 Data Loggers 7

4 Data Acquisition and Preservation 9
4.1 Site Inspections 9
4.2 Data Preservation 10

5 Instrument Calibration and Validation 11
5.1 Calibration of Intensity Gauges 11
5.2 Validation of Intensity Gauges 11

6 Data Processing 13

6.1 Filling Gaps Using Backup Intensity Gauge Data 13
6.2 Filling Gaps with Synthetic Data 13

Annex A – List of Referenced Documents 14

Annex B – Topography 15

Annex C – Exposure 16

Annex D – Obstructed Horizon 18

Annex E – Anti-Splash Grid Design 20

Annex F – Evaporation Reduction Methods 21

Annex G – Calibration of Intensity Gauges 22

Annex H – Validation of Intensity Gauges 23

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:

- NEMS *Glossary*
- NEMS *Quality Code Schema*

About this Standard

Introduction

This document provides requirements, information and methodologies to enable the consistent collection, processing and archiving of rainfall data. The key to planning, maintaining and recording rainfall measurement is the understanding of and catering for stationarity of record and gauge exposure.

Historically, within New Zealand, the 'standard rain gauge' was the daily manual rain gauge or primary reference gauge, which was fitted with a 127-mm orifice (5 inch) installed 305 mm (1 foot) above ground level.

The variety of rain gauges pictured below highlights the need for standardisation.

Figure 1 – Rain Gauges

A selection of primary reference and intensity gauges currently and historically used in New Zealand. These gauges demonstrate the large variance in orifice height and diameter.

Photograph: NIWA Instrument Systems.

Prior to the 1950s, few rainfall intensity gauges existed within New Zealand, particularly outside of the urban areas.

Significant growth in hydrological research and growing operational needs for hydrological information in New Zealand during the 1960s, coupled with the International Hydrological Decade that commenced in 1965, saw many of what are now the nation's long-term rainfall intensity recording sites being established.

Changes in instrumentation types over the years have generally resulted in improvements in the resolution of time and rainfall depth over the recording history of many sites. Improvements in resolution have, however, come at a cost to maintaining stationarity. The time interval over which data has been collected has also changed significantly over time.

Rainfall intensity in New Zealand has been recorded as a total over various time intervals. These time intervals have typically been 1-hour, 15-minute, 7.5-minute, 6-minute or 5-minute time intervals. Current data loggers now permit a greater range of options, and very short time resolutions can now be achieved.

Over the life of many rainfall intensity recording gauges, consistent exposure has not been achieved. Changes in exposure have often occurred as a result of growth of vegetation and changes in orifice heights, and also changes in site fencing. As a consequence of this lack of consistency of exposure, the identification of long-term trends in rainfall totals and intensities are difficult or impossible to identify.

Objective

The objective of this Standard is to ensure rainfall intensity data is gathered, processed, and preserved over time across New Zealand in a consistent manner, and is suitable for ‘at site’ and comparative analysis.

Scope

The scope of the Standard covers all processes associated with:

- site selection and deployment
- the acquisition of rainfall data from automatic recording sites
- quality assurance (QA) that is undertaken prior to archiving the data, and
- calibration and validation of gauges.

This Standard focuses on liquid precipitation. This document is not intended to describe the measurement of solid precipitation.

This document is not intended to describe network design, but rather the manner in which sites are deployed in a network.

Exclusions

Specific methodologies for the processing of rainfall data are not covered in this document.

About this Version

Version 1.0 of this document was reviewed in 2015. The review was undertaken following submissions from users and a NEMS *Rainfall* national workshop, held in August 2015.

Significant changes have been made to some sections of the document; in particular, the sections relating to exposure and validation.

It is recommended that, given the significant number of changes that have been made to this document, the user re-familiarise themselves with the contents of the entire Standard.

The Standard – Rainfall

For data to meet the Standard, the following shall be achieved:

Metadata *Section 1.1*		Metadata shall be recorded for sites and measurements.
Stationarity *Section 1.2*	Stationarity shall be maintained.	

Requirements

The following criteria apply to gauges deployed at sites:

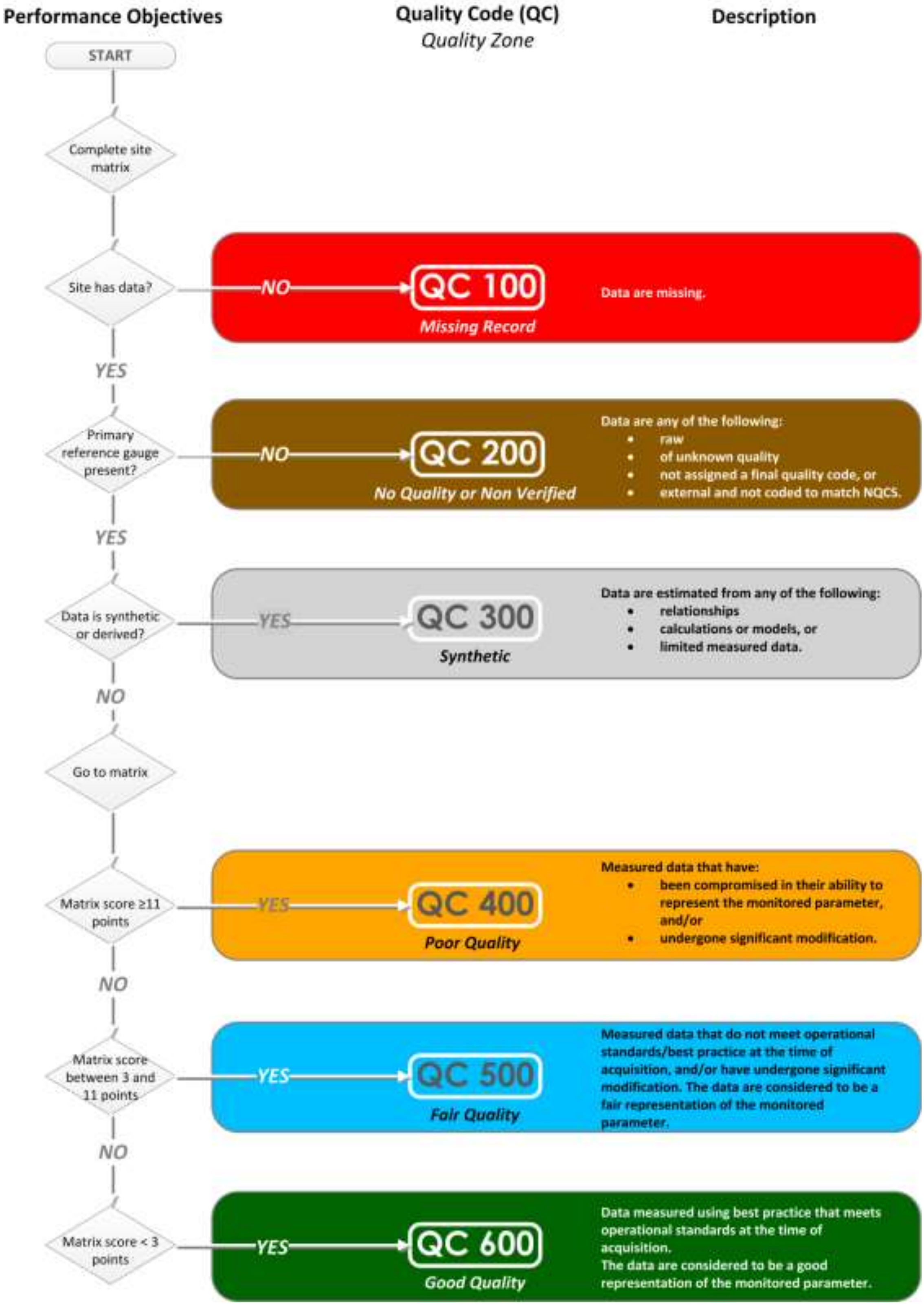
Site Topography *Section 2.1*	Slope of land	Slope less than 19° Site not on a roof
Exposure *Section 2.2*	Wind effects	Site shall not be subject to median average annual wind speeds > 3m/s
Obstructed Horizon *Section 2.3*	All gauges	No obstruction present within a 2:1 ratio of distance to height
Required Gauges *Section 3.1*	All gauges	Primary reference gauge and intensity gauge are present
Distance Between Gauges *Section 3.2*	Primary reference gauges and intensity gauges	Between 600 mm and 2000 mm
Verification of Gauges	Primary reference gauges Section 3.3.1	Gauge complies with requirements for verified primary reference gauges
	Intensity gauges Section 3.4.1	Gauge complies with requirements for verified intensity gauges
Primary Reference Gauges *Section 3.3*	Resolution	Can be read to 1-mm resolution
	Orifice diameter	127–203 mm
	Height	305 mm ± 20 mm *or* ground level with anti-splash grid installed
Intensity Gauges *Section 3.4*	Resolution	≤0.5 mm
	Orifice diameter	127–203 mm
	Height	285–600mm *or* ground level with anti-splash grid installed

Continued on next page…

Timing of Measurements *Section 3.6*	Totalising interval	Maximum period ≤ 60 s *or* event recording
	Accuracy *Section 4.1.2*	Deviation no greater than 60 s from New Zealand Standard Time
	Time zone	Express time as New Zealand Standard Time (NZST). *Do not use New Zealand Daylight Time (NZDT).*
Site Inspections *Section 4.1.1*	Frequency	Minimum once every 3 months
Data Validation *Section 4.1.3.2*	Deviation – intensity gauge vs. primary reference gauge	The deviation of the intensity gauge to the primary reference gauge does not exceed ±10% of the primary reference gauge reading *or* 5 mm where less than 50 mm of rain has fallen.
Processing of Data		All changes shall be documented. All data shall be quality coded as per the Quality Codes flowchart.

Quality Codes – Rainfall

All data shall be quality coded in accordance with the NEMS *Quality Code Schema.* The schema permits valid comparisons within and across multiple data series. Use the following flowchart to assign quality codes to all rainfall intensity data. Where necessary, refer to the Rainfall Site Matrix and Rainfall Data Quality Matrix.



Rainfall Site Matrix

When quality coding rainfall data, assess your site against the following matrix.

Criteria	3 Points	1 Point	0 Points
Site Topography 200m radius from site *Section* 2.1	Site on steeply sloping land > 3° *or* on a roof ☐	Site on moderate sloping land (19°–34°) ☐	Site on flat land – slope <19^{0} ☐
Exposure Average annual wind speed *Section* 2.2	Site subject to high wind (>6 m/s) ☐	Site subject to moderate wind (3–6 m/s) ☐	Subject to low winds (<3 m/s) *or* ground level with anti-splash grid ☐
Obstructed Horizon Within a 100 m radius of the gauge *Section* 2.3	> 10° obstruction within 2:1 in any 45° segment ☐	< 10° obstruction within 2:1 in any 45° segment ☐	No obstruction within 2:1 distance to height ☐
Distance Between Gauges *Section* 3.2	Distance between gauges < 600 mm or > 2000 mm ☐		Distance between gauges 600–2000 mm ☐
Resolution of Primary Reference Gauge *Section* 3.3.1	Cannot be read to ≤ 1mm ☐		Can be read to ≤ 1mm ☐
Orifice Height - Primary Reference Gauge *Section* 3.3.2	0–285 mm *or* > 325mm *or* no primary reference gauge ☐		305mm ±20mm *or* ground level (with anti-splash grid) ☐
Orifice Diameter - Primary Reference Gauge *Section* 3.3.3	< 127 mm *or* > 203 mm ☐		127–203 mm ☐

Continued on next page…

Criteria	3 Points	1 Point	0 Points
Orifice Height - Intensity Gauge *Section* 3.4.2	600–1000 mm and does not match PRG *or* > 1000 mm ☐	600–1000 mm and matches PRG ☐	285–600 mm *or* ground level (with anti-splash grid) ☐
Orifice Diameter - Intensity Gauge *Section* 3.4.3	<127 mm or >203 mm ☐	☐	≥ 127 mm and ≤ 203 mm ☐
Resolution of Intensity Gauge *Section* 3.4.4	> 1 mm ☐	0.5–1.0 mm ☐	≤ 0.5 mm ☐
Measurement Timing Section *3.6*	Totalising period > 60 s and not event recording ☐		Totalising period ≤ 60 s *or* event recording ☐
SITE SCORE			

Rainfall Data Quality Matrix

When processing rainfall record, assess your data against the following matrix. The criteria apply directly to site inspections and the conditions encountered on site.

Criteria	**12 Points**	**3 Points**	**1 Point**	**0 Points**
Time Since Last Inspection Section *4.1.1*	> 18 months ☐	12–18 months ☐	3–12 months ☐	≤3 months ☐
Timing Accuracy Section *4.1.2*	> 900 s ☐	Deviation > 60 s from NZST ☐		Deviation ≤ 60 s from NZST ☐
Verification of Gauge – Primary Reference Gauge Section *3.3.1*	Gauge not verified on inspection ☐			Gauge verified on inspection ☐
Verification of Gauge – Intensity Gauge *Section 3.4.1*	Gauge not verified on inspection ☐			Gauge verified on inspection ☐
Measurement Accuracy – Primary Reference Gauge Section *4.1.3*	> 5%, or 5 mm (where less than 100 mm of rain is collected) ☐	2–5%, *or* 2–5 mm (where less than 100 mm of rain is collected) ☐		≤ 2%, *or* ≤ 2 mm (where less than 100 mm of rain is collected) ☐
Deviation of Intensity Gauge From Primary Reference Gauge Section *4.1.3*	> 20% (where more than 50 mm of rainfall has occurred) ☐	> 10% *or* > 5mm (where less than 50 mm of rainfall has occurred) ☐		< 10% *or* < 5mm (where less than 50 mm of rainfall has occurred) ☐

Continued on next page…

Criteria	12 Points	3 Points	1 Point	0 Points
Snowfall – has occurred since last inspection *Section 4.1.4*	Yes, > 20 mm snowfall ☐	Yes, ≤ 20 mm snowfall☐ ☐	☐	No ☐
DATA QUALITY SCORE				

Total Points

(Site score plus data quality score)

QC 600	< 3 points
QC 500	3–11 points
QC 400	12+ points

Note: If 3 or more criteria are in the '3 points' column, the data are deemed to be of poor quality.

1 Metadata and Stationarity

Metadata and stationarity are two of the most important aspects of long-term data reporting. This section describes these aspects and how they apply to rainfall recording sites. Metadata and stationarity have immense value in that they allow data to be used on an inter-generational level. If stationarity is maintained and metadata has been recorded and preserved, the same data can be used with the same degree of confidence regardless of when it is being looked at.

1.1 Metadata

Metadata shall be recorded and retained for all rainfall recording sites; without metadata it is impossible to assign any meaningful quality codes to rainfall data. The minimum metadata required to assign a quality code is the site location and time of measurement. Rainfall data without its associated metadata should not be used to report on rainfall intensities or to establish long-term relationships.

Metadata for sites includes, but is not limited to:

- site location and characteristics (includes topography, exposure and obstruction)
- photos
- primary reference gauge type, dimensions, resolution and location
- intensity gauge type, dimensions, resolution and location
- all calibration and validation results
- data logger recording interval
- all data processing notes and methodologies, and
- site quality code matrix score.

Metadata shall be recorded and retained for all records, both raw and processed, for each gauge on site.

1.2 Stationarity

Stationarity in regards to rainfall recording is the maintenance of a stationary *x*, *y*, *z* location for the recording instruments over the life of the site. This includes ensuring obstruction and exposure remain consistent. Stationarity allows for meaningful comparisons to be made across different sites over a long period of record.

1.2.1 Stationarity of the Primary Reference Gauge

All intensity gauge data shall be adjusted to the primary reference gauge; where possible the primary reference gauge shall not be moved.

In some cases, the primary reference gauge may require relocation due to unforeseen circumstances, or it is beneficial to do so due to major changes in site characteristics such as obstruction. In these cases, to maintain stationarity of the record, a new primary reference gauge shall be installed at the new location and an overlapping period of inspections of two years and a minimum of eight inspections shall be collected in order to establish a correlation between both gauges.

Where a gauge is irreparably damaged, a replacement gauge shall be installed to the same specifications of the original gauge (height, location, diameter, and gauge type) in order to maintain the stationarity of the record.

1.2.2 Stationarity of the Intensity Gauge

It is understood that, due to the different heights of various intensity recording instruments, maintaining a constant height across the intensity data series may not be possible. In these cases it is advisable to maintain the same *x*, *y* location with the only changes being in either gauge type or height. Any changes shall be documented in the metadata.

2 Site Selection

Site selection is important factor in determining on-going data quality; careful site selection can also help increase the value of the data and its possible applications. Topography, exposure, and obstruction all affect the ability of a recording site to accurately record meaningful data.

2.1 Topography

Site topography affects wind flow and rain-shading of gauges, both of which adversely affect the catch of a rain gauge. Topography is the slope of the land which the site is deployed on, and in accordance with this Standard, is measured based on the maximum and minimum elevation in the 200-m radius surrounding the gauge.

Rooftop deployment of rain gauges should be avoided as it has a significant effect on the data. Demonstrations as far back as 1769 show that gauges deployed on a roof catch as little as 80% of the rainfall that is recorded in ground level gauges (Frisinger, 1977).

All metadata relating to the topography of the site must be recorded and filed with the collected data.

For information on how to calculate slope, see Annex A – List of Referenced Documents

2.2 Exposure

Exposure is widely recognised as the biggest factor affecting rainfall intensity recording and can significantly affect the ability of a gauge to accurately record rainfall. Overexposure occurs at sites where the effects of wind on the gauge have not been mitigated, and where the gauge is subject to high wind speeds. These effects shall be considered when choosing where to deploy a rain gauge and measures employed to reduce the effects of wind on rain gauges.

Average annual wind speed at a site can be determined by either a wind sensor deployed on site, or by referring to regional climate maps available online (see Annex C – 'Exposure').

Note: Online maps provide the median annual average wind speed. These data have been collected over a period of 30 years.

Sites can be designed in order to reduce exposure to wind with a permeable wind break such as a hedge, low trees or a commercial wind break installed in a uniform manner that sufficiently disturbs the air flow and reduces wind speed past the gauges.

All metadata relating to wind speeds at the site shall be recorded and filed with the collected data including the method used to obtain wind speeds, and what site modifications have been made that may alter the wind speeds at the gauge.

2.3 Obstructed Horizon

Obstructed horizon describes the proximity of other objects to the gauge orifice. Any object that is closer to the gauge than twice the object's height above the gauge within a 100-m radius is deemed to impact on the air flow at the site and affects the ability of the gauge to accurately record the rainfall.

The degree of obstruction can be measured in a number of ways but must be done annually with any trees present in full leaf. Once determined, the degree of obstruction and the method used to obtain it shall be filed as metadata; this shall be done for all gauges on site.

It is advisable to have photos of the site looking outward towards any potential obstruction from the gauge's rim level. If a fish-eye lens is used, it is advisable to include a reference object in the image. This object should be set at a distance away from the gauge that is equal to two times the difference in height between the object and the gauge.

For information on how to establish if a gauge is obstructed, and the degree to which it is obstructed, see Annex D – 'Obstructed Horizon'.

3 Deployment

To maximise the quality of the rainfall data recorded, instrument type, location, proximity to other gauges and data logging instrumentation all need to be considered.

3.1 Required Gauges

A rainfall site shall contain an intensity gauge that is accompanied by a valid primary reference gauge that meets the requirements set out in this Standard. Where a primary reference gauge is not present, the rainfall data shall be quality coded as QC 200.

3.2 Distance Between Gauges

Distances between gauges at rainfall sites can affect measurements either by being too small, or by being so large that factors affecting one gauge do not affect the other.

The minimum distance of 600 mm is to ensure no splashes from rain hitting one gauge are caught in the other. The maximum distance of 2000 mm is to ensure that both gauges are located sufficiently close to one another to avoid any differences in environmental conditions causing significant bias in the recorded rainfall in one gauge, but not the other.

3.3 Primary Reference Gauges

The primary reference gauge is the collector gauge that all rainfall intensities shall be adjusted to. A primary reference gauge is designed to provide a static reference point to which periods of record can be related to in order to establish long-term relationships. The primary reference gauge shall be able to be read to a resolution of 1 mm or better.

3.3.1 Verification of Primary Reference Gauges

Primary reference gauges must be verified in order to have data quality coded beyond QC 400. If a primary reference gauge is not verified, its data cannot be considered an accurate representation of the measured rainfall. The verification status of a gauge is determined by its physical condition and characteristics at the time of inspection. To be a verified gauge, a primary reference gauge shall:

- have a level rim with no rim damage
- have a steeply bevelled rim
- have a known, consistent orifice diameter-to-volume relationship
- have no leaks
- have no blockages
- have some form of evaporation prevention, and
- be able to be read to 1-mm resolution.

Where a primary reference gauge is not verified, the reason(s) why shall be documented and filed with the metadata for the site.

3.3.2 Height of Primary Reference Gauges

The height of primary reference gauges has an effect on the exposure and can affect the degree of gauge obstruction. Setting a gauge at 305 mm ± 20 mm is consistent with a large proportion of New Zealand's historical rain gauge recording sites, and is sufficiently high to minimise splash into the gauge from the ground while low enough to significantly reduce wind effects across the gauge.

If an anti-splash grid is used, a gauge can be deployed at ground level. The grid is designed to minimise the risk of splashes from the ground entering the gauge while allowing the gauge to be deployed at ground level, reducing the wind effects across the gauge.

Annex E – 'Anti-Splash Grid Design' contains guidance for suitable and effective deployment of anti-splash grids.

3.3.3 Orifice Diameter of Primary Reference Gauges

A common orifice diameter for primary reference gauges is 127 mm. This Standard allows for orifice diameters between 127 mm and 203 mm. This range means that standpipes can be used as primary reference gauges, and also allows for a primary reference gauge that has an orifice matching that of a typical intensity gauge to be deployed and still meet the Standard. The primary reference gauges shall be able to be read to a resolution of 1 mm or better.

3.3.4 Evaporation Prevention in Primary Reference Gauges

Primary reference gauges should have some form of evaporation prevention. Some tests carried out on primary reference gauges show losses due to evaporation in the range of 0–4% (Sevruk, 1982). The gauges in Sevruk's study had their receiver canisters buried, thus were not subject to the same temperatures and evaporation potential that an above-ground gauge might encounter. For more information on methods of evaporation prevention, see Annex F – 'Evaporation Reduction Methods'.

3.4 Intensity Gauges

The intensity gauge is designed to record instantaneous intensity data at a rainfall site. These gauges come in various designs, models and resolutions.

3.4.1 Verification of Intensity Gauges

To meet QC 600, an intensity gauge must be verified. The verification status of a gauge is determined by its physical condition and characteristics at the time of inspection. To be a verified gauge, an intensity gauge shall:

- have a level rim with no rim damage
- have no leaks
- have no blockages
- have fully functioning components
- be free of any restriction adversely affecting bucket tips

- be calibrated to the manufacturer's specifications, and
- have passed its most recent validation check in the last 12 months.

Where an intensity gauge is not verified, the reason(s) why shall be documented and filed with the metadata for the site.

3.4.2 Height of Intensity Gauges

Deployment of intensity gauges at heights ranging from 285–600 mm allows for various gauge types to be deployed and still meet the Standard. Where an anti-splash grid is used, an intensity gauge may be deployed at ground level. The grid is designed to minimise the risk of splashes from the ground entering the gauge while allowing the gauge to be deployed at ground level, reducing the wind effects across the gauge.

3.4.3 Orifice Diameter of Intensity Gauges

The orifice diameter of intensity gauges can vary across types; typically diameters are around 200 mm, but a range of 127–203 mm is allowable. This range allows for a variety of intensity gauge types to be deployed across sites and still meet the Standard if it has a known orifice diameter-to-volume ratio.

3.4.4 Resolution of Intensity Gauges

Intensity gauges can come in a range of resolutions. A 0.5-mm resolution gauge is suitable for most purposes, although higher resolution gauges, such as 0.1 mm or 0.2 mm, can be of particular use in urban settings for drainage schemes and investigations.

3.5 Backup Intensity gauges

In some cases, backup intensity gauges are deployed at sites to cover any period of record where the primary intensity gauge has encountered a fault, or missed record. In cases where a backup gauge is used to cover record, it shall be subject to the same tests that the primary intensity gauge would be in order to determine the data quality.

Where a backup gauge is used to cover a period of record, this shall be noted in the processing notes along with the results of the gauge's assessment against the site matrix and data quality matrix in this document. Gaps filled this way are not deemed synthetic.

3.6 Data Loggers

A data logger is an essential piece of equipment at a rainfall intensity recording site. Data loggers allow agencies to store intensity data onsite at the required resolution, and if telemetered, provide a raw backup of the recorded data.

There are many types of data logger available. Important features of a data logger are the time resolution, accuracy and recording intervals. Rainfall totals recorded at an interval of ≤ 60 seconds allow for accurate intensities to be used in analyses over a range of time periods. For rainfall events, onset and cessation of rainfall is important information; a data logger that records the current New Zealand Standard Time (NZST) to within 60 seconds and has a time resolution of 1 second allows for accurate event reporting across a range of totalising periods.

4 Data Acquisition and Preservation

This section deals with the acquisition and preservation of data via physical site inspections and archiving. It covers inspection frequency and site conditions encountered, and the data streams that are required to be retained by the collecting agency.

4.1 Site Inspections

Regardless of the maximum achievable quality code derived from the rainfall site matrix, any period of data may receive a lower quality code based on the results of a site inspection. All information collected during site inspections shall be recorded and assessed against the rainfall data quality matrix.

4.1.1 Inspection Frequency

Site inspections should be carried out at an appropriate frequency to maintain the integrity of the gauges deployed on site. Three months is generally a suitable frequency to ensure the primary reference gauge has not overflowed, that the chance of anything invalidating either gauge is minimised, and that there has been a sufficient amount of rainfall collected. Some sites are deployed in remote areas, are only accessible at certain times of the year, and are inspected less frequently. In these cases, the deployment should be such that the risk of anything compromising data integrity, such as an overflowing primary reference gauge, is minimised.

4.1.2 Time Accuracy

On inspection, it is important that the site clock is still recording time to within 60 seconds of NZST; this ensures that event rainfall is able to be used for accurate forecasting, reporting and analysis.

4.1.3 Inspection of Primary Reference and Intensity Gauges

On inspection, the gauges shall be checked to ensure they still meet the requirements of a verified gauge as outlined in Sections 3.3.1 and 3.4.1 of this document. Gauges must be inspected in a manner that allows them to be assessed against the requirements in the rainfall data quality matrix.

4.1.3.1 Accuracy of Primary Reference Gauge Readings

When inspecting a rainfall site, the primary reference gauge should be inspected to within 2%, or within 2 mm where less than 100 mm of rainfall has been collected, so that the data can be accurately apportioned to the intensity gauge and confidently archived for long-term analysis. The margin of error of the measurement type should be recorded with the metadata for each inspection when data are processed.

4.1.3.2 Deviation of Intensity Gauge from Primary Reference Gauge

The intensity gauge totals should not deviate from the primary reference gauge totals by more than 10% where more than 50 mm of rainfall has been collected, or > 5 mm where less than

50 mm of rainfall has been collected. Being within these limits allows for confidence in using the rainfall intensities for event analysis and long-term analysis. Where the gauge falls outside of these limits, a field validation of the intensity gauge should be carried out to indicate whether the intensity gauge is still within its calibration ranges. Field validation is explained in Section 5.2 – 'Validation of Intensity Gauges'.

4.1.4 Snowfall

This Standard applies to measurement of liquid precipitation, not to gauges expressly set up to measure snowfall. This section outlines methods for determining whether snow has fallen, how much has fallen, and its effects on rainfall measurements.

If snowfall has occurred between inspections, the likelihood of missing rainfall record is increased. This effect varies based on gauge type, deployment, snowfall depth and weather conditions. Any snowfall at rainfall sites will reduce the quality code of the measured data for that inspection period.

In the event that a gauge is blocked or buried by snow, its data are considered invalid and shall be coded as QC 100 – missing record.

While it can be difficult to precisely measure the snowfall depth that has occurred at a site, it is acceptable to estimate the snowfall using the measured rainfall at an adjacent lowland rainfall site. When estimating snowfall, the relationship 20 mm of snowfall = 2 mm of rainfall shall be used.

When estimating snowfall at site using this method, where the adjacent lowland site(s) that are unaffected by snow record more than 2 mm of rainfall during the same period, it can be assumed that more than 20 mm of snowfall has occurred. This assumed depth can then be reflected in the data matrix.

4.2 Data Preservation

The collecting agency is required to retain a copy of all data obtained from rainfall sites. This data includes, but is not limited to:

- primary reference gauge data
  - primary reference gauge values
- intensity gauge data
  - raw data including test tips
  - raw data with test tips removed
- processed rainfall records, and
- all associated metadata.

Data should be processed, archived and commented for review by the collecting agency.

5 Instrument Calibration and Validation

This section deals with the requirements for calibration and validation of rain gauges. Calibrations are carried out under laboratory conditions, while validations can be carried out in either laboratory or field conditions. Validations are a check to confirm that an instrument is recording within the tolerances of its calibration.

5.1 Calibration of Intensity Gauges

5.1.1 When to Calibrate

Intensity gauges shall be calibrated at intervals specified by the manufacturer, and a record of this shall be filed with the metadata.

5.1.2 How to Calibrate

Calibrations shall be carried out in a suitably equipped laboratory, by competent technicians. For more information on calibration of rain gauges, see Annex G – 'Calibration of Intensity Gauges'.

5.2 Validation of Intensity Gauges

5.2.1 When to Validate

Intensity gauges are often purchased with a factory calibration. Despite this, they shall be validated once received to ensure no change or damage has occurred in transit. Other times when gauges shall be validated are:

- prior to deployment at a site
- upon removal from a site
- annually
- when the gauge's recorded rainfall deviates from the primary reference gauge by more than 10% or > 5mm (where less than 50 mm of rain has fallen), and
- when received back from a calibration agent.

5.2.2 How to Validate

There are two acceptable methods of validation: the burette method, and the volumetric method. For further explanation, calculation and a list of common theoretical values, see Annex H – 'Validation of Intensity Gauges'.

5.2.2.1 The Burette Method

The burette method involves the gradual release of water via a burette into each bucket of the rain gauge. The results of this test must be within 5% of the known theoretical tip value for each bucket as determined by the manufacturer in order to pass validation.

5.2.2.2 The Volumetric Method

The volumetric method passes a known volume of water through a rain gauge at a known, consistent rainfall rate. The resulting number of tips will determine whether or not the gauge has passed validation.

In gauges with a siphon, the allowable deviation from theoretical tip counts is ± 5%. In gauges without a siphon, the allowable deviation from theoretical tip counts is –10% to +5%. This allows for potential losses, but does not allow the gauge to over-record in an excessive manner as a gauge should not be gaining tips in these situations.

6 Data Processing

This section deals with the requirements for filling gaps in continuous record. All gaps should be filled in long-term continuous data sets. While there are multiple methods for doing this, there is a hierarchy of quality that applies, as described below. For guidance on data processing methods and standards for rainfall data, refer to NEMS *Data Processing* (currently under development and scheduled for release in 2017).

6.1 Filling Gaps Using Backup Intensity Gauge Data

This is the preferred method for filling gaps in long-term intensity data. Backup gauges generally have a lower recording resolution than the primary intensity gauge on site, but they provide a real data stream that can be assessed against the Site Matrix and Data Quality Matrix. The primary reference gauge data can then be apportioned to the backup intensity gauge as you would your normal intensity gauge. The information, quality code and matrix score shall be filed with the processing notes.

6.2 Filling Gaps with Synthetic Data

Filling gaps with synthetic data becomes necessary when:

- primary reference gauge data are missing
- intensity gauge data are missing without a backup intensity gauge on site
- gauge(s) are not valid or appear compromised, or
- the data logger has failed.

There are multiple ways of deriving synthetic record for a site. Regardless of the method used, the agency responsible shall:

- state the method used including:
  - the formula used to derive the record
  - the sites used to derive the relationship and their metadata
  - the uncertainty value, and
  - the program(s) used to derive the data
- quality code the resulting data QC 300.

All of this information shall be filed with the metadata and processing notes.

6.2.1 When Gaps Are Not Filled

All efforts shall be made to fill gaps in record. Where deriving a synthetic relationship is not possible, or it is believed to be unrepresentative of the site, the gap shall be filed as missing record and quality coded accordingly.

Annex A – List of Referenced Documents

British Standards Institution (BSI). (2010) *Hydrometry. Specification for a reference rain gauge pit* (BS EN 13798:2010). London, UK: Author.

Frisinger, H. H. (1977). *The history of meteorology to 1800* (pp. 88–91). Boston, MA: American Meteorological Society (Science History Publications).

Holwerda, N. (2015). Rainfall and oil. *Current* (newsletter of the New Zealand Hydrological Society), *47*, 13.

Sevruk, B. (1982). *Methods of correction for systematic error in point precipitation measurement for operational use* (Operational Hydrology Report 21). Geneva, Switzerland: World Meteorological Organization.

Annex B – Topography

Site topography is defined by the slope at which the site including its surrounding 200m is situated.

Calculating the Slope of a Site

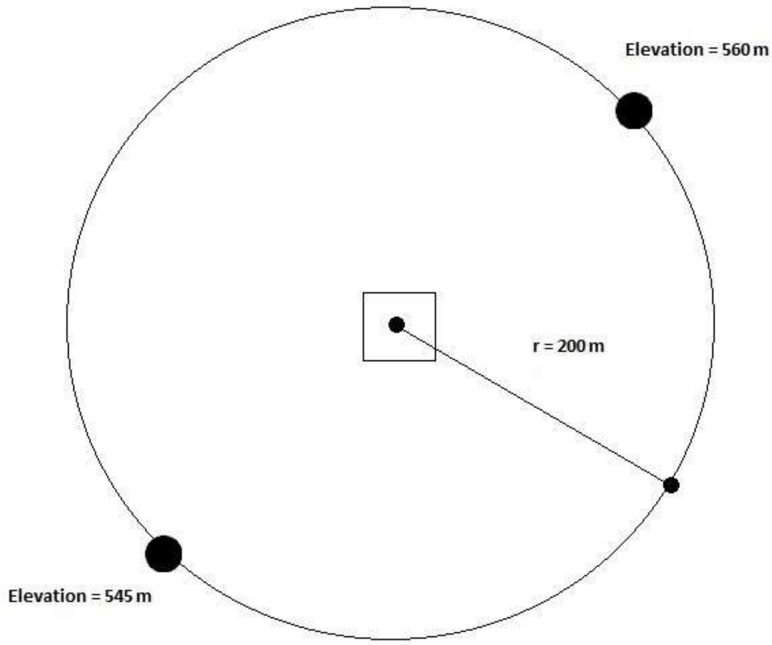
The slope of the site can be calculated using the following trigonometric formula:

$$\text{Tan } \theta = O/A \text{ (opposite/adjacent)}$$

where: θ = slope (in degrees)

O = elevation change within the extent measured (maximum elevation – minimum elevation)

A = diameter of the area measured (400 m)



O = (560–545) = 15

A = 400

Tan θ = 15/400

or

θ = Tan^{-1} (15/400)

θ = 2.15^0

Figure 1 – Example of slope calculation

Annex C – Exposure

Exposure is identified using the average annual wind speed at a rainfall site, or as measured in its vicinity. This can be mitigated using wind shields, semi-permeable shelter planting, or a ground-level deployment with an anti-splash grid.

Calculating the Exposure at a Site

To establish the average annual wind speeds at a site, agencies can use wind data collected from a wind sensor deployed at site. Where no 'at site' data is available, agencies can find average wind speed using climate maps of median average annual wind speed; see an example on the following page.

Currently, these climate maps are available online at:
https://www.niwa.co.nz/climate/research-projects/national-and-regional-climate-maps

For higher-quality versions of these maps, contact NIWA at climate-enquiries@niwa.co.nz

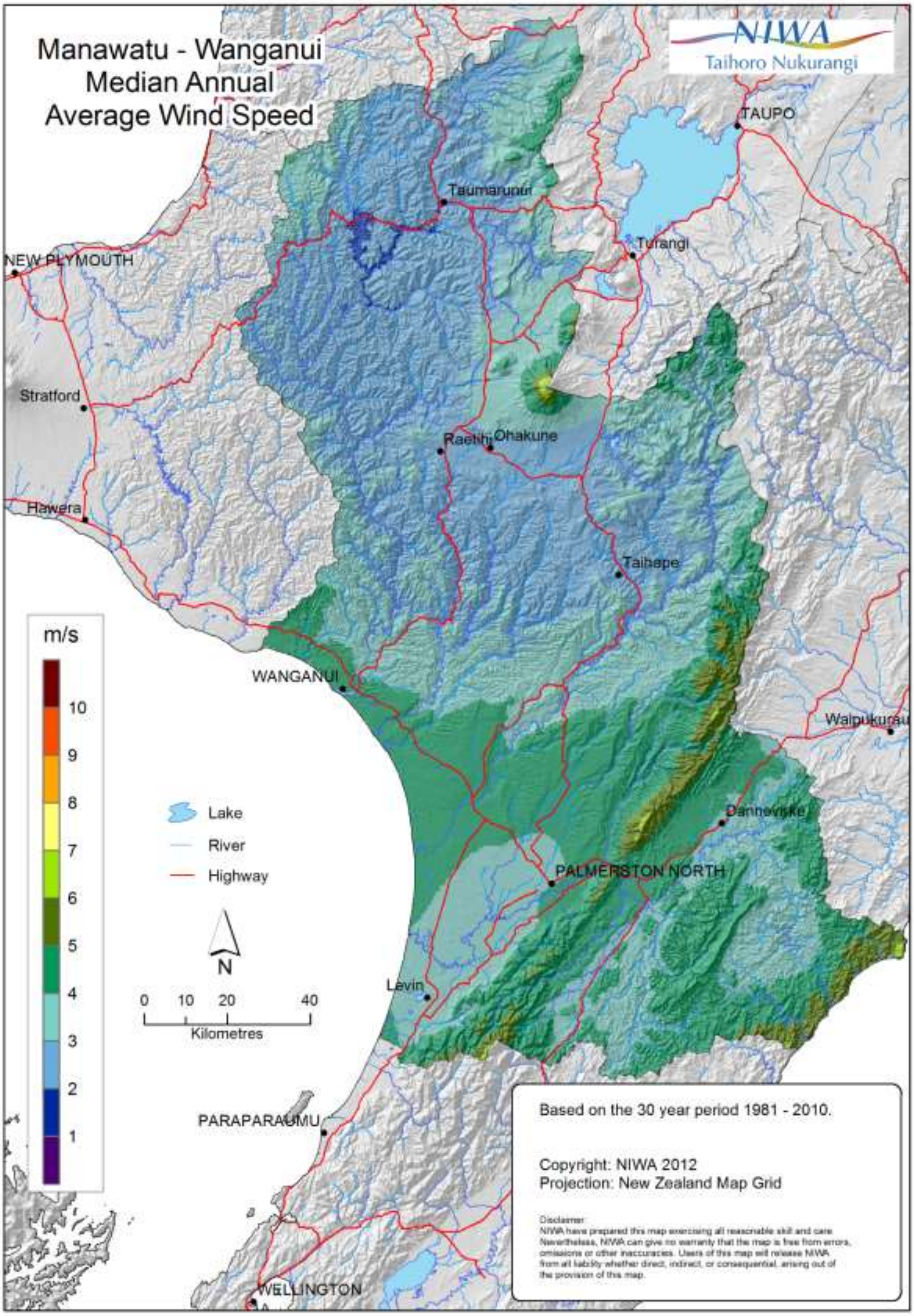


Figure 2 – Map of median annual average wind speed
Source: The climate and weather of Manawatu-Wanganui, NIWA, 2012.

Annex D – Obstructed Horizon

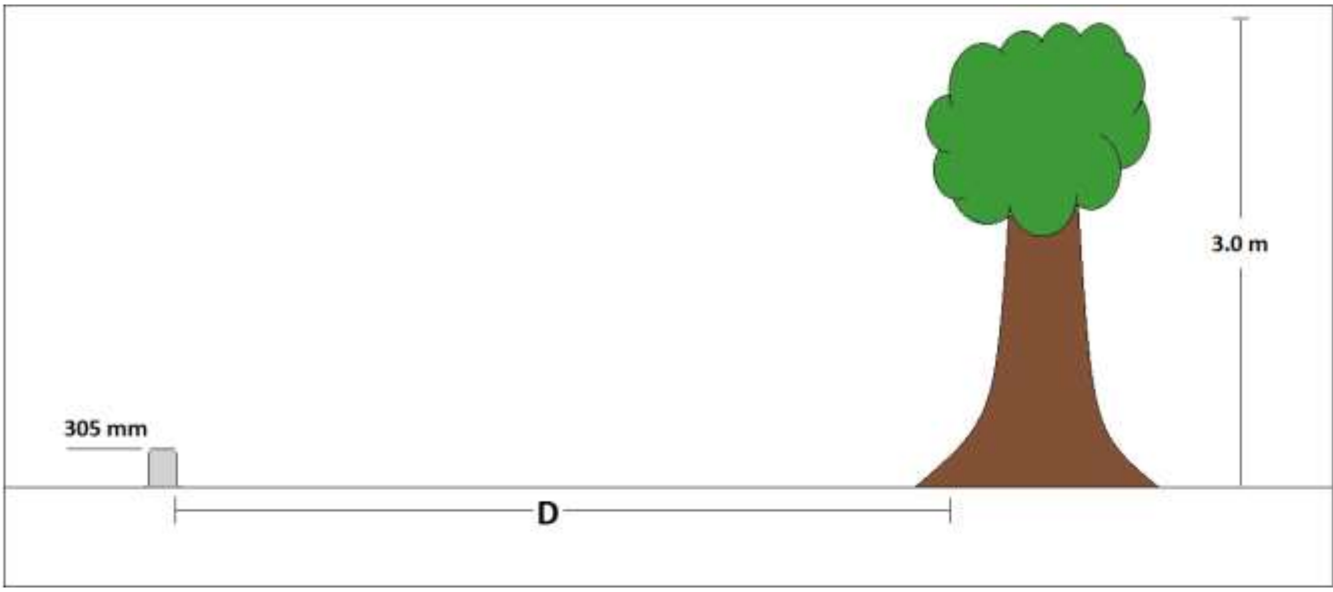
Determining if a Gauge is Obstructed

A gauge is deemed to have an obstruction if any object is located within a distance less than two times the difference between the object's height and the gauge height within a 100-m radius of the gauge.

Example

A primary reference gauge stands 305 mm high and a nearby tree is 3 m tall. In this instance, if:

- D < 2 x (3–0.305) m, it will be deemed an obstruction



- D ≥ 2 x (3–0.305) m, it is not deemed an obstruction.

Figure 3 – Obstructed horizon example

Methods for Determining Obstruction and the Level of Obstruction

Any objective measurement method can be used to determine obstruction. It can be done manually via tape measure or laser measure with an angular reference, and it can also be determined via hemispherical photography.

<u>Determining Obstruction via Laser Measure or Tape Measure</u>

Using this method, the observer measures the height of any potential obstruction, the height of the gauge, and the distance to the object using either a tape measure or laser measure. The observer then manually calculates whether or not any objects fall within the 2:1 rule. Photos of the objects should be taken from the gauge, at the rim height of the gauge, for future reference and to be filed with the metadata for the site.

To determine the degree of obstruction manually, observers can use a compass, or an angular reference such as a protractor to establish the angle that is being obstructed. This should be done from the gauge in order to determine not only the degree of obstruction, but whether multiple obstructions fall within a 45° segment, for use in assessing the site against the rainfall site matrix.

<u>Hemispherical Photography</u>

This method involves the use of a camera equipped with a fish-eye lens, and a reference object within the field of view of the camera. Photos must be taken from each gauge, and from the rim height of the gauge.

A reference object should be set up at the 2:1 level; for example, an object set at 1 metre higher than the gauge, and 2 metre away from the gauge. This is done to eliminate the possibility of lenses with different distortion factors biasing the results. In looking at the resulting photographs, anything that is closer to the centre of the image than the reference point is an obstruction.

To determine the degree of obstruction, a digital overlay of an angular reference can be added to the image to quickly establish how many degrees the obstruction spans. Alternatively, this can also be done manually by the observer with a protractor over the image.

All photographs, processed and unprocessed, should be filed with the metadata along with the degree of obstruction in the image.

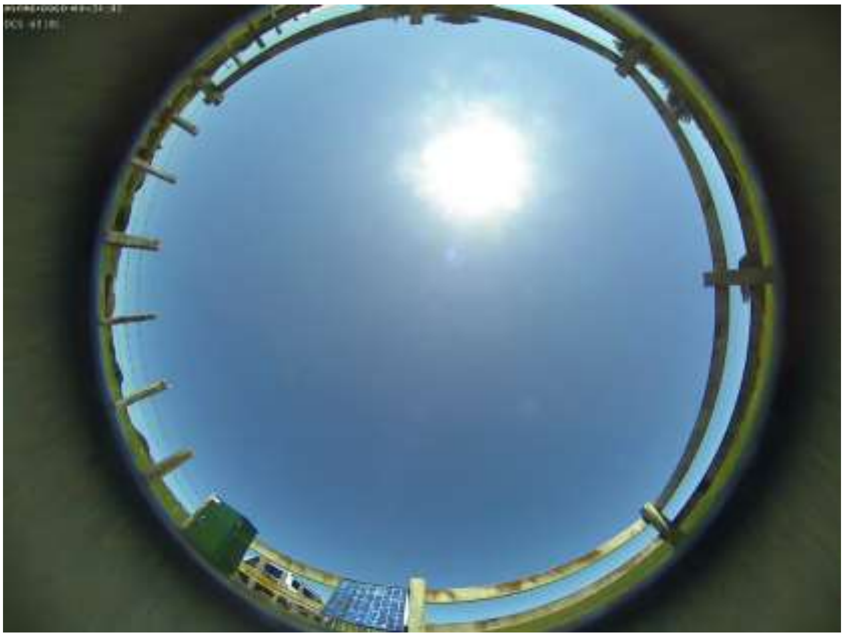


Figure 4 – Photograph taken with hemispherical camera

Photograph: Micah Dodge, Horizons Regional Council.

If an obstruction identified in these photographs can be safely removed and there are no issues doing this with land owner, then this should be carried out, documented and photographs should be taken and filed as metadata.

Annex E – Anti-Splash Grid Design

Anti-splash grids for primary reference gauges and intensity gauges are recommended because they can reduce both wind effects on the gauge and the risk of splash around the orifice. There is no prescribed way an anti-splash grid must be installed, but British Standard BS EN 13798:2010 provides guidance on an effective, standard installation of anti-splash grids.

Regardless of installation design, it is important that:

- The pit associated with the grid is deep enough to allow the gauge to be set flush with the top of the grid.
- A drain is fitted into the bottom of the pit to prevent it from filling with water.
- The grating is not more than 5 mm thick.
- To minimise splash, the square space in the centre of the grid should be 250 mm wider than the gauge diameter.
- The grid area extends a minimum of 600 mm each side of the gauge space.

Figure 5 – Anti-splash grid
Photograph: Matthew Putt, Horizons Regional Council.

Annex F – Evaporation Reduction Methods

Some primary reference gauges have washers installed on the inlet which reduce the likelihood of evaporation from the receiver canister to the outer canister. In gauges that do not have these attachments, further measures may be necessary.

While not the only method, the most common way of reducing losses to evaporation in these cases is the use of oil.

Use of Oil in Primary Reference Gauges

Oil can be used in primary reference gauges to mitigate or eliminate the effect of evaporation on stored volumes. This can occur under many different environmental conditions, but is particularly more common where warmer temperatures are combined with high wind. Standpipe gauges are particularly susceptible to this occurrence.

When to Use Oil in Primary Reference Gauges

Although not limited to these situations, if a site's intensity gauge frequently records higher rainfall than the primary reference gauge, where that deviation exceeds 10%, and the intensity gauge is passing its validation tests, it is wise to consider the use of oil in your primary reference gauge. If the primary reference gauge is a standpipe, due to their high susceptibility to evaporation, it is highly recommended that oil be used.

How to Use Oil in Primary Reference Gauges

Once the primary reference gauge has been emptied, oil is added to a known level – 5mm should be sufficient. Measure the oil level in the gauge, and record it in the site records for reference in the next inspection.

When the next inspection is done, the readings can be adjusted to take into account the extra volume in the gauge due to the oil.

Before leaving, add more oil to the gauge to return it to a known level, and record that for the next inspection.

What Oil to Use

This is presently unknown. Canola oil has been trialled with some documented success (Holwerda, 2015), but it may not be suitable in a range of temperatures. Eco-toxic or environmentally harmful oils are not allowed in national parks, so a safe and acceptable alternative needs to be developed or found for consistent use nationally.

If Oil is Used

If oil is used in a primary reference gauge, its use must be documented and filed with the metadata so the oil's effect on the recorded rainfall can be established when checked against previous record.

Annex G – Calibration of Intensity Gauges

Intensity gauges are to be calibrated in accordance with the criteria set out in Section 5.1 of this document; that is, at a suitably equipped laboratory by competent technicians. While there are multiple acceptable methods, the minimum criteria are stated below.

The calibration shall:

- be performed with:
  - a known water mass
  - an accuracy of within 2.5%, and
  - a known flow rate (or multiple rates)
- include pre- and post-calibration checks
- not be a single test; the test must be repeated
- be fully documented, and
- be returned with a certificate of calibration.

Gauges must be calibrated at an interval not exceeding that recommended by the manufacturer. While not a requirement under this Standard, if a gauge repeatedly fails validation, it is advisable to have it calibrated in order to ensure it has not deviated significantly from its stated accuracy, and to ensure ongoing data quality.

Annex H – Validation of Intensity Gauges

Intensity gauges are to be validated in accordance with the criteria explained in Section 5.2 of this document.

The Volumetric Method

This method uses a known volume of water passed through the gauge at a known rate, and assesses the gauge based on the resulting tip values. Table 1 indicates acceptable ranges for the most common gauge types deployed in New Zealand at the time of writing of this document, using a 653-ml volumetric device.

Table 1 – Acceptable volumetric validation ranges for common gauges

Gauge Type	Gauge Resolution (mm)	Bucket Tipping Volume (ml)	Allowable Tip Range
OTA	0.5 mm	15.70	37 to 44
	0.2 mm	6.28	94 to 110
TB3 (with siphon)	0.5 mm	14.40	39 to 44
	0.2 mm	5.20	99 to 110
TB3 (without siphon)	0.5 mm	15.70	37 to 44
	0.2 mm	6.28	94 to 110

To Validate Using the Volumetric Method

1. **Perform validation as per the manufacturer's instructions for the volumetric device.**
2. **Record the number of tips achieved by the gauge.**
3. **Assess the value against the theoretical values. If the value is outside of the –10% to +5% range, the gauge fails validation.**
4. **Record the result of the test and file it with the metadata for the site.**

The Burette Method

The burette method involves manually adding water to the tipping bucket of the rain gauge in a controlled fashion in order to make the bucket tip, and knowing how much water you have added to do so. Using the burette method, it is easier to see if there is any bias in the buckets of your rain gauge. Each gauge type has its own theoretical tipping value based on the catch area and stated resolution of the gauge (for example, 0.5 mm).

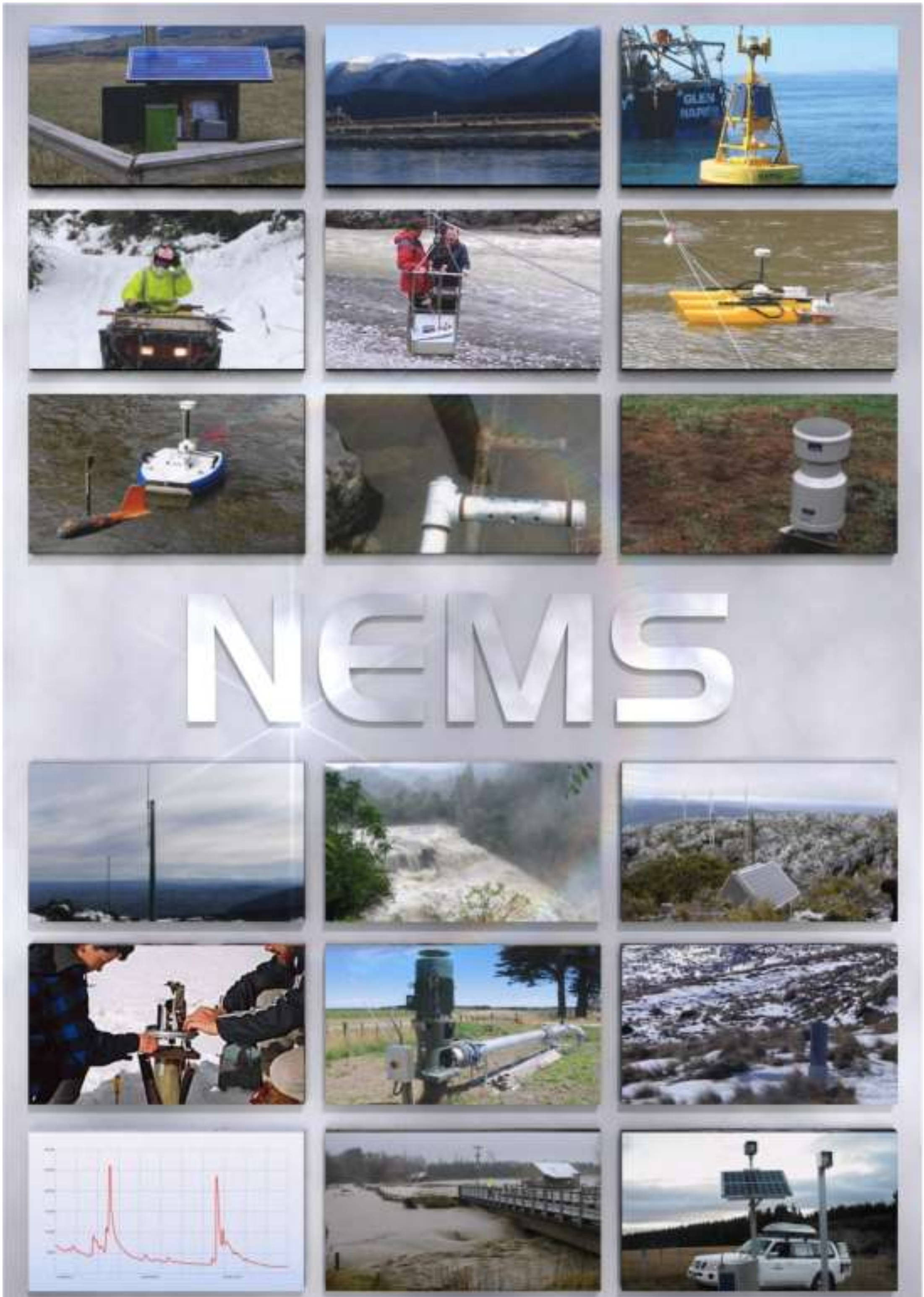
To Validate Using the Burette Method

1. **Fill the burette to a known point, usually the 0 point.**
2. **Slowly release water directly into the bucket, reducing the rate to single drops as you approach the tipping point.**
3. **Immediately shut off the burette once the bucket tips.**
4. **Record the volume of water used.**
5. **Repeat this test a minimum of four (4) times per bucket, and take the mean result for each bucket.**
6. **Check the result against the theoretical tipping volume; if the result deviates by more than 5%, the gauge has failed validation.**
7. **Record the result of the test, and file it with the metadata for the site.**

Table 2 shows the theoretical bucket tip volumes for some of the most common gauges deployed in New Zealand at the time this document was written.

Table 2 – Acceptable burette validation ranges for common gauges

Gauge Type	Gauge Resolution (mm)	Bucket Tipping Volume (ml)	Allowable Range
OTA	0.5 mm	15.7	14.9 to 16.5 ml
	0.2 mm	6.28	5.9 to 6.6 ml
TB3 (with siphon)	0.5 mm	14.4	13.7 to 15.1 ml
	0.2 mm	5.2	4.9 to 5.5 ml
TB3 (without siphon)	0.5 mm	15.7	14.9 to 16.5 ml
	0.2 mm	6.28	5.9 to 6.6 ml


NEMS