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New Zealand Piped Irrigation System Performance Assessment Code of Practice



JANUARY 2023

IRRIGATION
NEW ZEALAND

Contents

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Background

WHY SHOULD WE HAVE A CODE?

Good, well managed irrigation is beneficial for agriculture, the wider economy and to our communities. Poor irrigation can have negative economic and environmental impacts through reduced yields and wasted water, nutrients and energy.

As the largest user of water in New Zealand, the irrigation industry understands its obligation to manage water and to recognise the rights of other users. Implementing the Code will ensure irrigation is sustainably managed, accountable, responsible and trusted.

Adoption of this Code will enable cost effective, defensible assessments of irrigation systems and management, and identify opportunities for improvement. This will directly benefit irrigators, the environment and the community.

WHAT IS THE CODE?

The *New Zealand Piped Irrigation System Performance Assessment Code of Practice* provides standardised guidelines to measure and benchmark performance of irrigation. This code applies to assessments of pressurised irrigation systems, performed on-site under prevailing conditions typical for that system. The level of implicit statistical error resulting from selected methodologies must be noted.

The Code uses performance indicators that are common with the *New Zealand Piped Irrigation Systems Design Standards*, allowing benchmarking while recognising the unique character of individual farms, their irrigation requirements and constraints.

WHAT IS NOT IN THE CODE?

The Code does not cover testing to validate an original equipment manufacturer's (OEM) design or construction of a particular make or model of irrigation machine nor assessments of that equipment for the purposes of supplying generic design or sales information. OEMs should follow relevant standards for equipment manufacture such as those published by the International Organisation for Standardisation.

WHO SHOULD USE THE CODE?

The code Is written for those performing calibrations and evaluations to ensure consistency in testing and reporting across the range of service providers. As such it is written from the perspective of an evaluator. This does not mean that the code can not be used by irrigation system owners/operators; they can and should use this code as required.

REGULATION AND THE COP

While the Code was not written for regulatory purposes, performance assessment of irrigation systems is now becoming a regulatory requirement. Regulators should become familiar with the benefits of the information provided from a performance assessment and the limitations of both a system calibration and a full assessment. As these two methodologies provide different levels of system performance information IrrigationNZ recommends that assessments for regulatory purposes should follow the calibration methodology.

OTHER RELEVANT GUIDANCE DOCUMENTS

- New Zealand Irrigation Technical Glossary
- New Zealand Piped Irrigation Systems Design Code of Practice
- New Zealand Piped Irrigation Systems Design Standards
- New Zealand Piped Irrigation Systems Installation Code of Practice
- New Zealand Water Measurement Code of Practice
- NZ Electrical (Safety) Regs

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References

RELATED CODES AND STANDARDS

International Organisation for Standardisation (ISO)

ISO 7749-2: 1990 Irrigation equipment – Rotating sprinklers – Part 2: Uniformity of distribution and test methods

ISO 8026 Agricultural irrigation equipment – Sprayers – General requirements and test methods

ISO 8026:1995/Amd.1:2000 Agricultural irrigation equipment – Sprayers – General requirements and test methods AMENDMENT 1

ISO 8224/1 – 1985 Traveller irrigation machines – Part 1: Laboratory and field test methods

ISO/FDIS 8224-1:2002 Traveller irrigation machines – Part 1: Operational characteristics and laboratory and field test methods (FDIS)

ISO 9261: 1991 Agricultural irrigation equipment – Emitting-pipe systems – Specifications and test methods

ISO 11545: 2001 Agricultural irrigation equipment – Centre-pivot and moving lateral irrigation machines with sprayer or sprinkler nozzles – Determination of uniformity of water distribution

ISO 14050: 2002 Environmental management – Vocabulary

American Association of Agricultural Engineers (ASAE)

ANSI/ASAE S436.1 DEC01 Test procedure for determining the uniformity of water distribution of center pivot and lateral move irrigation machines equipped with spray or sprinkler nozzles (ANSI)

ASAE EP405.1:2001 Design and installation of micro-irrigation systems

ASAE EP 458: 1995 Field evaluation of micro-irrigation systems [Withdrawn]

Other

ITRC Irrigation Evaluation: Drip micro 2000 [de facto standard]

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Rout, R. (2004) *Key Performance Indicators for Irrigation Design.* Irrigation New Zealand (unpublished draft)

Smajstrla, A.G., B.J. Boman, D.Z. Haman, D.J.Pitts, and F.S.Zazueta. 1998. *Field evaluation of micro-irrigation water application uniformity*. Bulletin 265, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida.

Sparrow, D. and M. Skewes. 1998. *Irr-E-Pack: Irrigation Evaluation Package, User Manual.* Primary Industries and Resources, SA. Murray Darling Basin Commission.

How to use this code

THIS CODE CONTAINS EQUATIONS AND ABBREVIATIONS, DEFINITIONS OF THESE CAN BE FOUND IN THE NEW ZEALAND IRRIGATION TECHNICAL GLOSSARY, AS SUCH BOTH THESE DOCUMENTS SHOULD BE READ TOGETHER.

PART A AND B MUST BE READ BEFORE MOVING ON TO PARTS C–H.

PART A

Introduces the process and requirements in order to carry out checks, calibrations and performance assessments. Outlines how to report your findings.

PART B

Initial checklists for compliance and water supply

PARTS C–H

Parts C–H are system specific processes for measuring system performance.

The Code recognises different levels of system performance assessment depending on purpose. In increasing level of complexity, system performance assessment includes:

1. Operational checks
2. System calibration
3. Full system performance assessment.

PART I

Part I contains additional assessments for energy efficiency and seasonal irrigation efficiency

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PART A: An Introduction to Performance Assessment

Note: This is Part A of a series of nine (Parts A–I).

Part A: Contents

Date of Issue: January 2023

The Code is presented as a series of booklets, each with a defined purpose.

Part A: An Introduction to Performance Assessment
(This booklet)
Part A provides an overview of performance assessment, explains the broad philosophy behind assessment approaches taken throughout the Performance Assessment series, and contains specific formulae and reporting standards.

Part B: Compliance and Water Supply Checklists
Part B relates to all system types. It contains recommendations for checks to ensure compliance with regulations, rules and consent conditions, safe effective operation of water supply systems.

Parts C–H: System Performance Assessments
Parts C–H contain guidelines and recommendations for Operational Checks, System Calibrations and In-field Performance Assessments specific to a range of irrigation system types.

Part I: Conducting Energy Efficiency Assessments and Seasonal Irrigation Efficiency

IrrigationNZ Technical Glossary
The Glossary and Calculations are common with the NZPIS Design Code of Practice.

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1. Conducting operational checks

The operational checks are a base set of observations to be made regularly to ensure the system is operating efficiently. Intended for use by suitable farm staff, they ensure there are no obvious performance issues or faults, and that the system is safe to operate.

Additional checks, that apply to all system types, can be found in *Part B: Compliance and Water Supply Checklists.*

See Parts C–H for system specific operational checklists:

- *Part C: Micro-irrigation*
- *Part D: Solid-set irrigation*
- *Part E: Sprayline irrigation*
- *Part F: Travelling irrigators*
- *Part G: Linear move irrigators*
- *Part H: Centre pivot irrigators*

2. Conducting system calibrations

This section presents protocols for irrigation system calibrations to be undertaken by irrigation managers and operators efficiently with minimum equipment.

Calibration involves checking irrigation system performance and making adjustments to ensure performance is as intended. Standard procedures described cover most irrigation system types used in New Zealand agriculture.

WHERE CALIBRATION FITS

These Calibration Protocols collect a minimum amount of information for a basic assessment of system performance to be completed. Only some of the potential performance indicators are determined, albeit they are key ones, and causes of poor performance are only generally identified and reported.

These protocols should be used as a relatively quick and regular check of system performance to maximise irrigation efficiency and minimise any adverse impacts. They inform irrigation managers and can be adopted as part of audited self-management programmes.

NOTE:
A calibration will normally include Operational Checks of system pressure and flow, combined with visual observations that the system is working.

NOTE:
If a more detailed assessment of performance or determination of causes of poor performance are required, a full In-field Performance Assessment should be considered.

CALIBRATION OVERVIEW

Calibration is a four step process:

1. Gathering information about the system (such as the KPIs documented in the system commissioning report and any as-built drawings) and measure in field data, make basic system observations
2. Calculate the current performance values
3. Comparing results with the original KPI expectations and report the differences
4. Make recommendations to the operator to make adjustments to irrigation system settings required to achieve intended performance.

Gathering information

Calibration begins with a simple field test which can be completed during the course of a normal irrigation event. The key measurements include determining:

- the amount of irrigation applied at specified points AND
- irrigator speed of moving systems OR
- the duration of each irrigation event of stationary systems.

The protocols are based on measurements at multiple points specified according to the type of system, and calculations to determine generic performance values.

Different irrigation system types require different data collection processes. Follow placement instructions carefully and ensure readings are as accurate as possible.

Performance indicators

Performance indicators cover key aspects of the system's operation. They are calculated from data collected during the field test.

Generic indicators that apply to all systems include:

- the depth of irrigation applied during an irrigation event
- the intensity of application and
- how uniformly the irrigation is distributed to the land surface..

Applied depth is the rainfall equivalent amount of irrigation applied, measured as depth, typically millimetres. It is an average across the irrigated area where the calibration test is performed. Applied depth is calculated by dividing measured irrigation volumes by the area to which they are applied.

Application Intensity is a measure of how quickly the water is applied and is compared to the soil's ability to absorb water as it lands. Excessive intensity can cause surface ponding and runoff, and reduce irrigation efficiency and effectiveness

Distribution Uniformity (DU) describes the evenness of application across the irrigated area. The higher the DU, the better the system is performing.

Other performance indicators specific to system type may be determined.

Adjusting settings

Comparing calculated with intended performance exposes any deficiencies. Adjustment recommendations can be made to correct or allow for performance differences.

Example:
Travelling irrigators may be sped up to apply less irrigation, or slowed down to apply more. If this is not possible, the return interval might be adjusted.

Example:
Solid set systems, including spraylines and micro systems with multiple blocks can be run for different times to achieve intended irrigation depths.

NOTES:

- Irrigation Calibration provides information for the system operating only where the test is completed (i.e. only the sampling points taken or the position of the irrigator machine in the field), running at the pressure and weather conditions on the day.
- Calibration should be undertaken on a regular basis to ensure performance is maintained. An annual calibration is recommended.
- Where a number of significantly different blocks are involved in an overall system, calibration of each separately managed block should be considered.
- If findings are unexpected, or suggest low performance, the performance assessor could make additional field observations of system issues or failing that seek additional advice from the operator or the supplier company.
- Low distribution uniformity may indicate poor sprinkler or emitter condition, or may indicate insufficient pressure in the system. Adjustments can be recommended to the operator and a new field test completed.

NOTE:
It is not normally the role of the performance assessor to correct system failings unless they are qualified to do so and have the authorisation from the system owner/operator.

CALIBRATION PROTOCOLS

All calibrations report on the same critical performance indicators. However, the methods for collecting data in the field and the details of calculations vary between system types. Therefore a series of Calibration Protocols covering different system types are provided.

See Parts C–H for system specific calibration protocols:

- *Part C: Micro-irrigation*
- *Part D: Solid-set irrigation*
- *Part E: Sprayline irrigation*
- *Part F: Travelling irrigators*
- *Part G: Linear move irrigators*
- *Part H: Centre pivot irrigators*

3. Conducting full system performance assessments

This section presents procedures for efficient and reliable full system performance assessments conducted in the field. Procedures for planning, conducting, analysing and reporting system performance are described.

The following procedures were developed as guidelines for full system performance assessments of irrigation systems. While the field testing is still a 'snapshot' taken under prevailing field conditions, the more extensive evaluations are intended to provide informative reporting that promote good system management and maintenance, supports efficient irrigations scheduling practices and can assist In comparison of systems during development.

WHERE FULL SYSTEM PERFORMANCE ASSESSMENT FITS

A full system performance assessment seeks objective information for analysing performance. More detailed than a simple calibration, it collects a broader suite of KPI information to identify departures from the design KPI arising from problems and their causes, enhance performance, or demonstrate compliance with regulatory or market requirements.

The Parts C–H take into account international practices and standards, which prescribe different procedures and sampling methods but are not necessarily equivalent to these international practices and standards. Parts C–H attempt to encompass thorough testing requirements but ensure that procedures are cost effective and practical which is why they can stray from the international practices and standards at times.

FULL ASSESSMENT OVERVIEW

Irrigation full system performance assessment procedures objectively check an irrigation system and management practices, and allow a system to be benchmarked against the original design KPIs and in some cases established design standards. Irrigation maintenance and management plans can be drawn up to improve the system use of water, energy and labour.

In addition to in field measurements and calculations of depth, rate and uniformity from test results for determination of water application efficiency, a full irrigation performance assessment may include:

1. Visual inspection
2. Assessment of pump, pipe and filter performance including energy use
3. Seasonal irrigation efficiency estimation.

Each process involves evaluating the system in its current state as per a calibration assessment but in addition takes into account an assessment of current or historic management practices. Analysis and reporting compares these results to the design KPIs, specified standards or benchmarks, and makes recommendations for improvement.

NOTE:
Like a calibration level assessment, that is the start of the improvement process, a full performance assessment is further part of the process towards irrigation "best practice". It is important that managers use the generated information to develop irrigation management and maintenance programmes that continuously improve the irrigation system and practice.

ASSESSMENT VALIDITY AND RELIABILITY

Selected measurements are taken of the system at a given time and place. Actual in-field measurements are preferred wherever possible over and above assumed data. This ensures that the generated results describe what is happening, not what is supposed to happen.

By following the assessment procedures diligently the full assessment will provide satisfactory accuracy and identify causes of non-performance as well as their effect on overall performance. They provide irrigator owners, regulators and other stakeholders with confidence that findings are valid, repeatable and comparable.

Technical note regarding reliance on the assessment outcomes: Some parameters, in particular distribution uniformity, are determined using stratified or targeted sampling approaches in preference to strict randomised sampling. This helps identify the factors contributing to non-performance. In practice, this has been shown to give similar performance results to randomised sampling, but in any case, limitations and confidence levels should be recognised.

KEY PERFORMANCE INDICATORS

Key performance indicators are presented in the *New Zealand Piped Irrigation System Design Code of Practice*. They include:

Water use efficiency

- Crop irrigation demand
- Management allowable deficit
- Return interval
- Application uniformity
- Application intensity
- Application depth
- Adequacy of irrigation
- Application efficiency
- Distribution efficiency
- Headwork efficiency
- Supply reliability
- System capacity.

Other efficiency indicators

- Energy
- Labour
- Capital
- Capital cost
- Operating cost
- Effectiveness
- Productivity
- Returns
- Environment
- Average system efficiency
- Drainage
- Runoff.

Indicators selected for this Code relate to estimates of efficiency across an irrigated growing season or year. They provide information relating to economic or environmental implications of inefficient irrigation systems or management.

APPLICATION OF PARTS A–H

These Parts are stand-alone guidelines to determine irrigation system performance in the field. They provide information for inclusion in assessments of irrigation efficiency, and can be combined with other assessments such as energy efficiency and pump performance.

The guidelines describe procedures that ensure:

- evaluations are representative of normal operating conditions
- key in-field system performance observations are recorded
- sampling is undertaken in a way that permits extrapolation and comparison
- key performance indicators are assessed and calculated accurately and correctly
- results are reported in standard units and formats so that comparisons may be made.

Planning an assessment

Appropriate preparations should be made prior to visiting the field. These preparations include collection of relevant data about the system and its management, ensuring all required equipment is available, and that the system will be ready for testing when the evaluator arrives at the field.

NOTE:
Basic system checks should be completed before the performance assessment is undertaken.

VISIT PLANNING

There are benefits in the usual system operator being involved in the assessment, to operate the equipment safely and in the usual way, and to understand the assessment process. A performance assessor should consider halting testing if the operator is not available at the initial system start up and should expect not to conduct the testing alone (which is also sensible for safety considerations).

Agreements to be obtained prior to the visit include:

Assessment date(s)

1. Setting a date, time and meeting place
2. Any site specific safety briefing or farm management protocols (e.g. emergency points of contact, stock movements, gate positions, system lock outs and operator instructions during the test period)
3. **Ensuring any required support staff will be present and available**

Service and fees

4. Confirming assessment(s) to be conducted
5. Establishing how results will be reported
6. Establishing fee for service

System availability

7. Ensuring the system will be available for assessment
8. Ensuring any system maintenance has been completed
9. Ensuring access to irrigation system, equipment and suitable position in the field.

Conducting an assessment

The following is a series of checklists that provide guidance for steps to be undertaken during a system calibration or full system performance assessment.

PROJECT NAME: ______________________________

DATE: ______________________________

PRE-SITE VISIT INFORMATION CHECKLIST

Much required information can be obtained through a general questionnaire completed by the irrigation manager. The minimum expected information that should be sought by a performance assessor prior to conducting an assessment includes:

General property information

- ☐ Owner/Contact name and details
- ☐ Property location and address
- ☐ Property plan, aerial photos, contour map
- ☐ Enterprises

Climate information

- ☐ Long term rainfall data
- ☐ Long term ET data
- ☐ Current or Last Season rainfall
- ☐ Current or Last Season ET

Soils information

- ☐ District/property soil maps
- ☐ Soil texture
- ☐ Soil water holding capacity data
- ☐ Soil limitations

Farm water supply information

- ☐ Water source and quality
- ☐ Resource consent limits and conditions
- ☐ Overall system layout
- ☐ Total flows
- ☐ Filtration type

Irrigation system information

- ☐ Permanent system layout
- ☐ Movable system positions
- ☐ Age and condition
- ☐ Connection to farm water supply
- ☐ Irrigation machine type
- ☐ Motive power and operating speed
- ☐ Controller location
- ☐ Operating instructions
- ☐ Design flow
- ☐ Operating pressure
- ☐ Sprinkler package
- ☐ Whether other water takes influence the system

Irrigation management information

- ☐ Irrigation need monitoring
- ☐ Irrigation interval (rotation length)
- ☐ Irrigation duration
- ☐ Target application depth

MEET THE IRRIGATOR

The owner/manager should:

- ☐ Be present during the assessment, to ensure the equipment is operated correctly, consistent with usual practice
- ☐ Make adjustments or alterations to the machine, and provide assistance if required
- ☐ **Take responsibility for any jobs that involve tampering with the irrigation system, such as fitting pressure gauges or flow meters**

CONFIRM QUESTIONNAIRE RESPONSES

In consultation with owner/manager:

- ☐ Review pre-visit questionnaire responses
- ☐ Further Investigate missing details as required
- ☐ Review or draft property and system plans

CONFIRM ASSESSMENT DETAILS

In consultation with owner/manager:

- ☐ Confirm purpose of assessment
- ☐ Confirm normal and test operating conditions
- ☐ Locate key features and components in the field
- ☐ Select test locations and type of test to be conducted

CONDUCT PRE-TEST INSPECTION

- ☐ Observe crop growth patterns and record abnormalities
- ☐ Assess soil condition, root depth and estimate water holding capacity
- ☐ Assess wheel track condition on moving systems
- ☐ Familiarise with system layout and components
- ☐ Measure and record topography if variable, focusing on key system points

SET-UP TEST EQUIPMENT

- ☐ Install temporary flow meter if used
- ☐ Fit pressure test points as required
- ☐ Determine location for, and set out collectors
- ☐ Set out speed test markers
- ☐ Establish weather monitoring location and equipment

PRE-START CHECKS

- ☐ Take water meter readings
- ☐ Take power meter readings if possible and specific to the system being tested
- ☐ Check headworks components and layout as prescribed
- ☐ Assess filter condition and record contaminant type and amount
- ☐ Assess sprinklers or emitters for blockages or wear

OPERATING CHECKS

The owner/manager should operate the system, including automatic controllers and motor starting.

WITH SYSTEM OPERATING

- ☐ Check flow rates measured by water meter
- ☐ Check for correct equipment functioning
- ☐ Measure un-irrigated machine or boom lengths
- ☐ Record system pressures at prescribed locations
- ☐ Assess surface ponding
- ☐ Assess for crop interference
- ☐ Assess leakages and off-target applications
- ☐ Conduct machine speed tests as required

SPRINKLER/OUTLET CHECKS

- ☐ Check sprinkler or other outlet operation and record abnormalities
- ☐ Measure outlet flows as prescribed
- ☐ Determine wetting radius of sprinkler package and/or end-guns etc.

UNIFORMITY TESTING

- ☐ Record key weather conditions throughout test period
- ☐ Lay-out uniformity collectors according to test arrangement
- ☐ Collect applied water in collectors
- ☐ Set up evaporation collectors as soon as collector volume measurement begins and record volume and time
- ☐ As collectors stop receiving water, begin recording measurements, including the time for each reading
- ☐ At completion, record evaporation collector volumes and the time.

SPECIFIC TESTS

Conduct any tests specific to the irrigation system type or assessment. Examples may include:

- ☐ Alternative pressure/flow tests for micro-irrigation systems
- ☐ Specific span tests on pivot or linear systems
- ☐ Alternative gun-angle tests on travellers

POST-TEST CHECKS

- ☐ Take flow meter readings
- ☐ Take power meter readings, if possible and relevant
- ☐ Observe system drainage patterns
- ☐ Nozzle and regulator checks against design sprinkler chart documented at time of commissioning
- ☐ Ensure all data readings have been made and recorded

PRE-LEAVING CHECKS

(Ideally in the presence of the owner/manager)

- ☐ Ensure test and temporary equipment is recovered
- ☐ Ensure the system is returned to pre-test condition
- ☐ Ensure system is closed down or returned to automatic settings as required

Data analysis

Much of the data analysis requires repetitive and relatively complex calculation. The use of prepared software is recommended.

SOFTWARE

Supporting software packages are available from a variety of sources but an assessor should understand the limitations of software tools and the degree of accuracy they will provide. Software should not be a substitute for understanding of the necessary calculations that can be made manually. Software often prompt evaluators to make and record particular measurements or assessments, assist with the calculations, and generate reports and recommendations based on inputted values.

The various software packages may not use the same units as those prescribed in these guidelines, and may be based on different procedures of sampling methods. If these factors are noted, most can be adapted to the requirements outlined in this section of the code.

Current software options Include:

- Bucket Test (App for calibrations)
- IRRIG8Lite (free software for calibrations)
- Irrig8 (restricted software for full system performance evaluations)
- DairyNZ's "bucket test calculator" (Excel sheet available to download from their website).

DETERMINE SYSTEM PERFORMANCE

1. Process collected data as prescribed to calculate the key performance indicators for the system as tested
2. Complete other system analyses as required
3. Compare results to benchmark values
4. Identify key causes of non-performance
5. Assess the contribution of factors to overall performance
6. Estimate cost savings that may be achieved from system and/or management improvements.

Equipment specifications

COLLECTORS FOR SPRAYER AND SPRINKLER IRRIGATION

These guidelines apply to collectors (catch cans) used to intercept irrigation water under sprayer or sprinkler irrigation systems where only a part of the flow from one or more sprayers or sprinklers is captured.

NOTE:
The guidelines for collector design and dimensions established in this Code are based on specifications for collectors established in ISO 7749-2:1990, and in ISO 11545:2001(E).

NOTE:
Where a performance assessment is conducted according to specifications in any recognised standard, the collectors must meet the specification established in that standard.

Minimum requirements for collectors

Ensure that all collectors used for a test are identical and shaped such that water does not splash in or out.

Ensure that the lip of the collector is sharp, symmetric and without depressions or deformities.

Ensure the entrance diameter (mouth) of the collector is half to one times its height, but not less than 75mm.

Ensure that the height of the collector is at least twice the average depth of water collected during the test, but not less than 150mm.

NOTE:
Collectors that are intended for collecting water for transfer to a measuring device, will have a sharp edged round opening as described above. They may be cylindrical or conical, with sidewalls inclined to at least 45° from the horizontal.

NOTE:
Other types of collectors may be used, provided that their accuracy is not less than the accuracy of the collectors described above.

Minimising error

To minimise measurement error, testers are encouraged to use collectors that are as large as possible (ISO). A 10 litre bucket with a mouth opening of 250–300mm is generally practical.

NOTE:
Many buckets have a widened lip/rim, in which case the best estimate for diameter is to measure to the centre of the rim. Set collectors level, and so their mouth is the same height as, and not affected by, the canopy.

COLLECTORS FOR MICRO-SPRINKLER IRRIGATION

The guidelines for collectors established in this part of the Code apply to micro-sprayers and sprinklers where the entire flow from an individual emitter is collected for measurement. There is currently no international specification for this test.

Special consideration must be given to in-field measurements in orchards where one sprayer or sprinkler is used to apply water to two young plants with small root systems. Careful observation will identify whether plants are receiving applied water.

Minimum requirements for collectors

The minimum requirement for collectors is that all water emitted is collected without affecting the flow rate of the sprayer or sprinkler by blocking flow or causing pressure changes. This will involve shrouding the sprayer or sprinkler with a vented cover in such a way that normal operating pressures and flows are maintained.

Minimising error

To minimise measurement error, testers must ensure that normal operating pressures and flows are maintained. Either of two alternative approaches may be used:

1. Place a shroud over the sprayer or sprinkler in-situ and direct the captured flow to a second vessel for collection (Figure 1.1)

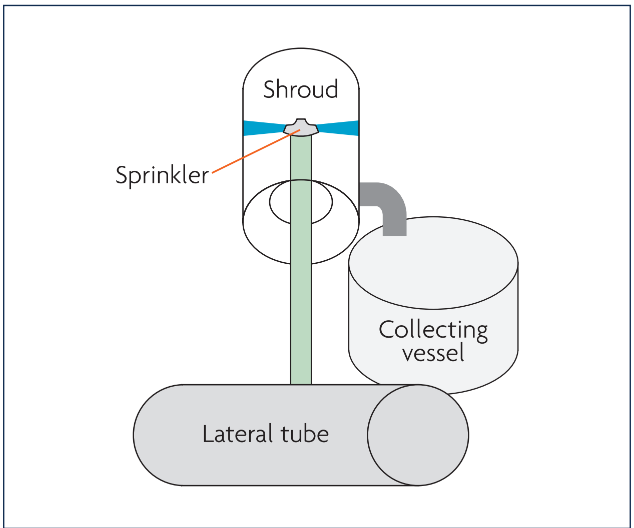

Figure 1.1. Shroud for sprayer discharge collection

2. Place the sprayer or sprinkler in a container ensuring the sprayer or sprinkler outlet is not flooded and is at the same elevation as in the field. For sprinklers that are above the canopy, these should be tested at their usual height and not lowered to the ground. This will impact pressure and therefore performance.

COLLECTORS FOR DRIPLINE IRRIGATION

The guidelines for collectors established in this Code recognise the specifications for collectors established in ISO 9261:1991(E) *Agricultural irrigation equipment – Emitting pipe systems –* Specification and test methods apply only to new pipe and emitting devices measured in laboratory conditions.

In-field measurements, especially of buried dripline, require special consideration. Pressure measurements along the laterals become a key test where water cannot be collected from drippers.

Minimum requirements for collectors

The system of collection used must capture all the flow from the section of pipe or emitters being assessed without affecting the flow rate of the sprayer or sprinkler by blocking flow or causing pressure changes.

Minimising error

To minimise measurement error, testers must ensure that all flow is captured and normal operating pressures and flows are maintained. Practically, this can be done by placing stopper rings around the pipe at the end of the section being measured, and a collection tray underneath the pipe or emitter in situ ensuring the outlet is not flooded and is at the same elevation as in the field (Fig 1.2). The captured flow should be transferred to a second vessel for measurement.

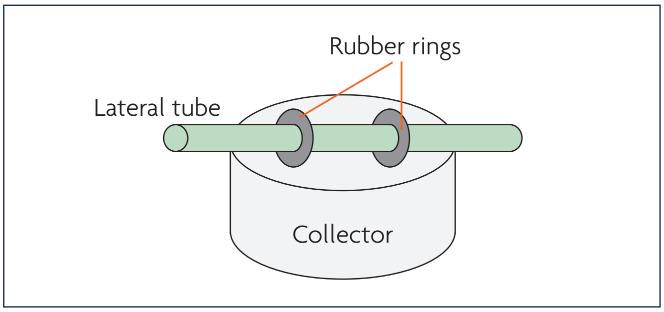

Figure 1.2. Drip-line collector

MEASURING DEVICES

Measuring devices should be cylindrical (rather than conical) and graduated with marks at no less than 10% of the volume being measured to avoid interpolation errors in reading.

Ideally the measuring device capacity will exceed the volume to be measured. This avoids error and time involved in splitting collected volumes into multiple readings.

Standard plastic measuring cylinders of a range of volumes (100–2,000mL) are suitable for field use.

PRESSURE GAUGES

Meet specifications in adopted standards

Where an audit is conducted according to specifications in any recognised standard, the pressure gauges and sampling methods must meet the specification established in that standard.

Existing accuracy standards

ISO Standards 7749-2:1990, 11545:2001, and 9261:1991 specify that pressure gauges shall have an error not exceeding ± 2% of actual values.

ISO 8224/1:1985 Travelling irrigation machines establishes that pressure gauges shall have an error of less than ± 10 kPa.

For practical purposes, gauges with error of less than ± 2% of actual values should be used.

Gauge reading range

The pressure gauge used should have a reading range that is centred on the pressure value being taken.

Measurement techniques

A variety of pressure measurement techniques and positions are specified in standards and other guidelines. The critical factor is to ensure the same method is used for all similar measurements in any evaluation exercise.

Micro-irrigation laterals

Unless pressure test points are fitted to a micro-irrigation system, pressure measurements in the field are made using a pressure gauge with a pitot tube. The pitot is inserted into a hole punched in the lateral tubing, and the pitot directed to face into the flow (Fig 1.3).

The measurement is made with the lateral in its normal position, and the hole is sealed with a 'goof plug' once the reading is completed.

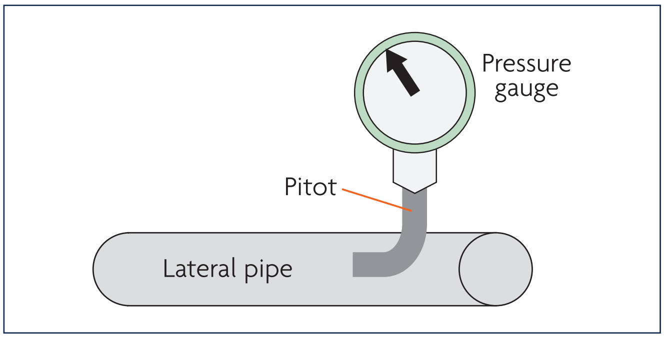

Figure 1.3. Pitot tube to measure soft lateral in-line pressure

Sprinklers, rotators or multi-outlet sprayers

See Fig 1.4. The test pressure shall be measured at the height of the main nozzle of the test sprinkler. The point at which pressure is measured shall be located at least 20cm upstream of the sprinkler so that the pressure measured is not affected by any local variation. No fitting or device which may cause a drop in pressure shall be installed between the point of pressure measurement and the sprinkler.

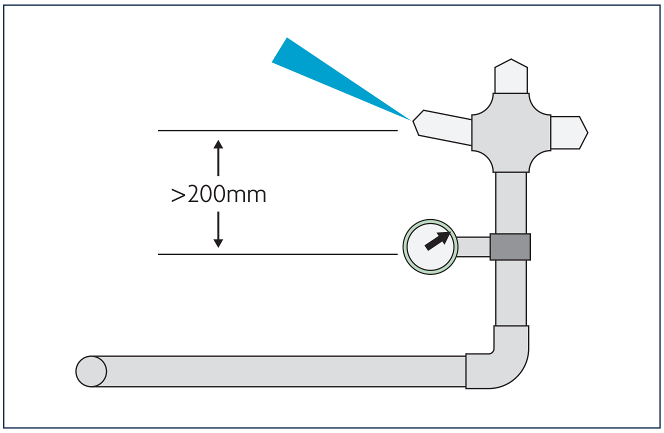

Figure 1.4. Measurement of sprinkler pressure

Sprayer or sprinkler orifice

For in-field pressure measurement on existing systems the simplest method is usually to take pressure readings at the nozzle outlet or orifice. This technique may not be possible with some designs, or where the orifice diameter is very small.

A pressure gauge fitted with a pitot is used, with the pitot inlet positioned in the centre of the flow stream just outside the orifice (Fig 1.5 Measurement of sprinkler pressure).

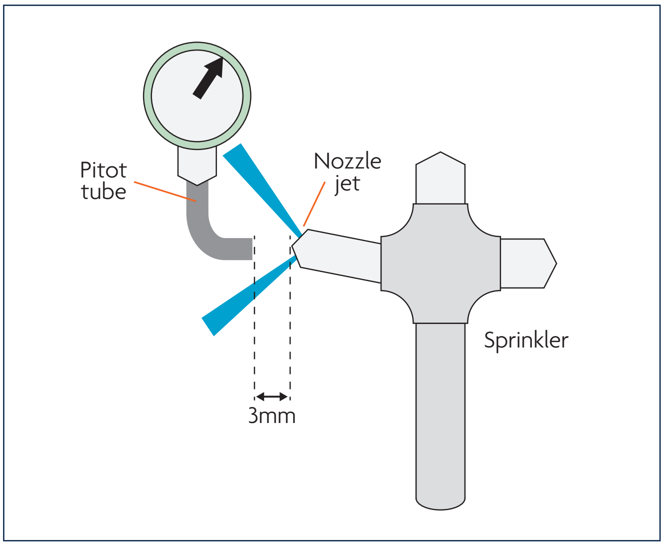

Figure 1.5. Measurement of sprinkler pressure

In-field sprinkler pressure measurement

It is difficult to obtain satisfactory pressure measurements from moving irrigators, and from irrigation systems such as centre pivots where very high discharge rates are common.

It is possible to install tees fitted with pressure test points upstream of the sprinkler in many instances. The pressure can then be measured using a gauge fitted with a long flexible hose and pressure test needle.

FLOW METERS: RANGE AND ACCURACY

Meet specifications in regulations

Flow meters must comply with the Resource Management (Measurement and Reporting of Water Takes) Regulations 2020 or with conditions specified in a Resource Consent, whichever is more stringent. The accuracy of flow meters is required to be ± 5% by law. The flow meter shall be verified as accurate at a maximum interval of 5 years, with the test conducted by a suitably qualified person as determined by the consenting authority.

For more information on flow meters, please read the *New Zealand Water Measurement Code of Practice*.

No water meter installed

Where no meter is fitted but a flow rate is deemed to be required to conduct a test, a range of external flow metering technologies is available. Care must be taken to install and operate any such device correctly in accordance with manufacturers' instructions. These should only be used by trained operators as they will give poor results to users who are unfamiliar with their operation.

WEATHER MONITORING

Most standards require monitoring of prevailing weather conditions throughout the period of system testing.

The main purpose of weather records during the test period is to assist post-test analyses. This may include identification of possible causes of non-uniformity (wind), or confirmation of measured evaporation rates (temperature and humidity).

Wind speed

Wind effects in particular can greatly affect system performance and should be monitored carefully.

Equipment used to measure wind speed should be accurate to better than ± 5%. Many small handheld meters are available with adequate performance.

> Many standards specify a maximum wind speed for reliable uniformity evaluations of 3m/s. If wind speed is greater than this, the system owner should be consulted and made aware of the potential limitations of results from testing.

Wind speed should be recorded at least once every 15 minutes throughout the test period. A logging meter simplifies this task. The average and maximum speeds should be presented in the report.

Wind direction

The direction of wind, and any significant variations, occurring during the test period should be recorded. Generally the direction relative to the irrigation system, particularly for system irrigating strips, is of significance.

Temperature

The ambient temperature, and the range of temperatures, during the test period should be recorded. Readings should be taken at no more than 15 minute intervals with equipment accurate to ± 1° Celsius.

Humidity

Equipment used to measure relative humidity should allow monitoring to ± 5%. A range of small handheld devices are available that meet this specification.

ELEVATION

System pressure is sensitive to changes in elevation. Systems that operate at very low pressures may be particularly affected by terrain and elevation determination can be critical in identifying factors contributing to non-uniformity.

Survey plans or topographical maps

Irrigation system design plans should provide topographical data to a satisfactory resolution.

Use such plans if available, and apply some in-field checks to verify accuracy.

Standard topographical maps (e.g. NZMS 1 1:50,000 series) do not provide enough resolution. They may however be useful in establishing benchmark elevations.

Benchmark elevation

It is not necessary to present elevations as metres altitude about mean sea level (m ASL). Reduced levels relative to a benchmark established on site are sufficient.

Suitable benchmarks will have a clearly defined point of measurement. They will be stable and enable repeated measurements, even at a later date. Examples include a defined point on a solid concrete pad (pump foundation) or similar.

Equipment lists for field work

MISCELLANEOUS EQUIPMENT

- Road map
- Farm location / physical address
- Contact details
- Contact phone number
- Data collection sheets
- Field book
- Pens, pencils
- Cell phone
- Camera
- Magnetic compass – identify North etc
- Angle finder
- Wind speed meter
- Thermometer / Humidity meter
- Altimeter
- Stop watch
- Shovel
- Soil probe / auger
- Thread tape
- Pouch – to hold tools, misc items
- Nylon stockings – to sieve flushing water

CLOTHING

- Gumboots
- Parka
- Overtrousers
- Long rubber gloves
- Towel
- Change of clothes

MISCELLANEOUS TOOLS

- Vice grips
- Spanner – 20cm adjustable
- Open end spanner set
- Wrench – 35cm adjustable
- Pliers – to insert goof plugs
- Secateurs
- Knife snap blade – cut emitters, drippers
- Wire cutters

LENGTH MEASUREMENT

- 100m and 10m tape measure
- Measuring wheel
- Fibre glass poles 1.5m – to mark speed test runs

PRESSURE MEASUREMENTS

- Pressure Gauges
  - 0–250kPa
  - 0–400kPa
  - 0–1000kPa
- Spare threaded pressure test points
- Flexible hose extension – to connect to gauges
- Pressure test needles – to connect to gauges
- Pitot tubes – to connect to gauges

Micro irrigation

- Pressure test points
- Clamps – to close off lateral tubing
- Lateral punch – to allow pitot insertion
- Goof plugs – to repair holes

Pivot/linear

- Threaded tee pressure test points – between dropper and pressure regulator
- Bayonet pressure test point – between pressure regulator and spray head

FLOW MEASUREMENT

- Measuring cylinders (depend on collector size)
- 100mL
- 250mL
- 1,000mL
- 2,000mL
- 5L Measuring jug

Micro irrigation

- Collection vessels
- Sprinkler shroud for uprights
- Jiffy clips – attached to lateral to prevent dribbling passed collector

Other systems

- Container of known volume (~ 20L)
- Shroud and pipe or hose – to divert sprinkler water to container
- Flexible hose 25–30mm, 1m long – to divert sprinkler flow to large container
- Collection vessels
- Clothes pegs – to stop sprinkler movement.

Field assessment of system performance by system type

Parts C–H provide guidelines for the assessment of both individual irrigation system performance and overall seasonal irrigation efficiency. These are intended to allow irrigators and other stakeholders to determine and benchmark performance, and to identify problem areas and the contribution these make to overall system in-efficiency.

These Parts are available as a series of additional documents specific to irrigation system type. They present guidelines for measuring irrigation system performance on-site under prevailing crop and weather conditions. Their primary focus is to determine Applied Depth, Distribution Uniformity and Application Intensity, and identify the proportional contribution key factors make, to non-uniformity. Other performance indicators include pump efficiency, headworks and mainline velocities and energy efficiencies.

Parts C–H schedules cover:

- *Part C: Micro-irrigation*
- *Part D: Solid-set irrigation*
- *Part E: Sprayline irrigation*
- *Part F: Travelling irrigators*
- *Part G: Linear move irrigators*
- *Part H: Centre pivot irrigators*

4. Reporting format

The purpose of reports is to provide the system owner/manager with information to help improve performance.

- Present key performance indicators as prescribed
- Present conclusions and comparisons with established performance benchmarks
- Present recommendations
- Present performance data graphically where appropriate
- Include base data and calculations in appendices.

SYSTEM LAYOUT

1. Provide a map of the irrigation area with North indicated
2. Identify water supply and mainline locations, access track, hydrants and any segment excluded from irrigation
3. Identify the area(s) watered outside the target area
4. Identify the location of sprinklers used in testing
5. Identify the location of the traveller at the start and end of the strip
6. Identify the wind direction during the test

Ground profiles

7. If the irrigated area contains significant elevation variation, provide a diagram and mark locations of ground profiles measured
8. Present maps of ground profiles with distance and reduced levels in metres.

TEST DESIGN

Present a plan showing the location of critical test elements as below:

Micro irrigation

1. Pressure test point locations
2. Flow test locations

Spraylines/multiple spraylines

3. Sprayline position in field
4. Grid test location
5. Collector placement
6. Irrigation strip width
7. Wetted radii and locations measured
8. Identify wind direction during testing

Travellers

9. Delivery tube laid position
10. Transverse test line locations
11. Collector placement
12. Irrigation strip width
13. Wetted radii and locations measured
14. Gun sector angle if relevant
15. Wind direction during testing for each transverse line

Lateral moves

16. Lateral position in field
17. Wetted length
18. Lateral uniformity test position
19. Collector placement
20. Wind direction during each test

Centre pivots

21. Pivot lateral position in field
22. Wetted radii
23. Radial uniformity test position
24. Collector placement
25. Wind direction during each test.

GENERAL OBSERVATIONS

Surface ponding

1. Note any observed surface ponding
2. Identify implications of soil water ponding or runoff on actual distribution uniformity.

PERFORMANCE INDICATORS

Pressure

1. Present pressure measurements made at headworks, hydrants and the machine (report in consistent units)
2. Note range of elevations identified in the field including minimum and maximum variations from a mean or mode elevation

Applied depth

3. Present a graph or graphs of collector volumes (corrected for evaporation) along each transverse line. Use shading to distinguish between collector rows
4. Present a graph or graphs of applied depths (corrected for evaporation and for overlap) across the irrigated strip width at each transverse line. Use shading to distinguish between collector rows

Application intensity

5. Present calculated instantaneous application intensity and assessed soil infiltration rate
6. Interpret the result:

   For example: The soil is a clay loam with signs of compaction. The calculated application intensity of 60mm/hr is high for this soil type.

   For example: Field observations found ponding and minor runoff under the wetting area. This indicates excessive application intensity, redistribution of water at the soil surface and high risk of by-pass flow. It will reduce the actual distribution uniformity.

Distribution uniformity

7. State the method used to determine uniformity, present the result and give an interpretation based on expectations for the type of system
8. Present low quarter Distribution Uniformity (DU_{lq}) as a decimal. Do not present it as a percentage

   For example: Lateral DU_{lq} = 0.83.

   Interpretation: This is considered “good” for a linear move irrigator on level ground.

CAUSES OF NON-UNIFORMITY

Identify the contribution to non-uniformity that can be attributed to key causes.

Inappropriate strip width

1. From transverse line and overlap calculations, determine the optimum strip width for highest distribution uniformity at the prevailing conditions and machine settings tested

Wind effects

2. From transverse line and overlap calculations, determine the effect of wind on distribution patterns if possible

Incorrect components

3. Report any components that do not meet specifications. Note number and proportion of sprinklers or other components represented

Boom distribution systems

4. Compare the result of the discharge (sprinkler) and collector distribution uniformity results:

   For example: Low quarter discharge uniformity was calculated based on measurements from 16 sprinklers. DU_d = 0.65.

   Interpretation: This is considered ‘poor’ for a travelling irrigator fitted with a boom distribution system.

Sprinkler condition

5. Report possible interference if sprayers not horizontally staggered
6. Report on nature of wear, damage or blockage, number and proportion of instances, and any possible causes
7. Present an overall interpretation.

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PART B: Compliance and Water Supply Checklists

Note: This is Part B of a series of nine (Parts A–I).

IRRIGATION NEW ZEALAND

Part B: Contents

Date of Issue: January 2023

The Code is presented as a series of booklets, each with a defined purpose.

Part A: An Introduction to Performance Assessment
Part A provides an overview of performance assessment, explains the broad philosophy behind assessment approaches taken throughout the Performance Assessment series, and contains specific formulae and reporting standards.

Part B: Compliance and Water Supply Checklists
(This booklet)
Part B relates to all system types. It contains recommendations for checks to ensure compliance with regulations, rules and consent conditions, safe effective operation of water supply systems.

Parts C–H: System Performance Assessments
Parts C–H contain guidelines and recommendations for Operational Checks, System Calibrations and In-field Performance Assessments specific to a range of irrigation system types.

Part I: Conducting Energy Efficiency Assessments and Seasonal Irrigation Efficiency

IrrigationNZ Technical Glossary
The Glossary and Calculations are common with the NZPIS Design Code of Practice.

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1. Compliance checklist

This is a minimum list of checks to ensure safe operation and regulatory compliance. Checks should be made before the irrigation season starts.

These include checks of the physical system and performance checks of water flow, pressure, and emitter delivery. It can be helpful if two people work together to perform checks.

NOTE:
Ensure all legal requirements are known and understood before operating the system.

NOTE:
Documentation such as Resource Consents and Operation Manuals will give more detail than this checklist, including information specific to the system.

Additional documents covering specific types of irrigation system contain Operational Checklists for:

- Micro-irrigation systems
- Solid-set irrigation systems
- Sprayline irrigation systems
- Travelling irrigators
- Linear move irrigators
- Centre pivot irrigators.

Management system

Safety

1. Ensure Health and Safety protocols in place
   - Protocols documented
   - Record of staff training

Regional plan rules

2. Ensure all rules governing water takes, irrigation and other relevant activities are documented
   - Read and understand all rules and their implications
3. Ensure compliance processes are defined and readily accessed
   - Ensure information is documented and accessible
   - Ensure processes are in place to inform all staff of requirements
   - Put critical dates in diary

Resource consent conditions

4. Collate copies of all Resource Consents
   - Read them and understand all conditions
5. Ensure compliance processes are defined and readily accessed
   - Ensure information is documented and accessible
   - Ensure processes are in place to inform all staff of requirements
   - Put critical dates in diary

Irrigation scheme and market/supply contract conditions

6. Ensure copies of current scheme rules/supply requirements and contracts are available
   - Read them and understand all conditions
7. Ensure compliance processes are defined and readily accessed
   - Ensure information is documented and accessible
   - Ensure processes are in place to inform all staff of requirements
   - Put critical dates in diary.

Irrigation system

Safety

1. Ensure appropriate system checks have been completed
   - See additional documents covering different system types (as mentioned on page B3)

Water supply

2. Check the supply intake meets Rule and Consent conditions

Water measurement

3. Confirm the water meter is installed to standards

   NOTE: Obtain documentation from an accredited installation company – see IrrigationNZ accreditation website for a list of companies in your region.

4. Ensure the water meter has been verified.

   NOTE: Obtain documentation from an accredited verification company – see IrrigationNZ accreditation website for a list of companies in your region.

5. Confirm any data logging and telemetry equipment has been tested and is functioning
6. Monitor the maximum take rate. Check against Consent Conditions

   NOTE: Check flow rate during irrigator fill and other potentially high flow periods.

Fertigation/chemigation

7. Check all required non-return valves are fitted – however testing of most non-return values requires a suitably qualified person. Where irrigation is connected to a potable supply testing of non-return valve may need to be conducted by a registered plumber. You would need to check local regulations before implementing any changes to these fittings.

2. Water supply checklist

This is a minimum list of checks that focuses on the system water supply: wells, surface intakes, pumps and mainlines. These checks should be made before the irrigation season starts. This Is usually the responsibility of the owner/manager or their irrigation service company.

Checks include structural and mechanical checks of the structure, and performance checks of water flow, pressure and nozzle delivery. It can be helpful if two people work together to perform checks.

NOTE:
Be safety conscious – pressure, electrical and mechanical hazards present.

NOTE:
Every system should be supplied with a System Operation Manual. Read it and follow instructions. The manual may include extra checks not listed here. It will give more detail than this checklist including information specific to your system.

Begin the checks with the system turned off.

- Tag/lock electrical isolator or motor switches to prevent accidental starting
- Observe the state of all equipment, looking for damage or wear and tear
- Tighten, adjust, maintain or replace components as required
- Lubricate all parts as specified in manuals.

Make checks with the system running.

- Consider which aspects required qualified expert (e.g. electrical)
- Ensure the irrigator travel path is clear before starting moving machines
- Check the operation of intake, pump, motor, headworks, valves and hydrants.

Check drawdown, flows and pressures

- Ensure the depth to water and system operating points are as expected.

NOTE:
Many items can be fixed on-farm. Others require specialist skills or equipment.

SYSTEM-OFF CHECKS

NOTE:
Completed with the system NOT running.

WARNING:
Ensure electrical isolator and motor switches are tagged/locked.

Well/bore

1. Check the ground water level after recovery and before irrigation
   - Measure water depth below the top of the casing
   - Compare depth to measurements from previous years

   NOTE: Consider well test to check for deterioration in performance

Surface takes

2. Check intake structures for damage
   - Check strainers are secure, not damaged, not blocked

Pump system

NOTE: Complete basic shed maintenance

3. Check bearings and shafts not worn
   - Lubricate as required
4. Check belt condition and tension
   - Replace if worn

Headworks

5. Check filter for damage and cleanliness
   - Clean and replace strainers/elements/discs if necessary
6. Check pressure gauges are fitted and in good condition
   - Fit or replace if required

Mainline and off takes

7. Check visible mainline and fittings for any obvious damage
   - Make any repairs as required
8. Check off-take valves or hydrants for any obvious damage
   - Make any repairs as required

Power supply

NOTE: Exercise caution

9. Check for any obvious problems, worn cables or fuel lines

NOTE: Get expert assistance if required.

Control unit

10. Check electronic controls and ensure battery is charged.

PREPARE TO START

WARNING: CHECK IT IS SAFE TO START THE SYSTEM

- Before continuing consider completing the System-off Irrigation System checks. This is particularly significant for moving machines such as travelling guns or booms, linear/lateral moves and centre pivots
- Ensure nothing is parked in the irrigator travel path
- Remove tags or locks from isolator switches.

SYSTEM-ON CHECKS

NOTE:
Completed WITH the system running.

Well/bore

1. Check dynamic water level depth
   - Measure water depth below the top of the casing
   - Compare depth to measurements from previous years

Pump system

2. Complete visual inspection
   - Check there are no new noises or unusual vibrations
   - Ensure no leaks – repair as necessary
3. Measure and record inlet pressure
   - Compare to previous records
4. Measure and record outlet pressure
   - Compare to previous records
5. Measure and record flow rate
   - Compare to previous records
6. Measure and record energy consumption
   - Compare to previous records

Headworks

7. Complete visual inspection
   - Check there are no new noises or unusual vibrations
   - Ensure no leaks – repair as necessary
8. Check the water meter is functioning
   - Compare measurements to expected values.
9. Check the main control valve operation
10. Measure and record outlet pressure
    - Repeat for different irrigation blocks or zones
    - Compare to previous records

Mainline and off-takes

11. Pressure test mainline
    - Fill and pressurise mainline
    - Close all valves on mainline
    - Monitor pressure drop
12. Complete visual check for leaks in mainline, off-takes or hydrants
13. Measure pressure at furthest hydrant or off-take
    - Compare measurements to expected values

Control unit

14. Ensure the control valves are functioning correctly.

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PART C: Micro-irrigation

Note: This is Part C of a series of nine (Parts A–I).

IRRIGATION NEW ZEALAND

Part C: Contents

Date of Issue: January 2023

The Code is presented as a series of booklets, each with a defined purpose.

Part A: An Introduction to Performance Assessment
Part A provides an overview of performance assessment, explains the broad philosophy behind assessment approaches taken throughout the Performance Assessment series, and contains specific formulae and reporting standards.

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Parts C–H: System Performance Assessments
(Part C = this booklet)
Parts C–H contain guidelines and recommendations for Operational Checks, System Calibrations and In-field Performance Assessments specific to a range of irrigation system types.

Part I: Conducting Energy Efficiency Assessments and Seasonal Irrigation Efficiency

IrrigationNZ Technical Glossary
The Glossary and Calculations are common with the NZPIS Design Code of Practice.

Ministry for Primary Industries
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Introduction

Purpose

The *New Zealand Piped Irrigation System Performance Assessment Code of Practice* provides nationally recognised guidelines to measure and benchmark performance of agricultural and horticultural irrigation systems.

Part C is specific to micro-irrigation systems, specifically driplines and micro sprinkler systems commonly seen on orchards, vineyards and greenhouses. It makes recommendations for planning and conducting assessments and reporting on the performance of irrigation systems and their management. Its focus is on key performance indicators that are common with the New Zealand Piped Irrigation Systems Design Standards.

SYSTEM PERFORMANCE

The Code recognises different levels of performance assessment depending on purpose. In increasing level of complexity, system performance assessment includes:

- Operational Checks
- System Calibration
- Full System Performance Assessment.

Related documentation

- **New Zealand Piped Irrigation System Performance Assessment Code of Practice:**
  - Part A: An Introduction to Performance Assessment
    Part A provides an overview of performance assessment, explains the broad philosophy behind assessment approaches taken throughout the Performance Assessment series, and contains specific formulae and reporting standards.
  - Part B: Compliance and Water Supply Checklists
    Part B relates to all system types. It makes recommendations for checks to ensure compliance with regulations, rules and consent conditions, safe effective operation of water supply systems and energy efficiency assessments of pumps and delivery systems.
  - Parts C–H: System Performance Assessments
    Parts C–H contains guidelines and recommendations for performance assessments specific to a range of irrigation system types.
- **New Zealand Piped Irrigation Systems Design Code of Practice**
- **New Zealand Piped Irrigation Systems Design Standards**
- **New Zealand Piped Irrigation Systems Installation Code of Practice**
- **New Zealand Water Measurement Code of Practice**
- **New Zealand Irrigation Technical Glossary**

System description

A micro-irrigation system consists of a network of lateral pipelines fitted with low discharge emitters or sprinklers generally operating at low pressure. In this Code these systems will be referred to as drip/micro systems collectively.

Dripline can either be polyethylene laterals where drippers have been inserted individually to match the crop spacing or manufactured dripline where the drippers are moulded directly into the lateral at various spacings. Both these configurations can have pressure compensating drippers/emitters or non-compensating emitters.

Micro sprinkler systems use a polyethene lateral to supply small sprinklers often mounted on stakes connected to the lateral by off take tubes. Generally, these are designed to spray under the crop canopy around tree or vine bases. These systems are normally for Irrigation but in some locations may serve a dual purpose of providing frost protection.

For some drip/micro the design of the layout and system operation is characterised by watering only part of the total soil area, relying on soil moisture translocation to provide even coverage across the crop root zone and depth. In this instance the uniformity of application along the length of the crop row or irrigation lateral is critical to achieving good irrigation practice. Thus, Emitter Uniformity (EU) is measured. In systems that rely on the distribution of the water as a spray across a wider portion of the soil surface (for either irrigation or frost protection), good irrigation performance relies on the uniformity of distribution rather than the soil's textural characteristics to move water laterally. In this case Distribution Uniformity (DU) is critical and can be measured.

A complexity with dripline systems is that while most are mounted above ground, allowing direct access for measuring emitter outputs, some system designs have the dripline placed below the surface, for various reasons, such as better performance under high evaporation conditions. In these cases it is more difficult to determine Emitter Uniformity by direct volumetric measurement so the Code relies on measuring pressure at particular points in the laterals to determine alignment with the design key performance indicators. This indirect measurement approach relies on the fundamental relationship between pressure and flow for a given emitter orifice.

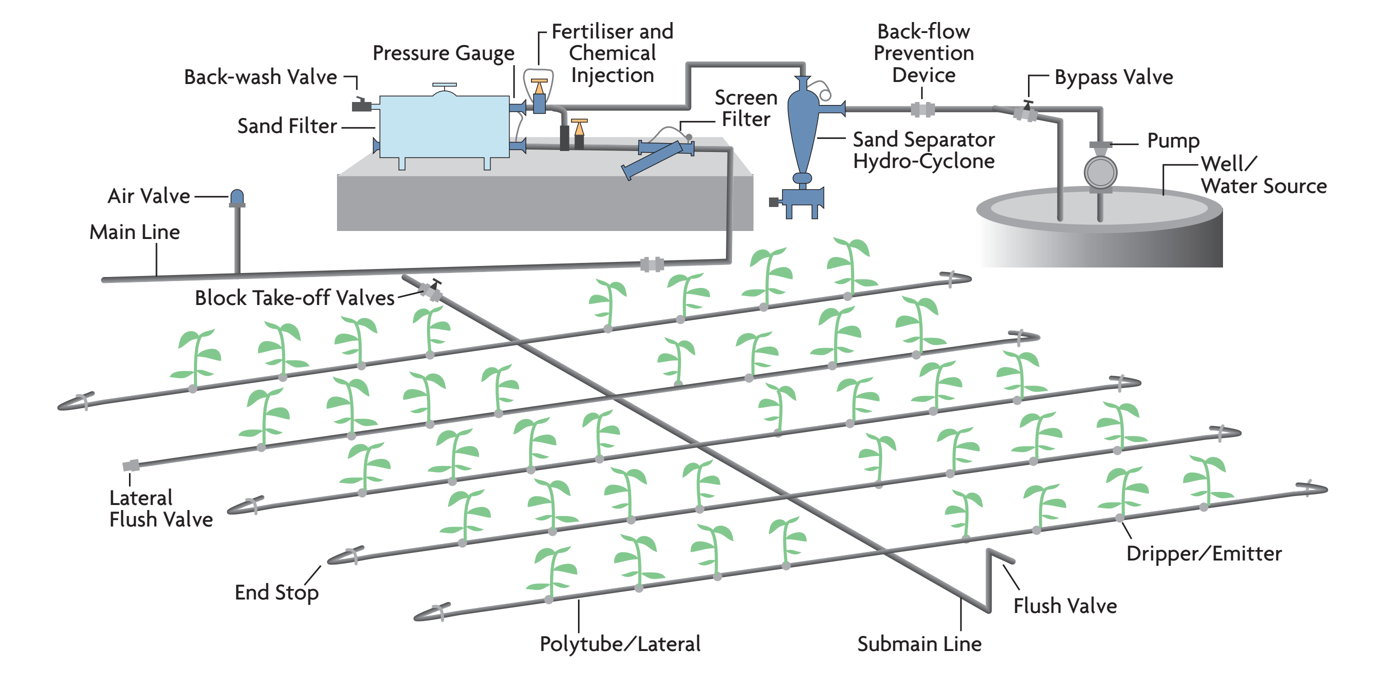

Figure C.1. Components and layout of a drip irrigation system. Based on a diagram from Jain Irrigation.

Special features for analysis

SOIL MOISTURE

The behaviour of water (lateral and vertical translocation) in a dripline wetted zone is influenced by conditions existing in the soil at the time (soils texture and soil moisture), and by previous irrigation practices (remaining water holding capacity and surface infiltration rates).

LOW OPERATING PRESSURES

Micro-irrigation systems usually operate at low pressures. This means a small actual pressure variation is large in relative terms, and can have a significant effect on flow variation. The Code particularly looks to determine if the pressure variations measured are within the original design tolerances. It is typical to see pressure gradients down drip/micro laterals but these may be acceptable for the design flowrates and emitter outputs, especially where pressure compensating emitters are used.

PRESSURE COMPENSATING EMITTERS

Pressure compensating emitters are designed to give a more even discharge across a wider range of working pressures than a non pressure compensating system design. Pressure compensating systems also provide better uniformity of discharge where significant elevation changes occur across a lateral block which is common in orchards and vineyards.

DISTRIBUTION/EMITTER UNIFORMITY

Overall field distribution uniformity of a micro-irrigation system is determined by variation in emitter discharge and emitter spacing .In a brand-new, well designed system, overall system performance is determined by accepted pressure variation within the lateral network, emitter performance (measured flow) and variation in manufacture.

In older systems, there is a focus on emitter uniformity which is calculated using measured flows from emitters but does not include outlet spacing for the uniformity calculation. Emitter performance is affected by damage to and deterioration of components, and by physical blockages of the very small orifices. The natures of the drip and micro sprinkler systems with very small orifices, requires that water quality be high.

PERMANENT SET SYSTEM

Because drip/micro irrigation systems typically have the emitters fixed In position relative to the plants, each plant receives water from the same emitter(s) each time it is irrigated. if there is non-uniformity in the system this means inconsistent discharge of water to certain plants is repeated every irrigation cycle. Thus, high uniformity is a critical design factor. There is no ‘smoothing’ effect to even out water application across a block as occurs with moving sprinkler systems, where emitter non-uniformities may cancel each other out in subsequent irrigation cycles. [However, see Parts D–H for other system types where it is shown this is an unreliable assumption for achieving good irrigation practice].

MULTIPLE OUTLETS PER PLANT

In many cases individual plants are served by more than one emitter. Even small drip-irrigated row crop plants can be considered to have multiple emitters if the wetted area per emitter is such that, if every other emitter was blocked, each plant would still receive some water. In most drip/micro systems, especially pressure compensated systems, the discharge that would have occurred from a blocked emitter does not subsequently get discharged as higher flow rates from unblocked emitters. While a plant may receive some water to keep it alive, it will likely suffer poor growth due to restricted water supply.

SMALL ROOT FRACTION WETTED

Most drip and some micro systems wet only a fraction of the available root area. Because most areas in New Zealand receive significant rain throughout the year, permanent crop root systems generally cover the entire field.

With only part of the ground area wetted by a drip/micro-irrigation system, the system design normally assumes a given volume of water per plant or area is discharged and then soaks and spreads further into the soil root zone. A good design will have analysed and taken into account the particular soil texture present in each part of the irrigation network. Care must be taken to avoid poor sideways distribution of water from point sources and excessive volumes applied to free draining soil textures that allow deep drainage losses.

SYSTEM VARIABILITY

The performance of drip/micro irrigation systems may vary at different positions in the field. Contributing factors include topographic variation and elevation changes, lateral pipe lengths, water quality and variable distances from headworks to lateral pipe inlets. In addition soil variability will likely occur across a field or multiple irrigation blocks. Variability in the system compounded by variability in soils and crop stages means the design and testing of the irrigation system needs to focus on removing as many system variables as possible. Direct measurement of EU and DU helps determine if the variations exceed the agreed design performance criteria that should have taken into account any physical limitations.

FIELD ELEVATION AND KPIS

If the field is level (i.e. minimal elevation changes), the hydraulically closest and furthest points from the zone valves will normally have the highest and lowest emitter pressures respectively. These will be sampled in positions in lateral lines as part of the basic testing procedure. While pressure variation may also occur down mainlines relative to the distance from the headworks, in most drip/micro systems the potential variation in block supply point pressures are set at the downstream side of a block valve.

If field elevation varies significantly, consider increasing the number of tests to increase accuracy of emitter uniformity assessments. Record the (relative) elevations of each test site, and draw a profile sketch along a typical lateral if necessary. This can then be related back to the design hydraulic grade line to see If the measured values meet the tolerances considered during the design phase.

Ideally a well-designed drip/micro system will have been fully tested and commissioned at the end of the installation process and all critical pressures will be noted in a well documented commissioning report. If these test pressure points are not documented the Performance Assessment process will require reverse engineering to understand if the values being measured in the field are acceptable or fall outside the equipment manufacturer design specifications. This is a complex process for drip/micro systems.

1. Operational checklist

This is a minimum list of checks that should be made for drip/micro irrigation systems.

Be safety conscious – electrical and mechanical hazards may be present.

Every system that conforms to the IrrigationNZ Design Code of Practice should be supplied with a System Operation Manual and a documented commissioning report that sets out critical flow and pressure measurement KPIs across the blocks. The manual may include extra checks not listed here. It will give more detail than this checklist including information specific to your system.

SYSTEM OFF CHECKS

Filtration

1. Check condition of filters and filter media
   - No leakage from seals or joints
   - Rings/screens are clean with no holes
   - Pressure gauges are fitted and in good condition.

Fertigation/chemigation

2. Ensure the system is physically sound
   - No signs of corrosion
   - System clean, no blockages
   - No leaks
   - Backflow prevention is installed as required.

Control valves and offtakes

3. Ensure wiring and hydraulic lines are secure
4. Ensure manual valves are correctly set

Flushing points

5. Check flushing points are accessible
6. Ensure caps are in place

Pipe network

7. Visually inspect sub-mains/headers as possible
8. Visually inspect laterals are undamaged. Note any that are broken or open and recommend the system owner has them repaired

Emitters

9. Check emitter fitted are as specified in the design
10. Inspect for damage or blockage
11. Inspect risers for wear or damage

Control unit

12. Visually inspect electronic controls
13. Check battery charge.

SYSTEM ON CHECKS

Pump

1. Complete checks as specified in *Part B: Water Supply Performance Assessment*

Headworks

2. Complete checks as specified in *Part B: Water Supply Performance Assessment*
3. Check the flow rate of each station

Pipe network

4. Check for leaks along mainline
5. Check for leaks along sub-mains
6. Check for leaks along laterals
7. Check laterals flush clear

System pressure

8. Check pump pressure for each station
9. Check pressure before and after filters
10. Check all off-take pressures correct
11. Check the lateral end-pressure
    - Test at ends of far laterals.

Emitters

12. Check all emitters/sprinklers are flowing
13. Check sprinkler parts are moving freely.

2. Calibrating micro-irrigation systems

The Irrigation Calibration method for drip and micro-irrigation systems assesses the mean depth of water being applied to individual irrigation stations (also called Zone or Block valves). It is based on measurement of flow from selected emitters and calculation of whole station Crop Applied Depth, Soil Applied Depth in the wetted area and Emitter Uniformity.

This allows the system manager to confirm the system Is applying the expected target depth as per the design , and whether the system is applying water evenly across the irrigation station.

By repeating the process in different irrigation stations, an assessment can be made of the ability of the system to meet the design intentions to apply targeted depths in each station across the whole property.

NOTE:
Refer to *Part A: An Introduction to Performance Assessment* for more information about calibrating irrigation systems.

2.1 What will the testing show?

The main things the calibration test will show are:

Mean station applied depth
The depth of water the irrigation system is applying on average to each station. Compare the measured applied depth to target application depth, The target application depth for each irrigation event is calculated by the operator/manager from rainfall and evapotranspiration for a given soil moisture holding capacity, Alternately, you may be able to compare the target depth applied per hour as per the system design specifications. . Station run times are set (durations and return intervals) to deliver the correct applied depths.

Soil applied depth
The depth of water (in mm) being applied to the total crop area actually wetted by the irrigation system.

Emission uniformity EU
The evenness of discharge from individual outlets. The higher the EU, the better the system is performing. And the higher the uniformity, the more confident you can be that sampled measurements are truly representative of the overall system performance.

Application intensity
The depth of water being applied per hour. This equivalent to the terminology used to describe a rainfall event In mm/hr.

Adjusted station run time
Calculates the irrigation duration to ensure 7/8ths of each Station gets at least the Target Application Depth. It accounts for design outlet spacing and flow rate across soil types and any variations in these factors or system distribution and emitter uniformity.

Target Depth ÷ EU = average mm required for 7/8ths to receive the target mm minimum.

EXAMPLE:

- 10mm target depth
- 0.7 EU
- 10mm ÷ 0.7 = 14.3mm

If the system applies on average 5mm/hr then the run time would not be 2 hours to achieve 10mm across 7/8ths of the crop but rather 2 hours 50 minutes to raise the average applied depth to 14.3mm thus ensuring that 7/8ths received 10mm minimum.

WHEN SHOULD CALIBRATION BE DONE?
Complete the calibration test if commissioning any new areas and after any major changes. Calibration should be repeated as part of system checks at the start of every season.

Drip/micro irrigation system performance is largely unaffected by weather conditions, with the exception of some micro spray systems where wind can affect spray patterns even when under the protection of the crop canopy. Performance can be influenced if system pressure significantly alters, such as if pumping systems are changed or bore levels drop.

2.2 Calibration process

Before starting, ensure System Operational Checks (Section 1) have been completed.

Calibration is a four step process:

1. Gathering information about the system design and KPIs (as-builts if held)
2. Calculating performance indicator values from collected field measurements
3. Comparing results with the design specifications (design specifications at commissioning or against commissioning reports if during maintenance)
4. Adjusting irrigation system settings as required to achieve intended performance or undertaking repairs and maintenance.

GATHERING INFORMATION

Equipment

Equipment needs are very basic and most should already be available on the property. A suggested list includes:

- Containers to collect water from outlets
  - 9 Litre buckets are good for sprinklers
  - 2 Litre ice cream containers are good for drippers
- 1 measuring cylinder
  - 1 or 2 Litre for high flows (sprinklers)
  - 100mL or 200mL for lower flows (drippers)
- 1 tape measure
- 1 stop watch
- 1 pen or pencil
- 1 recording sheet.

Sampling method

Calibration is based on measurements collected at specified locations within an irrigation station (Figure 2.1).

NOTE:
A "station" is a part of the irrigation system controlled as a single unit, typically by an off-take with a gate valve or solenoid valve. A station is also called Zone or Block valves in some design software tools. In each zone, 12 samples are taken as shown in the diagram below.

Follow placement instructions carefully and read volumes as accurately as possible to be sure of best results.

FIELD MEASUREMENTS

Repeat the following field measurements and calculations in each station of interest.

Emitter/sprinkler measurements

1. Measure the distance between outlets along a lateral. It is often best to use an average distance between a number of outlets
2. Measure the distance between adjacent laterals, usually adjacent rows. Take an average spacing between several laterals
3. Estimate the average width (below ground) of the wetted strip along each row. This will require some insight to the type of crop grown, its stage of growth and the historical placement of water that may have impacted lateral and vertical root growth patterns.
4. Determine the area of each station [Row length x row number x row spacing]

Application test

5. Collect the output from one emitter at the beginning, middle and end of the lateral nearest to the station inlet (Figure 2.1)
6. Measure the volume of water in each container and record on the record sheet
7. Repeat along two middle laterals
8. Repeat along the lateral furthest from the inlet.

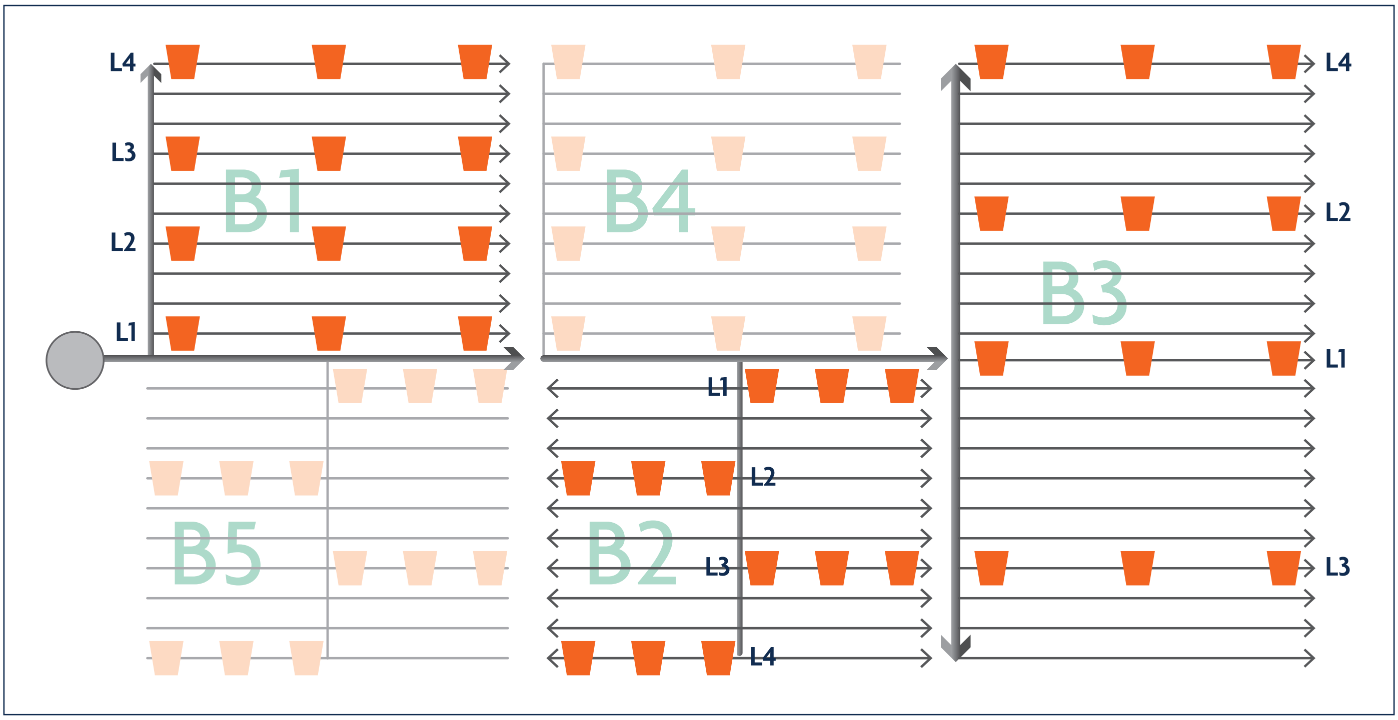

Figure 2.1. Recommended locations for emitter or sprinkler flow measurements for drip/micro irrigation calibration.

PERFORMANCE INDICATOR VALUES

Emitter or sprinkler flow rates

1. Calculate *Average Volume* collected (mL)
   [Average of 12 collected volumes]
2. Calculate *Average Emitter Flow Rate* (L/h)
   [Average volume (ml) ÷ collection time (min) x 0.06]

Application intensity

3. Calculate *Application Intensity* (mm/h)
   [Average emitter flow rate (L/h) ÷ (outlet spacing (m) x lateral spacing (m))]
4. Calculate *Station Flow Rate* (m^3/h)
   [Application Intensity x Station Area x 10]

Applied depth

5. Calculate *Mean Station Applied Depth* (mm) [Application Intensity (mm/hr) x Run Time (hrs)]
6. Fraction Wetted = Wetted Strip Width ÷ Lateral Spacing
7. Calculate *Soil Applied Depth* (mm)
   [Applied Depth x Fraction Wetted]
8. Fraction Wetted = Wetted Strip Width ÷ Lateral Spacing

   NOTE:
   Run Time (hrs) Is the duration of the Irrigation event to apply the Intended depth. It Is not the time taken to complete the test/collect the volume In the container.

Emission uniformity

9. Calculate the *Emission Uniformity*
   [Low quarter average volume ÷ average volume]
10. Calculate *Low Quarter Average Volume* (mL)
    [Average of lowest 3 emitter volumes]

    NOTE: 3 buckets is one quarter of the 12 samples collected.

COMPARE RESULTS WITH EXPECTATIONS

Flow rates

1. Compare *Average Emitter Discharge* to the manufacturer's quoted flow rate
2. Compare the calculated *Application Intensity* to expectations set out in the system design report or commissioning report
3. Compare calculated *Station Flow Rate* with *Water Meter Flow Rate*

Applied depth

NOTE:
Refer to the design report or commissioning report taking into account any return intervals.

4. Calculate *Target Depth to Applied Depth ratio*
   [Target Depth ÷ Applied Depth]
   - < 1 – under applying
   - = 1 – correct
   - > 1 – over applying

   Acceptable variances: 0.90–1.10 (0.95–1.05 is better)

Using the systems measured uniformity, you can calculate the required depth to ensure 7/8ths of the crop receives the minimum Intended depth.

5. Compare Soil Applied Depth with Soil Moisture Deficit
   ~ Soil Applied Depth < Soil Moisture Deficit ÷ EU

Example:

- 10mm target depth with a system EU of 0.7
- 10mm ÷ 0.7= 14.3mm average required to ensure 7/8ths of the crop receives 10mm

Emission uniformity EU

6. Interpret calculated EU value
   - EU > 0.95 — Uniformity is very good; the system is performing very well
   - 0.95 – 0.90 — Uniformity is good; performance better than average
   - 0.90 – 0.80 — Uniformity is fair; performance could be improved
   - 0.80 – 0.70 — Uniformity is poor; system should be investigated
   - EU < 0.70 — Uniformity is unacceptable; system must be investigated

CHECK KEY PERFORMANCE INDICATORS

1. If Applied Depth or Uniformity are unacceptable
   - Repeat Operational Checks
   - Ensure system is at recommended operating pressure
   - Get professional assistance.

RUN TIME

2. Calculate Adjusted Run Time (h)
   [Target Depth ÷ EU ÷ Application Intensity].

NOTE:
Including EU ensures the Run Time applies sufficient water to adequately irrigate 7/8th plants.

3. Full system performance assessment of drip/micro irrigation systems

This section presents procedures for conducting efficient and reliable full system irrigation performance evaluations of drip/micro irrigation systems.

Procedures for planning, conducting, analysing and reporting full system performance are described. They are intended to promote efficient work practices and informative reporting that facilitates easy comparison of systems.

Procedures are presented for assessing emitter uniformity of irrigation systems applying water through non-pressure compensating and pressure compensating emitters, micro-sprayers, or mini-sprinklers, where each plant is watered by one or more outlets.

NOTE:
Complete Operational Checks (See Section 1) before commencing a system assessment.

3.1 Data collection

This schedule outlines procedures to be followed when assessing a drip/micro irrigation system under prevailing field conditions. Because test conditions will vary, key conditions must be measured and recorded to assist any comparisons between subsequent tests of the same system, or when benchmarking against other systems.

NOTE:
The purpose of the particular test may influence decisions to proceed with or abandon testing.

NOTE:
To provide system operator general operation/management information, conditions at the time of the test should be representative of those experienced in normal operation.

NOTE:
If testing is part of System Commissioning or fulfilling specific purchase contract criteria, adherence to test condition limitations is necessary.

TEST SITE

Specific locations are selected to allow overall field performance indicators to be calculated.

- Emitter discharge measurements are made in three areas representing the typical pressure variations across a lateral block to assess emitter performance and variability. Due to deposition of sediment at different flow rates these may also represent the cleanest, average and dirtiest parts of the system.
- Station by station emitter discharge tests determine station specific application intensities, uniformity and depths.
- Pressure sampling determines if the system is within the working pressure range specified by the system designer which will be based on the emitter manufacturer specifications.

SYSTEM SURVEY

System layout

1. Prepare a site map, or annotate a copy of the as built drawings of the system, recording the headworks, mainline, take-off points, sub-mains, manifolds and laterals
2. Mark location of pressure regulators, flush valves and positions where tests are to be conducted (see example Figure 3.1)

Topography and elevation

3. If the field is not level, determine elevation differences between test sites and across the station as a whole.
   - Prepare a sketch of the block showing the profiles along each of the typical laterals chosen for testing.

SYSTEM OPERATION

CAUTION:
Caution is necessary if water has been treated for any purpose, such as with acid or biocides, or contains effluent or other potential bio-hazards.

System pressure

1. Complete the test at normal operating pressure or as agreed between the client and performance assessor
   - Ensure the pressure is maintained during the test. [The operator should advise if any automated watering is scheduled that may affect the delivery pressures.]
   - Ensure pressure measurements are taken for every block, even if water is not being collected. This Is to test for consistency with the design report or commissioning reports; low valve pressures may affect non-compensated emitters more than pressure compensated systems.

Injection devices

2. If the system is designed with an injection device that is normally operative, perform the test with the injection device operating, as these components can affect delivery pressures. Otherwise ensure it is not operational for the duration of testing.

FIELD OBSERVATIONS

Crop type

1. Record the field's planting history for previous season and year
2. Note crops planted in the area under examination, and stage of growth

Crop appearance

3. Observe the crop for signs of stress or growth difference [Photographs might be useful in this respect]
4. Check for plants receiving little or no water because of system faults or blockages
5. Measure or estimate the crop ground cover proportion

Soils

6. Dig, or auger, several holes within the irrigated area
7. Determine the soil texture and depth of rooting
8. Estimate or otherwise determine soil infiltration rate and soil water holding capacity
9. Assess the level of water penetration at each site and record, taking into account recent irrigation cycles or rain fall that may have affected soils moisture levels. Note any soil features that indicate wetness, poor drainage or related properties and identify causes. [Soil moisture monitoring data may be available as a comparison too in-situ observations]
10. Assess the spread and depth of wetness under a number of drippers across the station and record

NOTE:
The behaviour of water in the dripper wetted zone is influenced by conditions existing in the soil at the time, and by previous irrigation practices. Examine the wetted zone under a number of representative emitters before the system is started, and record dimensions and approximate moisture content (see Figure 3.1).

Key dimensions include the surface wetted diameter, the wetted diameter at the widest point, the wetted diameter at about 30cm and the depth in relation to plant root zone (Figure 3.1).

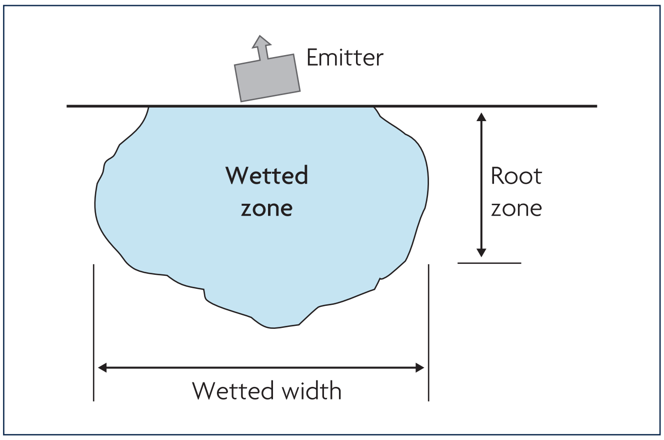

Figure 3.1. Wetting pattern under drip-irrigation outlet.

Emitters/sprinklers

11. Record details of the type of dripline, emitters or micro sprinklers fitted

NOTE:
Usually all sprinklers fitted in a micro-irrigation system should be the same. More than one type of emitter is often a sign of poorly managed system maintenance, in particular sprinkler or emitter blockage, which will likely lead to system performance failure.

Emitter spacing

12. For each station determine the emitter spacing and the number of emitters per plant
    - Calculate the average number of emitters by counting along a number of plants. The number may not be a whole number. This may also be determined by calculating this number across a whole block using total emitters [total lateral length divided by emitter spacing, divided by plant density (plants /m^2)]

Filtration

13. Identify the type(s) of filter fitted
14. Check filters [ideally noting pressure differential across the filter when running] and note nature and degree of contamination or blockage of the filter element
15. Determine when filters were checked or cleaned and the frequency of flushing

Lateral contamination

16. Randomly select at least three laterals in the station furthest from the filter
17. Inspect them for contaminants by flushing the most distant ends through a nylon filter (a stocking fitted over the open end makes a good filter to catch and inspect debris)
18. Record the time required for the water to run clear
19. Rate the amount of material (sand, clay, bacteria/algae, other) caught in the nylon sock using scale:
    - 1 = none
    - 2 = slight
    - 3 = medium
    - 4 = major

Emitter blockages

20. Conduct a visual check to determine that emitters are operating correctly (squirts and leaks around seals are obvious). Replace obvious failures before the test
21. Determine and record the cause of blockage in any emitters that are non-operational
22. Remove five emitters from distant hose ends and rate the material (sand, precipitates, bacteria/algae, insects, plastic parts, other) causing plugging using the scale:
    - 1 = none
    - 2 = slight
    - 3 = medium
    - 4 = major

NOTE:
This will require destruction of a few emitters, so ensure spares are available to repair any lines.

System leakages

23. Conduct an overall visual check (as possible) of headworks, mainline and the system to identify any leakages or other losses
24. Estimate percentage loss. [If practical measuring discharge volume from the leak and measuring pressure at the nearest testing point could be useful]

Pressure regulators

25. Identify locations of pressure regulators in the system, including automatic pressure control valves, manifold or off-take pressure regulators and pressure regulators on individual hoses
26. Identify any other points where pressure adjustments have been made, noting any presence of regulation valves in series

Unequal drainage

27. Observe the flow duration from emitters after the system is turned off. [This is particularly an issue on steep sites]
28. Determine the length of time some emitters continue to run after most have stopped
29. Assess the percentage of emitters that do this.

PRESSURE MEASUREMENT

NOTE:
Determine that pressure across the system remains within operating limits.

NOTE:
Pressure is NOT USED to determine flow rates of pressure compensating emitters

Headworks pressures

With system operating, measure:

1. Pump discharge pressure
2. Mainline pressure before and after each key component such as filters and control valves

Optionally measure:

3. Filter head loss
4. Pump control valve head loss
5. Throttled manual valve head loss

Mainline pressures

6. Measure pressure at each off-take upstream of the block control valves

NOTE:
The pressure at the start of the first lateral (see Figure 3.2 on the following page) is not a suitable substitute measurement for off-take pressure.

Distribution network pressures

NOTE:
An irrigation "station" is a management unit controlled by a single control valve. Also called Zone or Block control valves. Note under some designs blocks may be intended to run simultaneously with others to balance pump supply flow and pressures; this needs to be known before testing a block as a standalone unit to avoid invalid pressures or fluctuations.

NOTE:
Measure a minimum of three stations – or 10% of stations – depending on system size and topography.

NOTE:
In greatly undulating fields, areas with the highest and lowest elevations may represent the greatest variation. These should also be checked.

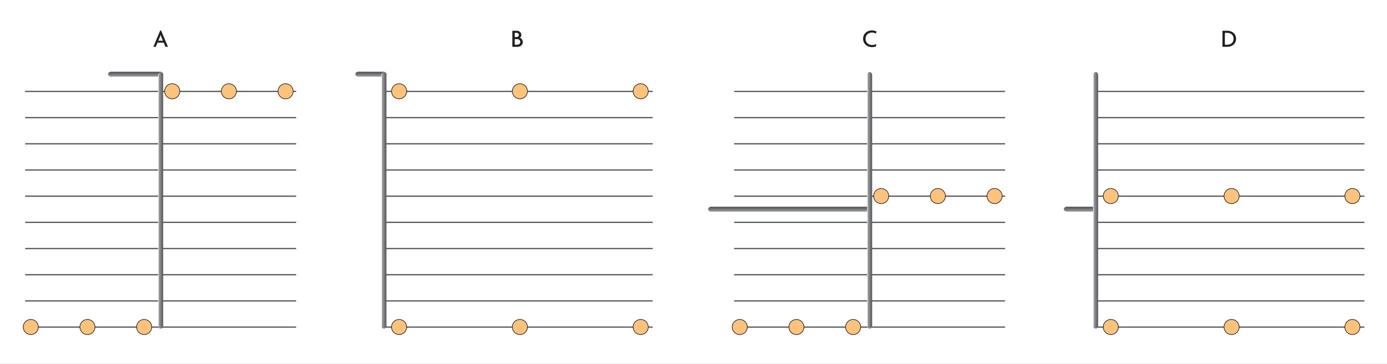

Figure 3.2. Location of positions for pressure testing

Station pressure variation

7. Measure the Pressure at the beginning, middle and end of the first and last laterals in each assessed station (see Figure 3.2 a–d)
8. Measure the Pressure at the beginning, middle and end of the first and last laterals in at least 10% of blocks If there are many blocks and high variability in system design/topography, ensure representative areas are captured

Lateral filter pressure loss

9. If there are in-line filters or strainers fitted at the beginning of laterals, randomly sample five filters from the 'dirtiest' station
10. Record the pressure in each lateral with the filter in-place, then remove the filter element and record pressure without it
11. Calculate pressure loss as the average of the five readings

FLOW MEASUREMENT

Total system flow

1. Record the system water flow rate with the system operating as normal
   - Wait until flow rates stabilise (up to 15 minutes) before taking readings
   - It may be necessary to take beginning and ending flow meter readings over a set time period to determine flow rate

Emitter discharge measurement

The purpose of these tests is to determine the Mean Emitter Discharge, Emission Uniformity and probable causes of variation (whether the result of manufacturing variability, pressure variation, in-field damage or blockages).

Dripper discharge measurement

NOTE:
The minimum collection time should be five minutes or such time as is necessary to collect at least 250mL. Measure volumes promptly especially in hot weather.

NOTE:
Ensure all discharge is collected including any from leaks around the emitter. Split rubber rings or Jiffy clips placed either side of the emitter help avoid 'dribbles' along the lateral tubing missing the collection container.

NOTE:
Drip systems with many closely spaced inbuilt emitters may be measured by collecting all discharge from a known length of lateral. Useful lengths are either 1.0 or 0.5 metres, in which case a corresponding length of spouting, or PVC pipe cut in half lengthways, is a convenient device to catch multiple flow streams.

NOTE:
Measure the Emitter Discharges at three different locations, representing the 'cleanest', 'average' and 'dirtiest' areas within the system (Figure 3.2 A–C). These locations each have a different probability of emitter clogging.

Sprinkler flow measurement

NOTE:
Higher flow sprinklers may require shorter collection times. Aim to collect for at least 1 minute or as long as possible within the volume of a 9–10 L container. Do not allow the emitter to become submerged in the collection vessel as the back pressure can affect its flow performance.

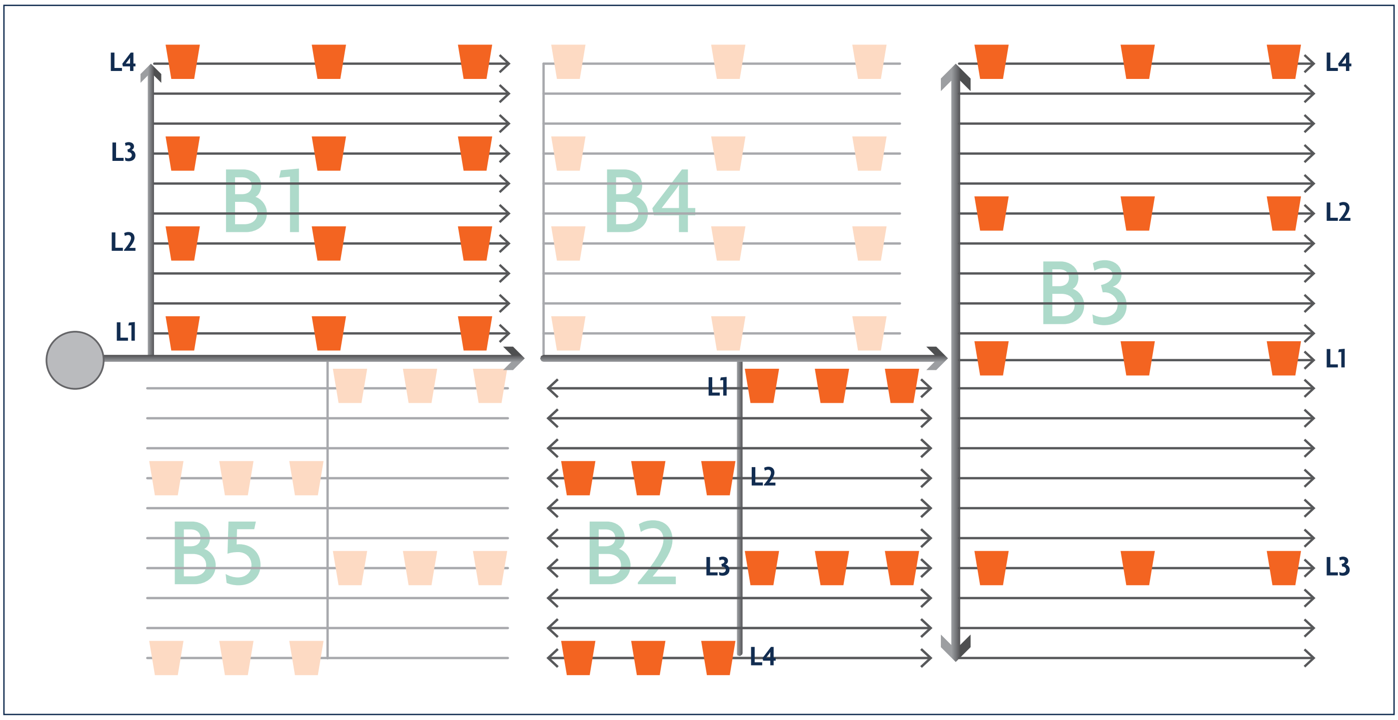

Figure 3.3. Recommended locations for emitter or sprinkler flow measurements for micro-irrigation calibration.

Cleanest area uniformity test

NOTE:

Usually the cleanest location (that least likely to have clogging) is the one hydraulically nearest to the headworks and filters (Figure 3.2 a). If a different area is known to be cleanest, select that area instead.

Average area uniformity test

NOTE:

For this and the 'clean area' tests, a sample size of 12 is sufficient assuming the system is clean and emitter variability is low.

Dirtiest area uniformity test

NOTE:

Usually the dirtiest location (most likely to have clogging) is the one hydraulically furthest from the headworks and filters (Figure 3.2 c). Often this is also a lower area. If a different area is known to be dirtiest, select that area instead. Dirt accumulation is often related to lowest pipe flow velocity where sediments settle out compared to being flushed along under higher turbulent flow rates. Low flow rates occur at the closed end of laterals and submains.

Station performance

NOTE:

An irrigation "station" is a single management unit controlled by a single control valve.

1. Measure the discharge of 12 emitters in each station (see Figure 3.2).

SYSTEM ENERGY USE

1. Obtain energy consumption (power meter readings or from pump control units displaying kWh) data for the period covered by flow measurement.

   NOTE: Energy use information is related to system pressures and volume pumped to determine energy and cost efficiency. Energy use is a key performance indicator recommended during system optimisation in the design process.

3.2 Data analysis

SIGNIFICANCE OF PRESSURE VARIATION

Micro-irrigation systems usually operate at low pressures. This means a small actual pressure variation can be large in relative terms, and can have a significant effect on flow variation.

Non-compensating outlets

Emitters and sprinklers with a simple orifice-type restriction controlling discharge rate have a predictable pressure to flow rate relationship. The flow at a given pressure can be measured in the field and compared with manufacturer's quoted values which may indicate the factor used in the flow pressure relationship.

Pressure compensating emitters

Pressure compensating emitters attempt to ensure even discharge across a range of working pressures generally by automatically adjusting the size of the orifice in response to pressure variation. This is called a dynamic response.

NOTE:
Because of the dynamic nature of pressure:flow in compensating emitters or sprinklers, measurement of the PRESSURE:FLOW RELATIONSHIP would not normally show the cause of flow variation in these systems. Flow variation in compensated emitters is more often due to manufacturing faults or maintenance requirements, i.e. the pressure compensating function simply does not work, or the emitter is blocked.

PERFORMANCE INDICATORS

Application intensity

1. Calculate *Application Intensity*

   NOTE: Application intensity under micro-irrigation is an important factor in the design process to set how long a station should run to apply a predetermined depth of irrigation.

   NOTE: Unlike other systems, low drip/micro application intensity is not generally considered as a likely system failure point based on soil infiltration rates. Some ponding may occur and thereby increase the area wetted under each emitter.

Applied depth

2. The designer will have set the *Volume Applied* to the area served to ensure that the depth of irrigation water applied is comparable with PET and water consumption for a given soil moisture holding capacity.

   NOTE: Under some drip/micro-irrigation, not all the surface area available above the plant root zone is wetted. Water movement within the soil profile is considered during the design process.

Infiltration depth

3. Calculate the *Infiltration Depth* in the wetted zone

   NOTE: The volume applied per irrigation is delivered to a fraction of the root zone available. The soil texture will influence the infiltration depth and lateral movement of the wetting front progress under the emitter lines.

4. Compare Infiltration Depth to the Root Zone Depth to determine whether excess irrigation is applied.

System uniformity

NOTE:
Capacity to control individual irrigation station watering times independently allows management to account for mean discharge variability between stations. Emitter variability within a station is not easily managed.

Emission (Emitter) uniformity (EU)
The purpose of uniformity determination is to firstly assess the evenness with which individual plants receive water, and secondly to identify those factors causing non-uniformity. It is reported as a decimal value

The procedure established below estimates an overall Field Emission Uniformity, and estimates the relative contributions to non-uniformity made by pressure, emitter manufacture, wear and tear, drainage and uneven spacing.

The use of statistical uniformity assessments enables the different contributing factors to be separated out. The determinations based on a relatively small sampling size will still be sufficiently accurate to identify areas where management can make changes to improve system performance.

In drip systems the coefficient often quoted is the emission uniformity coefficient (EU), which corresponds mathematically to the Christiansen coefficient used in sprinkler irrigation uniformity assessments.

In literature EU usually applies only to variation along a single lateral, which is not representative of a field as a whole. However, here a low quarter emission uniformity EU_{lq} is adopted to describe overall field performance.

Emission uniformity is not an efficiency measurement so is reported as a decimal value.

Emission v's distribution uniformity
Statistically derived emission uniformity (EU_{stat}) can be related to low quarter distribution uniformity (DU_{lq}), here presented as EU_{lq}, assuming a statistically normal distribution. The relationship is given by Equation 38.

Acceptability classifications for whole field uniformity determinations for each measure are presented in Table 1 (based on ASAE EP458).

Table 1 Acceptability of whole field determinations of uniformity

Rating	Emission uniformity (EU_{stat})	Distribution uniformity (DU_{lq})
Excellent	> 0.95	> 0.94
Very Good	0.94 – 0.90	0.93 – 0.87
Good	0.89 – 0.80	0.86 – 0.75
Fair	0.79 – 0.70	0.74 – 0.62
Poor	0.69 – 0.60	0.61 – 0.50
Unacceptable	< 0.60	< 0.50

Required adjustments

The flow measurements used to assess uniformity are a non-random sample, and cover only part of an irrigation event. Determination of 'global uniformity' requires that adjustments are made to account for various factors, including multiple outlets serving individual plants and unequal system drainage.

Adjustments are not generally required to account for evaporative losses from collectors as collection times are short and measurement should be rapid.

If the station contains areas with different emitters, flows or spacings, these areas need to be assessed separately.

Field emission uniformity (FEU_{lq})

1. Estimate overall field emission uniformity (FEU_{lq}) by combining contributing variable factors, using the Clemmens-Solomon statistical procedure.

   NOTE: Overall uniformity incorporates the effects of pressure variation, emitter variation, and the smoothing effect of multiple emitters supplying individual plants.

   In addition, it is adjusted for emitter defects (wear and plugging), unequal drainage after system shut-down and may be further adjusted to account for different plant or emitter spacings within the field.

Pressure emission uniformity (PEU_{lq})

2. Calculate Pressure emission uniformity (PEU_{lq}) from derived flows, using the low quarter uniformity formula.

   NOTE: The pressure emission uniformity coefficient describes a theoretical uniformity determined from pressure variation across the field, and the performance characteristics of the emitters.

   NOTE: NOT USED IN PRESSURE COMPENSATING SYSTEMS. The pressure emission uniformity coefficient is NOT USED in analysis of Pressure Compensating systems because the relationship varies across the pressure range.

   NOTE: Automated software can be controlled to avoid calculating PEU_{lq} by substituting Discharge Exponent $x = 0$ and Discharge Coefficient kd = the "manufacturer's nominal discharge" or the measured "clean area" mean emitter discharge.

Pressure derived flows

3. Calculate pressure derived flows for each of the pressure measurements taken across the field (see Figure 3.2 Distribution network pressures) using the emitter pressure flow relationship equation.

   NOTE: If the emitter discharge exponent and coefficient are not available from manufacturers' data they can be determined.

   NOTE: Pressure derived discharges are not reliable in pressure compensating systems as the relationship varies across the work pressure range.

   NOTE: If using software with calculations using the emitter pressure flow relationship negate the pressure flow relationship by substituting Discharge Exponent $x = 0$ and Discharge Coefficient kd = the "manufacturer's nominal discharge" or the measured "clean area" mean discharge.

Emitter emission uniformity (EEU_{lq})

4. Determine the emitter emission uniformity coefficient from emitter manufacturing coefficient of variation, CV_{man} and the mean emitter defect coefficient of variation, CV_{defect} determined from emitter performance tests.

   NOTE: Emitter variation is calculated to account for manufacturing variation, wear and tear and blockages, and the number of emitters per plant.

   NOTE: The statistical distribution parameter for a normal distribution, $K_{lq} = 1.27$ is used to convert to a DU_{lq} form.

Uneven drainage coefficient ($F_{drainage}$)

5. Calculate the uneven drainage coefficient

   NOTE: The uneven drainage coefficient is an estimate the impact of water draining from the system such that some plants receive greater amounts of irrigation than others. When short run times are used on undulating ground this can have a significant effect on overall system uniformity.

Uneven spacing coefficient ($F_{spacing}$)

6. Calculate the uneven spacing coefficient.

   NOTE: The uneven spacing coefficient is an estimate of non-uniformity caused by unequal plant or emitter spacings in different zones within the main field. In general, a full canopy planting should require a similar *depth* of water (but not volume per plant) regardless of the distance between plants, emitter spacing or emitter discharge rates.

OTHER UNIFORMITY FACTORS

Estimating CV_{man}

1. Calculate CV_{man}

   NOTE: In the absence of data from manufacturers or a testing facility, an estimated value of manufacturing variance can be calculated using data collected from the clean location emitter flow tests.

Table 2. Acceptable values for brand new emitter manufacture quality CV_{man}

Classification	Manufacturing Coefficient of Variation (CV_{man}) Burt & Styles	CATI (UFL)
Excellent	< 0.03	< 0.05
Average	0.03 – 0.07	0.05 – 0.10
Marginal	0.07 – 0.10	0.10 – 0.15
Very Poor	> 0.10	> 0.15

Emitter defect coefficient of variation (CV_{defect})

2. Calculate CV_{defect}

   The emitter defect coefficient of variation quantifies the contribution to non-uniformity resulting from broken, worn or blocked emitters.

   It is estimated as the difference between the coefficient of manufacturing variation (CV_{man}) and the coefficient of flow variation CV_Q in each test station 1, 3 and 4.

   NOTE: CV_{man} may have been determined in the field from the "cleanest area" flow test measurements. It is not possible to assess the individual contributions of emitter variation any more than as established above.

IMPACT OF PRESSURE VARIATION

NOTE:

Caution is required when evaluating pressure compensated systems as the pressure flow relationship is NOT CONSTANT across the pressure range.

Pressure adjusted emitter flow

1. Determine pressure adjusted flows for each emitter measured in the emitter performance tests (see clean, middle and dirty area tests). Adjust the flow of each emitter to an equivalent flow at mean field pressure.

   NOTE: DO NOT pressure adjust flows of Pressure Compensating systems.

Sources of pressure variation

2. Calculate the maximum pressure variation (kPa) between laterals, and the maximum pressure variation along laterals.

   NOTE: These should be expressed as a percentage of the total pressure variation. Non-uniformity arises from pressure variation in three identifiable places: variation between stations, along manifolds, and along laterals.

Station pressure variation

3. Identify the largest difference between inlet pressures to Stations. The pressure at the start of the first lateral may be used if not pressure test point is available at the off-take.

Manifold pressure variation

4. Identify the largest difference in Inlet Pressure between the first and last laterals on the manifolds.

Lateral pressure variation

5. Identify the largest difference between Inlet Pressure and End Pressure in the laterals.

Design uniformity (EU_{des})

6. Calculate Design uniformity (EU_{design}).

   NOTE: The design uniformity coefficient is an estimate of brand-new system uniformity determined from manufacturer's emission uniformity (EU_{man}), the number of emitters per plant, and accepted design pressure variation.

   NOTE: The equation utilises only mean low quarter and mean pressure values, so is not strictly a statistical measure. Report as a decimal.

APPLICATION CALCULATIONS

Equivalent applied depth (DZ_{app})

1. Calculate Equivalent Applied Depth (DZ_{app}).

   NOTE: The volume applied must be adjusted for the area served to ensure that the depth of irrigation water applied is comparable with PET and water consumption (mm/day). Under micro-irrigation, not all the area available for plant roots is wetted.

Infiltration depth

2. Calculate Infiltration Depth.

   NOTE: Infiltration depth under micro-irrigation is calculated from applied volumes and the wetted area per emitter (Figure 3.2).

3.3 Adjust irrigation system settings

APPLIED DEPTH

1. Compare Mean Station Applied Depths to Target Depth
    - Adjust station run time to achieve target applied depth

Adjusted run time

2. Calculate Adjusted Run Time for each Station
    - Adjusted Run Time (h) = Target Depth (mm) ÷ EU ÷ Application Intensity (mm/h)

    NOTE: Including EU ensures the Run Time applies sufficient water to adequately irrigate 7/8th plants.

Emitter uniformity

3. Identify impact of variables contributing to non-uniformity
    - Repeat Operational Checks (Section 1)
    - Adjust system components to achieve best performance
    - Ensure system is at recommended operating pressure
    - Get professional assistance.

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Appendices

PART C: Micro-irrigation

Appendix 1: Micro-irrigation case study

A vineyard drip irrigation system was assessed five years after installation and found to have unexpected performance variation. The primary causes were non-specification dripline, high emitter discharge variation and high pressure variation.

SYSTEM INFORMATION

The system covered by this evaluation was five years old. It covered 79 ha with a field elevation difference of 6m.
Each vine row had one drip-line with 1.5L/h emitters at 0.4m intervals.

System history included problems with emitter blockages in areas where winery wastewater had been discharged through the drip system. The waste distribution was moved to a spray system with higher flow rates and larger nozzle diameters.

The performance evaluation assessed three different management zones. Variable factors included plant spacing, the number of emitters per plant and emitter discharge rates and wetted areas. The design allowed for zones to run for different irrigation durations and return intervals.

Table 1 System and management data

	Zone 1	Zone 2	Zone 3
Area with combination (ha)	3.32	2.70	3.52
Ground area per plant (m^2)	3.0	2.4	2.4
Drip Brand	B	A	B
Number of Emitters/plant	3.8	3.8	3.8
Nominal emitter discharge (L/h)	1.7	1.6	1.7
Wetted area diameter (m)	0.3	0.3	0.3
Crop ET at Peak ET (mm/day)	3.3	3.3	3.3
Return Interval at Peak ET (days)	1.0	1.0	1.0
Target Application Depth (mm)	3.3	3.3	3.3
Set duration at Peak ET (hours)	1.0	1.0	1.0

Figure 1. Clamping lateral to reduce in-line pressure.

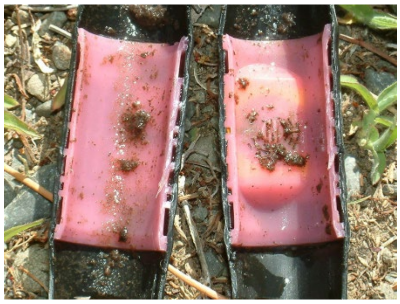

Figure 2. Dripper cut open to inspect for contaminants or other damage.

To assess performance, emitter discharge and pressure were measured in each zone. In Zone 1, 16 emitters were selected in the middle of a middle row were pressure difference was assumed minimal. After measuring discharge the pressure was reduced by about 20% by clamping the lateral (Figure 1) and the discharges re-measured. This enabled the relationship between pressure and discharge to be determined.

In Zone 2 another set of 16 emitter discharges and pressures were measured. This was selected as representing an “average” block in the vineyard.

In Zone 3 another 28 emitters were measured. This area was the area furthest from the pump and filters. Typically blockages show up sooner in such locations so system performance is anticipated to be lowest. Performance assessment protocols require a larger number of emitter measurements where variation is expected to be highest.

Pressure was tested at the beginning, middle and end of the first and last laterals in a number of blocks. These pressures were converted to equivalent discharge rates using the relationship calculated from Zone 1 data.

Additional measurements included pressure at the pump, through the headworks and at the end of the mainline (the take-off to the first irrigation block). Water meter flow and pump power consumption were also measured.

After testing, a number of emitters were removed and cut open for inspection (Figure 2).

RESULTS

Table 2 Evaluation measured data

	Zone 1	Zone 2	Zone 3
Average flow per emitter (L/hr)	2.54	1.56	2.21
Effective applied depth (mm)	3.2	2.4	3.5
Wetted area per emitter (m^2)	0.1	0.1	0.1
Percent area wetted (%)	8.8	11.0	11.0
Wetted Zone RAWC (mm equiv)	4.0	4.9	4.9
Water Meter Flow Rate (m^3/hr)	121.2	61.2	100.8
Energy consumption/hour (kWh/hr)	49.2	36.0	42.0
Energy consumption (kWh/mm/ha)	13.5	15.9	14.7

There was variation in discharge, as shown in Figure 3, but within each Zone this was acceptable. However, large variation between different Zones meant overall uniformity was poor.

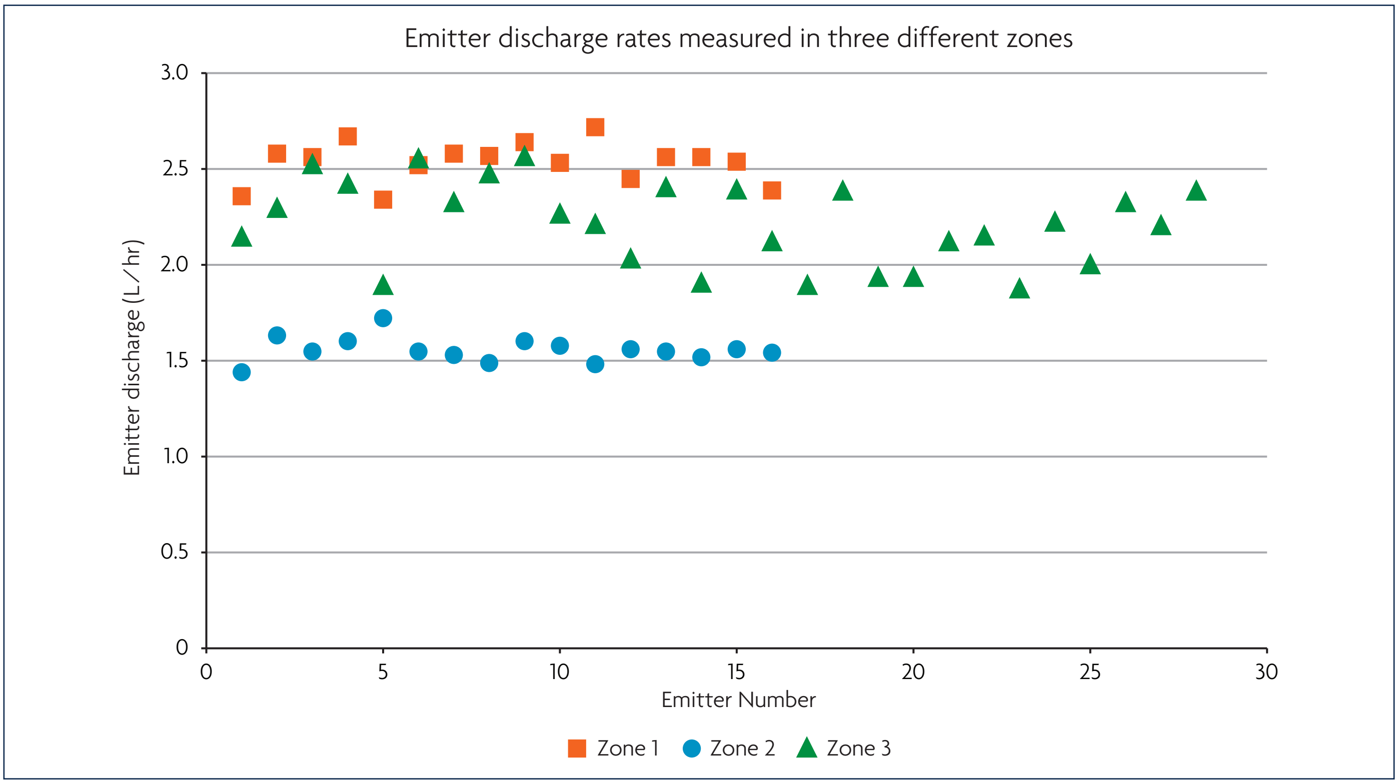

Figure 3. Emitter discharge rates measured in three different zones.

As expected and seen in Figure 3, the greatest variation was found in Zone 3.

The calculated field distribution uniformity was EU_{lq} = 0.70. This is considered poor for a micro-irrigation system.

Table 3 Interpretation of Field Emission Uniformity results: Drip-micro irrigation

Result	Perfect	Excellent	Good	Fair	Poor
EU_{field}	1.00	0.95 – 0.90	0.89 – 0.85	0.84 – 0.75	0.74 – less
ASAE 405.1		> 0.90	0.90 – 0.80	0.80 – 0.70	0.70 – 0.60

(Based on guidelines presented by Clemmens and ASAE 405.1.)

Analysing the data with the software showed the relative contribution of different variables:

The relative contributions were:

- Emitter variation = 27.4%
- Pressure variation = 34.2%
- Uneven drainage = 0.3%
- Block variations = 38.2%

Emitter variation combines manufacturing variation and damage and blockage after five years in the field. Inspection showed a build-up of algae in many emitters. Discharge rates in Zone 1 indicate this was not affecting performance.

The zone with Drip Brand A performed within 2.5% of the 1.6L/h nominal discharge per emitter and had an Emission Uniformity of 0.95 which , especially after five years operation, is excellent.

However the two zones with Drip Brand B, nominal 1.7L/h emitter discharge, performed very poorly. The measured discharge of emitters was 2.54L/h (149%) in Zone 1, and 2.21L/h (130%) in Zone 3. Their Emission Uniformity was 0.94 (excellent) and 0.86 (good).

Pressure variation results from elevation differences and friction losses between blocks, along manifolds and along laterals. Because the emitters in this vineyard were not fully pressure-compensating, pressure variation resulted in significant variation in emitter discharge rates. We measured a 10% drop off in discharge for a 20% decrease in pressure.

The causes of pressure variation include field elevation (equivalent to 60kPa), mainline losses and some excessively long rows. This is illustrated in Figure 4.

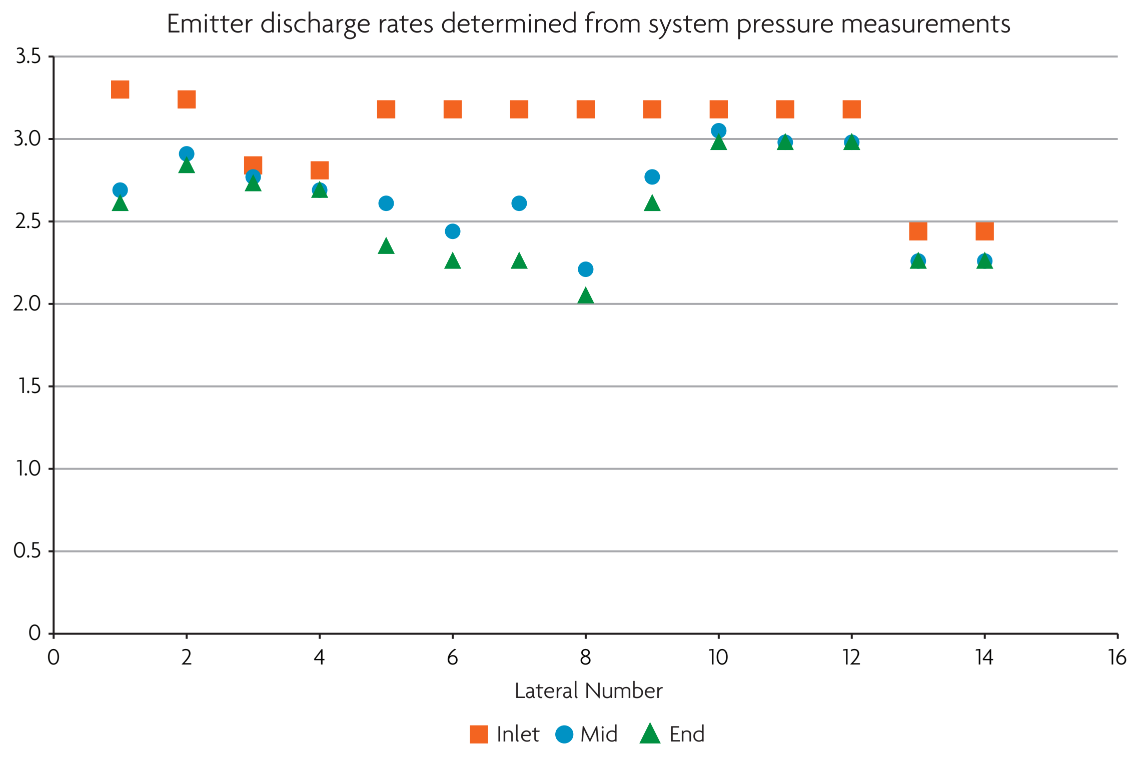

Figure 4. Emitter Discharge Rates determined from pressure measurements in driplines

Each pair of laterals corresponds to the first and last laterals in a block. Many laterals, including lateral 1, show a large drop between the inlets discharge and the mid and end lateral discharges. This is indicative of lateral pipe that is too small bore or excessively long for the amount of water being piped. The beginning of the lateral has all the water entering it, and friction losses are at their maximum. Further along the lateral, flow rates reduce as increasingly more water has been emitted.

Laterals 3 & 4, and 13 & 14 are blocks where the inlet pressure is too low. There is little pressure loss along the laterals, but discharge is below target across the whole block.

Uneven drainage assesses the effect of areas that fill first and keep running longest after shut down. This is more severe with frequent, short duration irrigation events.

Block variations relate to different plant or emitter spacings, or to run times of different blocks. We identified variation in plant spacing and flow rates, but block run times were the same. Plants that occupy greater areas use relatively more water and require more irrigation. This must be reflected in different emitter spacing or run time. This performance assessment found block variation accounted for 38% of the non-uniformity of the irrigation system.

RECOMMENDATIONS

Maintenance

- Hose flushing:
  Hoses should be flushed for several minutes at least once a month. This cleans out the sediment which settles out in the last half of the hoses, and which can cause serious plugging problems if it accumulates. Some growers install flushing hose end caps which automatically flush during system start-up and shut-down. These require careful design as they can fail to close if insufficient pressure is generated.
- Injection to prevent plugging:
  While the emitters appeared to be discharging correctly, the presence of obvious algal build-up is concerning. Chlorine is typically used to inhibit organic plugging of drip systems. Recommended dosages vary from 0.5 to 10 ppm. Timing of injections usually range from continuous injection to once per week. The dosage and timing will depend upon the water quality. Chlorine activity is enhanced by reducing the water pH (ie, making the water more acid).
  Plugging problems due to bacteria or algae often do not show up the first year or two of drip system operation, and then may reach suddenly catastrophic proportions unless chemicals are injected on a routine basis.
- Pressure control:
  Pressure variation between blocks may be caused by incorrectly set off-take valves or pressure regulating valves if fitted. These should be checked to allow the same pressure in each block.

Management

The block variation can be managed by adjusting Zone run-times.

- Differing emitter discharge rates:
  Blocks with Brand B dripline should be run for shorter durations to account for higher than specified discharge rates. Note however, that at high discharge there is high pipe friction so longer rows have lower discharges from emitters towards the lateral end. Replacing the dripline is necessary to fully correct this problem.
- Larger plants:
  Blocks with larger plants require more water so should receive longer irrigations. However the soil has very limited water holding capacity so care is needed to ensure the extra water does not drain past the effective rootzone to waste. Shorter durations at closer intervals may be needed.

New Zealand Piped Irrigation System Performance Assessment Code of Practice

PART D: Solid-set

Note: This is Part D of a series of nine (Parts A–I).

Part D: Contents

Date of Issue: January 2023

The Code is presented as a series of booklets, each with a defined purpose.

Part A: An Introduction to Performance Assessment
Part A provides an overview of performance assessment, explains the broad philosophy behind assessment approaches taken throughout the Performance Assessment series, and contains specific formulae and reporting standards.

Part B: Compliance and Water Supply Checklists
Part B relates to all system types. It contains recommendations for checks to ensure compliance with regulations, rules and consent conditions, safe effective operation of water supply systems.

Parts C–H: System Performance Assessments
(Part D = this booklet)
Parts C–H contain guidelines and recommendations for Operational Checks, System Calibrations and In-field Performance Assessments specific to a range of irrigation system types.

Part I: Conducting Energy Efficiency Assessments and Seasonal Irrigation Efficiency

IrrigationNZ Technical Glossary
The Glossary and Calculations are common with the NZPIS Design Code of Practice.

Ministry for Primary Industries
Manatū Ahu Matua

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Introduction

Purpose

The *New Zealand Piped Irrigation System Performance Assessment Code of Practice* provides nationally recognised guidelines to measure and benchmark performance of agricultural irrigation.

Part D is specific to solid-set irrigation systems. It makes recommendations for planning and conducting assessments and reporting on the performance of irrigation systems and their management. Its focus is on key performance indicators that are common with the New Zealand Piped Irrigation Systems Design Standards.

It was developed to provide guidelines for irrigators and others undertaking evaluations of such equipment as a 'snapshot exercise' under prevailing field conditions.

SYSTEM PERFORMANCE

The Code recognises different levels of performance assessment depending on purpose. In increasing level of complexity, system performance assessment includes:

- Operational Checks
- System Calibration
- In-field Performance Assessment.

Related documentation

- **New Zealand Piped Irrigation System Performance Assessment Code of Practice:**
  - Part A: An Introduction to Performance Assessment
    Part A provides an overview of performance assessment, explains the broad philosophy behind assessment approaches taken throughout the Performance Assessment series, and contains specific formulae and reporting standards.
  - Part B: Compliance and Water Supply Checklists
    Part B relates to all system types. It makes recommendations for checks to ensure compliance with regulations, rules and consent conditions, safe effective operation of water supply systems and energy efficiency assessments of pumps and delivery systems.
  - Parts C–H: System Performance Assessments
    Parts C–H contains guidelines and recommendations for performance assessments specific to a range of irrigation system types.
- **New Zealand Piped Irrigation Systems Design Code of Practice**
- **New Zealand Piped Irrigation Systems Design Standards**
- **New Zealand Piped Irrigation Systems Installation Code of Practice**
- **New Zealand Water Measurement Code of Practice**
- **New Zealand Irrigation Technical Glossary**

System description

Solid-set irrigation systems are characterised by permanently fixed sprinklers on rigid riser pipes, usually arranged in a grid pattern. The spacing between sprinklers varies considerably and the sprinkler layout pattern may be either square or triangular.

Long-lateral (bike-shift or long-line) systems are a special case. They are included in this section as evaluation procedures follow the same procedures as for solid-set systems. Long-lateral systems typically have medium sized impact sprinklers mounted on a moveable stand, connected to permanently buried mainlines and hydrants by a long polythene pipe. Each sprinkler is moved manually around 6–10 positions to cover 0.4 to 0.8 ha.

Special features for analysis

WIND EFFECTS

The performance of pressurised spray systems such as solid-set systems can be greatly affected by wind, particularly when nozzles are used on high angle settings or at high pressures that create smaller droplet sizes.

The uniformity testing should be carried out in conditions representative of those commonly experienced in the field. Wind speed and direction should be measured and recorded every 15 minutes.

PERMANENT SET SYSTEM

Because solid-set irrigation systems are not mobile any inherent non-uniformity (e.g. not the result of wind) is repeated with each irrigation. There is an increased demand for high uniformity as there is no 'smoothing' effect as with moving systems, where inherent non-uniformities vary between events and tend to cancel each other out.

LONG LATERAL SYSTEM

The long lateral irrigation systems are mobile, there may be a 'smoothing' effect and non-uniformities may cancel each other with successive irrigation events. However, the uniformity achieved depends on the placement of sprinklers at, and timing of, each shift.

FIELD VARIABILITY

Performance may vary at different positions in the field due to factors including topographic variation and elevation changes and friction in the distribution network.

If field elevation varies significantly, consider increasing the number of tests to increase accuracy of distribution uniformity assessments. Record the (relative) elevations of each test site, and draw a profile sketch along a typical lateral if necessary.

A solid-set system operating on a relatively flat, homogenous field should have similar performance in all positions. The assessor and client should discuss what testing is desired and the conditions under which any tests should be conducted.

OFF-TARGET APPLICATION

Spraylines may be operated with sprinklers set at either end of the strip to ensure at least the target application depth is applied to the whole crop. A variable percentage of water will be applied off target so application efficiency is reduced, more so on short runs.

1. Operational checklist

This is a minimum list of checks of solid-set irrigation systems that should be made.

Be safety conscious – electrical and mechanical hazards may be present.

Every system should be supplied with a System Operation Manual. The manual may include extra checks not listed here. It will give more detail than this checklist including information specific to your system.

SYSTEM OFF CHECKS

Filtration

1. Check condition of filters and filter media
   - No leakage from seals or joints
   - Rings/screens are clean with no holes
   - Pressure gauges are fitted and in good condition.

Fertigation/chemigation

2. Ensure the system is physically sound
   - No signs of corrosion
   - System clean, no blockages
   - No leaks
   - Backflow prevention is installed as required.

Control valves and offtakes

3. Ensure wiring and hydraulic lines are secure
4. Ensure manual valves are correctly set
5. Ensure hydrants are secure

Flushing points

6. Check flushing points are accessible
7. Ensure caps are in place

Pipe network

8. Visually inspect sub-mains/headers as possible
9. Visually inspect laterals are undamaged

Laterals

10. Visually check laterals undamaged
11. Check tapping saddles/connections secure
12. Inspect risers for wear or damage

Sprinklers

13. Check sprinklers fitted are as specified in sprinkler chart
14. Inspect for damage or blockage, and moving parts are free
15. Ensure alignment is correct

Control unit

16. Visually inspect electronic controls
17. Check battery charge.

SYSTEM ON CHECKS

Pump

1. Complete checks as specified in *Part B: Water Supply Performance Assessment*

Headworks

2. Complete checks as specified in *Part B: Water Supply Performance Assessment*
3. Check the flow rate of each station

Pipe network

4. Check for leaks along mainline
5. Check for leaks along sub-mains
6. Check for leaks along laterals
7. Check laterals flush clear

System pressure

8. Check pump pressure for each station
9. Check pressure before and after filters
10. Check all off-take pressures correct
11. Check the lateral end-pressure

Offtakes and control points

12. Check hydrants are not leaking

Sprinklers

13. Visually assess application pattern
14. Ensure moving sprinkler parts free.

2. Calibrating solid-set irrigation systems

The Irrigation Calibration method for solid-set irrigation systems assesses the amount of water being applied during an irrigation event. It is based on measurement of water collected in a sample grid of containers.

Applied Depth, Application Intensity and Distribution Uniformity are calculated. This allows the manager to determine the maximum depth that can be applied without causing drainage, the time required to apply the target depth, and whether the system is applying the same amount of water across the irrigation area.

By repeating the process at other sprayline positions and in other irrigation stations, a plan to apply target depths in each block across the whole property can be determined.

2.1 What will the testing show?

The main things the calibration test will show are:

Mean station applied depth
The rainfall equivalent depth of water the irrigation system is applying on average to each station. Compare the measured applied depth to target application to calibrate each station. Adjust station run times to correct applied depths.

Application intensity
The rainfall equivalent depth of water being applied per hour. If intensity exceeds soil infiltration capacity, ponding, redistribution and runoff will reduce irrigation effectiveness and efficiency.

Distribution uniformity DU
Distribution Uniformity describes the evenness with which water is applied. The higher the DU the better the system is performing. And the higher the uniformity, the more confident you can be that your measurements are truly representative of your system's performance.

Excess water use EWF
The excess water use factor identifies how much extra water is required during a set event because of non-uniformity.

Adjusted station run time
Calculates the irrigation duration to ensure 7/8ths of each sprayline position or irrigation station gets at least the Target Application Depth. It accounts for variations in outlet spacing, flow rate and uniformity.

WHEN SHOULD CALIBRATION BE DONE?
Complete the calibration test if commissioning any new areas and after any major changes. Calibration should be repeated as part of system checks at the start of every season.

NOTE:
Irrigation system performance can be significantly affected by weather conditions. Consider wind conditions when testing: Calm conditions may give a better assessment of the system's potential performance but if wind is normal for the site, testing may proceed.

NOTE:
Pressure variation will significantly alter performance. Consider testing:

- at different station locations
- different field elevations, or
- when alternative water-takes reduce system pressure.

2.2 Calibration process

Before starting, ensure System Operational Checks (Section 1) have been completed.

Calibration is a four step process:

1. Gathering information about the system
2. Calculating performance indicator values
3. Comparing results with expectations
4. Adjusting irrigation system settings as required to achieve intended performance.

GATHERING INFORMATION

Equipment
Equipment needs are very basic and most should already be available on the property. A suggested list includes:

- 20 containers of same opening diameter (>150mm)
  - 9 Litre buckets have been found suitable
- 1 measuring cylinder
  - 1 or 2 Litre for larger volumes (large containers, long run times)
  - 100mL or 200mL for smaller volumes (small containers, short run times)
- 1 tape measure (50m)
- 1 stop watch
- 1 pen or pencil
- 1 recording sheet.

Sampling method
Solid-set systems have overlapping sprinklers. Sampling should get a "fair" representation of water application. Follow bucket

placement guidelines carefully and read volumes as accurately as possible to be sure of best results.

Testing layout

The basis is a grid of 20 collection buckets arranged between adjacent sprinklers, but with consideration of crop effects (See Figure 2.1).

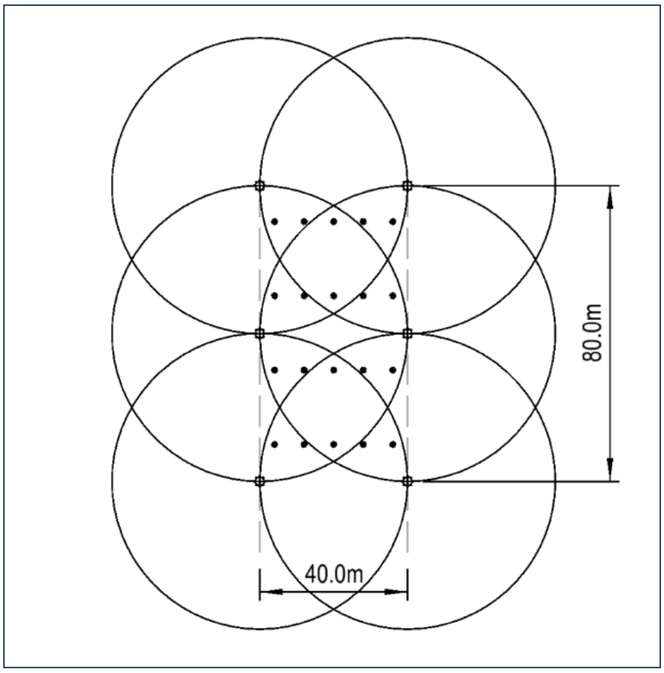

Figure 2.1 (A). Example collector bucket positions relative to rows and sprinklers.

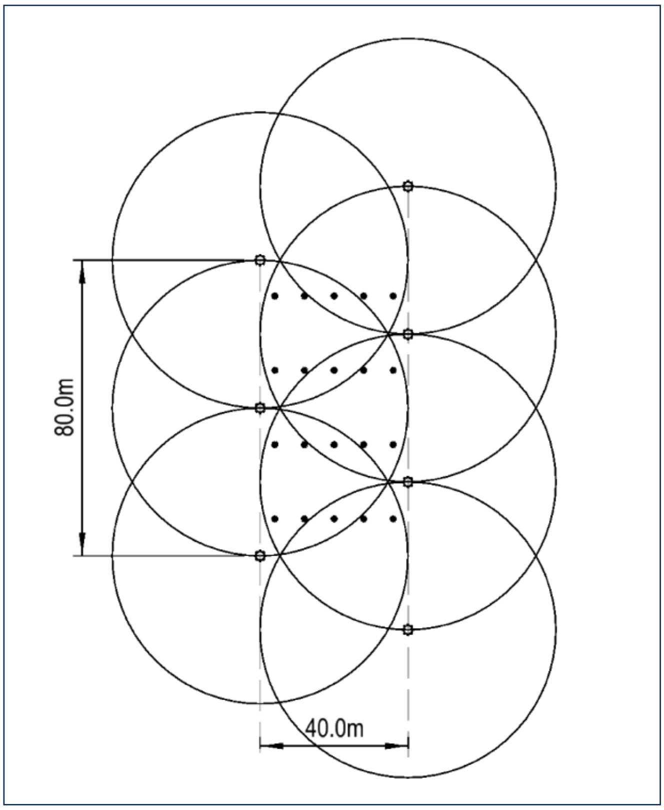

Figure 2.1 (B). Example collector bucket positions relative to rows and sprinklers.

Figure 2.1 (A) shows a grid arranged between six sprinklers set with a square spacing. Depending on sprinkler spacing, arranging a grid between four adjacent sprinklers may be a fair sample.

Figure 2.1 (B) shows a grid arranged between seven sprinklers set with a triangular spacing.

In each case, single, double and multiple overlap positions are sampled at a range of distances from the sprinkler heads.

Figure 2.1 shows a situation with row crops. It can also be valid to place collection buckets within rows or beds – example testing overhead frost protection systems in orchards/vineyards.

FIELD MEASUREMENTS

Repeat the following field measurements and calculations in each area of interest.

Management information

1. Record the Target Irrigation Depth
2. Record the Normal Irrigation Event Duration

System measurements

3. Measure the Outlet Pressure at the pump
4. Measure the Pressure at Station offtake
5. Measure the system Flow Rate

Sprinkler measurements

6. Measure the distance between sprinklers along a lateral

   NOTE: It is often best to use an average distance between a number of sprinklers

7. Measure the distance between adjacent laterals.

   NOTE: Take an average spacing between several laterals

8. Determine the area of each Block
   [Lateral length x lateral spacing x lateral number]

Application test

9. Run the system and record the duration

   NOTE: Ensure run time is long enough to collect enough water to measure accurately.

10. Measure the collector bucket mouth diameter
11. Measure the volume of water caught in each container and record on the Record Sheet.

CALCULATE PERFORMANCE INDICATOR VALUES

Applied depth

1. Calculate Applied Depth
   - Applied Depth (mm) = Average Volume collected ÷ Collector opening area
   - Average Volume Collected (mL) = Sum of all collected ÷ number of collectors
   - Collector opening area (m^2) = Pi × (Collector diameter)^2 ÷ 4

Application intensity

2. Calculate Application Intensity
    - Application Intensity (mm/h) = Applied Depth (mm) ÷ Test Duration (h)
3. Calculate Block Flow Rate (m^3/h)
    - Block Flow Rate = Application intensity (mm/h) × Block Area (ha) × 10

Distribution uniformity

4. Calculate the Distribution Uniformity (DU_{lq})
    - DU_{lq} = Low quarter average volume ÷ average volume
    - Low Quarter Average Volume (mL) = Average of lowest five collected volumes

Excess water use EWF

5. Calculate Excess Water Use Factor (EWF)
    - EWF(%) = DU Adjusted Depth ÷ Applied Depth × 100
    - DU Adjusted Depth (mm) = (Applied Depth ÷ DU) – Applied Depth.

COMPARE RESULTS WITH EXPECTATIONS

Flow rates

1. Compare calculated System Flow Rate with Water Meter Flow Rate

Applied depth

2. Calculate Target Depth to Applied Depth ratio = Target Depth ÷ Applied Depth
    a. < 1 – under applying
    b. = 1 – correct
    c. > 1 – over applying

    Acceptable variances: 0.90–1.10 (0.95–1.05 is better)
3. Compare Applied Depth with Soil Moisture Deficit
    - Applied Depth < Soil Moisture Deficit ÷ DU

Application intensity

4. Compare the calculated Application Intensity to Estimated soil infiltration rate
5. Compare with observations of ponding

Distribution uniformity DU

6. Interpret calculated DU value
    - DU > 0.90 — Uniformity is very good; the system is performing very well
    - 0.90 – 0.80 — Uniformity is good; performance better than average
    - 0.80 – 0.70 — Uniformity is fair; performance could be improved
    - 0.70 – 0.60 — Uniformity is poor; system should be investigated
    - DU < 0.60 — Uniformity is unacceptable; system must be investigated

ADJUST IRRIGATION SYSTEM SETTINGS

Check key performance indicators

1. If Applied Depth or Uniformity are unacceptable
    - Repeat Operational Checks
    - Ensure system is at recommended operating pressure
    - Get professional assistance.

Run time

2. Calculate Adjusted Run Time
    - Adjusted Run Time (h) = Target Depth ÷ DU ÷ Application Intensity

    NOTE: Including DU ensures the Run Time applies sufficient water to adequately irrigate 7/8th of the field.

3. Performance assessment of solid-set irrigation systems

This schedule presents procedures for conducting efficient and reliable irrigation evaluations of solid-set irrigation systems.

Procedures for planning, conducting, analysing and reporting system performance are described. They are intended to promote efficient work practices and informative reporting that facilitates easy comparison of systems.

NOTE:
Complete Operational Checks (See Section 1) before commencing a system assessment.

TECHNICAL MATERIALS – RELEVANT STANDARDS

Spray Irrigation Performance
ISO 7749-2: 1990 Agricultural irrigation equipment – Rotating sprinklers – Part 2: Uniformity of distribution and test methods

ISO 8026 Agricultural irrigation equipment – Sprayers – General requirements and test methods

ISO 8026:1995/Amd.1:2000 Agricultural irrigation equipment – Sprayers – General requirements and test methods AMENDMENT 1

3.1 Data collection

This schedule outlines procedures to be followed when assessing performance of solid-set irrigation systems under prevailing field conditions.

Because test conditions will vary, key conditions must be measured and recorded to assist any comparisons between subsequent tests of the same system, or when benchmarking against other systems.

NOTE:
To provide farmer general operation/management information, test conditions should be representative of those experienced in normal operation.

NOTE:
For System Commissioning or fulfilling specific purchase contract criteria, adherence to test condition limitations such as wind speed should be ensured.

TEST SITE

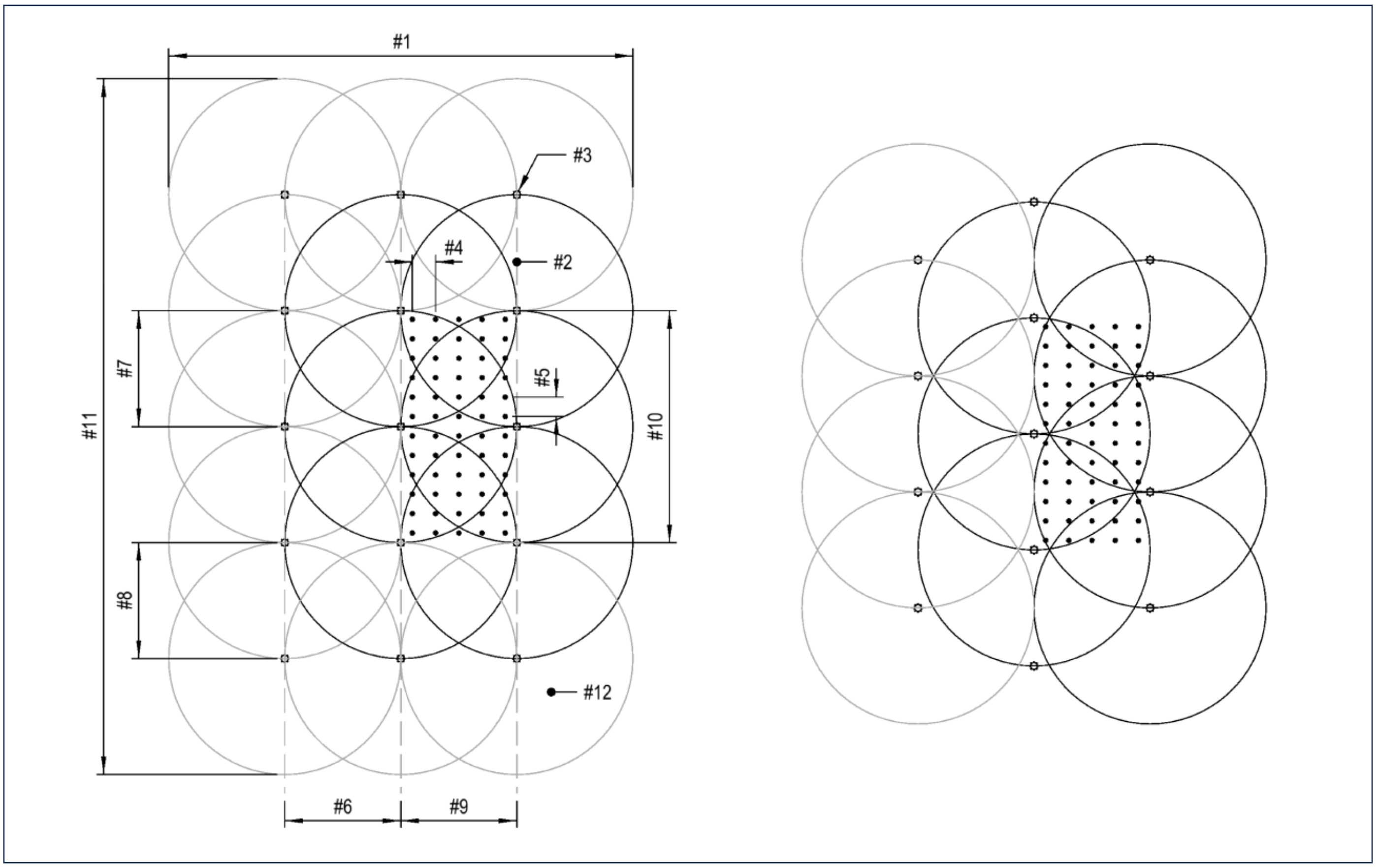

Figure 3.1. Location of sampling grid within a grid sprinkler pattern and a triangular solid-set pattern. Labels for the grid design are applicable for the triangular design

1. Field width
2. Lateral
3. Sprinkler
4. Collector spacing along the row, s_{cr}
5. Collector spacing down the column, s_{cc}
6. Hydrant spacing
7. Hydrant column spacing, D_s
8. Sprinkler wetted radius, r_w
9. Extent of collector columns
10. Extent of Collector rows
11. Field length
12. Off-target application

Location

Select a test location that is most representative of the system as a whole.

If the irrigation site is not level, conduct the test in an area having elevation differences that are within the design specifications of the sprinkler package.

Site variability

If site elevation varies significantly, consider multiple tests to increase accuracy of distribution uniformity assessments. This may involve several grid uniformity tests or a combination of grid uniformity and pressure flow uniformity tests.

3.2 System survey

SYSTEM LAYOUT

1. Prepare a map of the system recording the headworks, mainline, take-off points, sub-mains, manifolds and laterals
2. Mark location of pressure regulators, flush valves and positions where tests are to be conducted (see Figure 3.1)

Topography

3. Determine elevation differences between test sites and across the station as a whole
   - Prepare a sketch of the profile along a typical lateral.

Field area

4. Measure the Field length and width as defined in Figure 3.1

Fixed sprinklers

5. Record number of sprinklers
6. Record sprinkler spacing and lateral spacing

Long-lateral

7. Record the number of sprinklers operating at once
8. LONG-LATERAL: Record the number of sprinkler shifts per hydrant.

SYSTEM OPERATION

Water quality

The water used for the test should be the same as that normally used for irrigation including normal filtration, injection of effluent, chemicals or other processes unless specifically requested by the client.

WARNING:

For personal health and safety reasons, particular caution is necessary if water contains chemical treatments or biological wastes.

Sprinkler package

1. If the water distribution systems allows for different arrangements, use one setting that represents normal operation
   - The number of spraylines and sprinklers operating should remain constant during the test.

Sprinkler package – long-lateral systems

2. Testing long-lateral systems requires special consideration. A satisfactory sampling design includes assessing the distribution from each potential sprinkler position within the sampling area (see Figure 3.1)

System pressure

3. Complete the test at normal operating pressure or as agreed by client and tester
   - Ensure the pressure is maintained during the test
   - Ensure pressure measurements include lowest and highest areas.

ENVIRONMENTAL MEASUREMENTS

Wind

1. Record the direction and speed of the wind during the test period, and plot against relevant test locations on a map
   - Wind speed and direction relative to the sprayline should be monitored at intervals of not more than 15 minutes and recorded
   - Wind conditions at the time of the test should be representative of those experienced in normal operation
   - Wind speeds greater than 3 m/s can have significant effects on uniformity.

NOTE:

At speeds greater than 3 m/s the tester and client must understand the limitations of the test results. The uniformity test should not be used as a valid measure of the sprinkler package if the mean wind velocity exceeds 3 m/s.

Evaporation

The uniformity test should be conducted during periods that minimise the effect of evaporation, such as at night or early morning or in winter months.

2. Record the time of day, estimated or measured temperature and humidity when the test is conducted
3. Record the temperature and humidity in the test zone during the test period
4. Determine evaporation rates using evaporation collectors identical to those used in uniformity testing
   - Place a control collector in a representative location upwind of the test area.
   - Adjust readings for evaporation loss.

FIELD OBSERVATIONS

Crop type

1. Record the site's planting history for previous season and year
2. Note crops planted in the area under examination, and stage of growth

Crop appearance

3. Observe the crop for signs of stress or growth difference. Patchiness is indicative of poor system performance
4. Measure or estimate the crop ground cover proportion

Soils

5. Dig or auger several holes within the irrigated area
6. Determine the soil texture and depth of rooting
7. Estimate or otherwise determine soil infiltration rate and soil water holding capacity
8. Assess the depth of water penetration
9. Note any soil features that indicate wetness, poor drainage or related properties and identify causes

Ponding

10. Assess the amount of ponding that occurs within the irrigated area while the system is operating
11. Note if water is ponding, running over the ground, or causing soil movement
12. Estimate the percentage of water lost

Off-target application (F_{TARGET})

13. Estimate the proportion of discharge that falls outside the target area (off the edges of the field as a whole)

Runoff

14. Assess the amount of runoff from the irrigated area as a result of irrigation. Only consider volumes leaving the irrigated area.

SYSTEM CHECKS

Water supply

1. Complete checks of the water supply including pumping system and mainline as specified in *Part B: Compliance and Water Supply Checklists*

Filtration

2. Check filters and note nature and degree of contamination or blockage
3. Identify when the filter was last checked or cleaned
4. Identify if automatic cleaning or back-flushing is fitted and operational
5. Check for presence of contaminants in lines: sand, bacteria/algae, precipitates etc

Sprayline leaks

6. Check for damage to spraylines or misfit connections
7. Assess scale of leakages if any

Sprinklers

8. Record the nozzle type and orifice(s) fitted
   - Verify that the sprinkler package matches the design specifications
9. Measure sprinkler spacing along the sprayline
10. Measure sprinkler height above canopy
11. Check sprinklers are operating and set correctly (to horizontal)
12. Randomly select at least 12 sprinklers or sprayers along the length of the machine
   - Inspect them for blockages and record the cause of any blockages found
   - Assess orifice wear with a gauge tool or drill bit.

SYSTEM FLOW

Total system flow

1. Record the water flow rate as measured by a fitted water meter with the system operating as normal
   - Wait until flow rates stabilise (up to 15 minutes) before taking readings
   - It may be necessary to take beginning and ending meter readings over a set time period to determine flow rate.

Energy use

2. Obtain energy consumption data for the period covered by flow measurement
   - Enables calculation of irrigation energy costs.

SYSTEM PRESSURE

Headworks pressures

With system operating,

1. Measure pump discharge pressure
2. Measure mainline pressure after filters and control valves

Optionally measure:

3. Filter head loss
4. Pump control valve head loss
5. Throttled manual valve head loss

Mainline pressures

For multiple block solid-set and long lateral systems:

6. Measure Pressure at each hydrant

Sprayline pressure

7. Measure sprinkler pressures:
   - At first available pressure test point or sprinkler downstream of the hydrant
   - At a sprinkler in the middle of the sprayline
   - At the last sprinkler or end of the sprayline.

NOTE:
If pressure is read at a sprinkler, use a pressure gauge with a pitot attachment.

NOTE:
Sprayline pressures cannot be inferred from readings at the sprinkler if pressure regulators are installed.

SPRINKLER PERFORMANCE

Wetted radius

1. Determine the wetted length and width of the irrigated area, extending to approximately 75% of the wetted radius of outer-most sprinklers (Record to the nearest 10cm.)

Sprinkler pressure / flow

2. Measure the pressure and flow from 12 sprinklers across the irrigated area
    - Avoid the inlet end of laterals if possible as pressure variation will be high
    - Ensure sprinklers chosen are of the same specifications
    - Capture all flow without flooding the nozzle or affecting pressure
    - Shroud the sprinkler or sprayer with a loose hose and collect discharge for at least 30 seconds or 20 litres
    - Measure and record the volume collected (mL) and time (sec).

Grid uniformity test

Solid-set

3. Arrange a grid of collectors between six adjacent sprinklers (three in each of two rows) in a representative part of the system. The grid must fit within the six sprinklers (Figure 3.2)

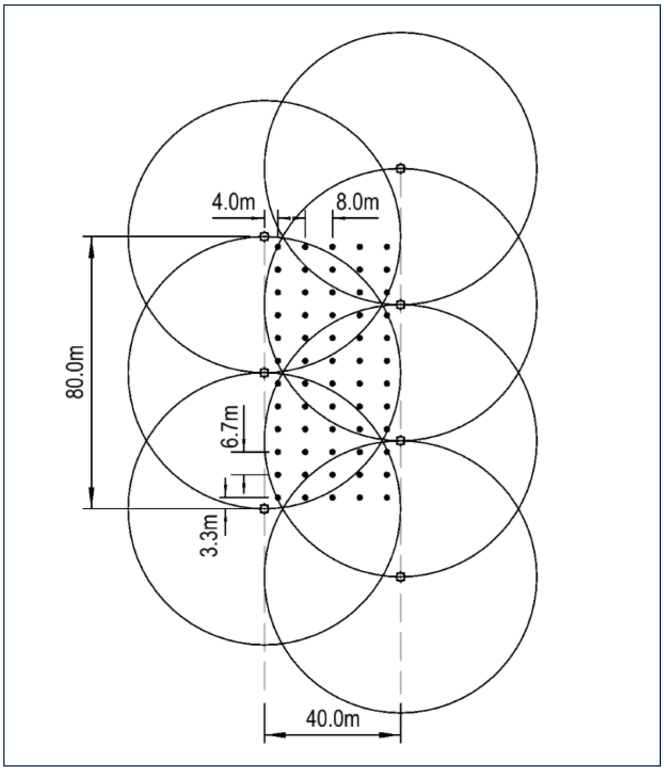

Figure 3.2. Collector spacing example.

Collector columns run up the page, rows run across the page. There should be 5 columns and 12 rows.

Collector placement Is Inside the sprinklers not in-line with the sprinklers.

The example given has a sprinkler spacing of 40m In a grid.

Column spacing = 40/5= 8m
bucket spacings should be 8m apart and start half a spacing in from the sprinkler post (4m)

Row spacing = 80/12 = 6.7m
bucket spacings should be 6.7m apart and start half a spacing In from the sprinkler post (3.3m)

The grid pattern Is the same for off-set sprinklers in the triangle pattern. The 4 sprinklers on one side are required to operate to capture the overlap in the corner buckets. See Figure 3.3.

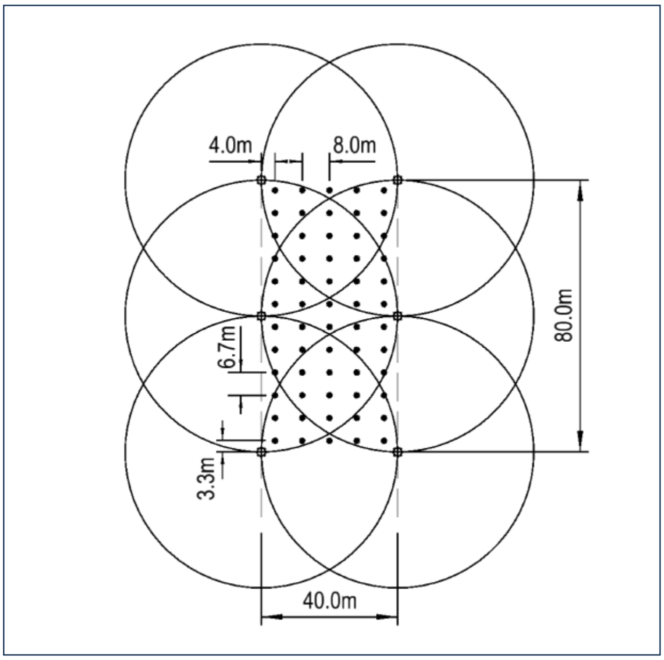

Figure 3.3. The four sprinklers on the right need to operate to ensure the overlap Is measured.

Long-lateral systems

4. Arrange a grid of collectors between four or six adjacent hydrants in a representative part of the system. The grid must fit within the selected hydrants
    - Ensure 60 collectors are used with 5 columns and 12 rows
    - Ensure the first and last columns of collectors are positioned one half column spacing from the first and last test sprinklers respectively
    - Ensure the distance between collector rows (Scr) is a factor of the sprinkler rows spacing (Dsr)
    - Ensure the first row of collectors is positioned one half sprinkler row spacing from the sprinklers

Test duration

Solid-set systems

5. Record the normal operation irrigation set time
6. Record the test duration time
   - Apply sufficient volume for reliable measurements to be obtained
   - Ensure appropriate adjustments are factored into calculations

Long-lateral systems

7. Long lateral systems require a modified operation plan under which selected sprinklers are moved at set intervals to imitate multi-event distribution patterns
   - Apply sufficient volume for reliable measurements to be obtained
   - Ensure each shift runs for the same duration
   - Ensure appropriate adjustments are factored into calculations

NOTE: To avoid unequal collection times, shut the system off before reading collectors.

OPTIONAL TESTS

Additional tests

1. Repeat tests as required to determine distribution uniformity under different weather (wind) conditions, or with the sprayline or other spraylines in different field location or fields

NOTE:
On highly variable terrain, a sprinkler pressure:flow test should be considered to establish performance variability across the entire system.

Adjusted pressure:flow test

The effect of pressure change on sprinkler discharge can be determined using the discharge coefficient. If a manufacturer's value is unavailable, or is queried, the discharge coefficient can be determined from measurements of the same emitters at different operating pressures.

2. Repeat the sprinkler pressure:flow measurements after adjusting the operating pressure by about 20%.

NOTE:
After this test, reset the system to its normal operating conditions.

3.3 Data analysis

SYSTEM

Irrigated area

1. Calculate the irrigated area of the test sprayline
   - Sprayline Area = Sprayline Length x Strip Width
2. Calculate the area irrigated per set
   - Set Area = Sprayline Area x Number of Strips per set
3. Calculate the total area irrigated
   - Total Area = Set Area x Number of Shifts.

PERFORMANCE INDICATORS

Water supply

1. Complete calculations of water supply including pumping system and mainline as specified in *Part B: Compliance and Water Supply Checklists*

System pressure

2. Calculate the Mean Field Pressure
   - Sum of all pressures / Number of pressure readings
3. Calculate Maximum Hydrant Pressure Variation (if relevant)
   - Highest Hydrant Pressure – Lowest Hydrant Pressure
4. Calculate Maximum Lateral Pressure Loss
   - Greatest difference between highest and lowest pressure on individual laterals
5. Calculate the maximum pressure variation among all readings
   - Highest reading – Lowest reading

Pressure derived flows

6. Calculate pressure derived flows
   - For each of the pressure measurements taken across the field using the emitter pressure flow relationship, Equation 22.

NOTE: If the discharge exponent and coefficient are not available from manufacturers' data they must be determined from pressure flow data collected in the field and calculated.

Pressure distribution uniformity (PDU_{lq})

NOTE: The pressure distribution uniformity coefficient describes a theoretical uniformity determined from pressure variation across the field, and the pressure:discharge performance characteristics of the emitters.

7. Calculate Pressure Distribution Uniformity (PDU_{lq})
   - Calculated from pressure derived flows, using the low quarter uniformity formula Equation 31.

NOTE:
If used in determining Field DU, PDU_{lq} replaces sprinkler flow uniformity, QDU_{lq}.

Application depth

NOTE:
To make valid assessments of solid-set performance, the depths measured by collectors must be adjusted to account for evaporation losses and for the difference between test and normal run-time durations. This *adjusted application depth* can be compared to a total system application depth.

8. Calculate Adjusted Applied Depth
   - Applied Depth (mm) = Average Volume collected ÷ Collector opening area
   - Average Volume Collected (mL) = Sum of all collected ÷ number of collectors
   - Collector opening area (m^2) = Pi x (Collector diameter (m))^2 ÷ 4.
9. Calculate Equivalent Applied Depth
   - Equivalent Applied Depth (mm) = Adjusted Applied Depth x Set Duration ÷ Test Duration.
10. Compare Equivalent Applied Depth to Target Application Depth
    - Report as percentage.
11. Compare Equivalent Applied Depth to Soil Water Holding Capacity

Total system application depth

12. Calculate application depth based on total system flow, cycle duration and irrigated area using Equation 45

Application intensity

13. Calculate Mean Application Intensity
    - Application Intensity (mm/h) = Adjusted Applied Depth (mm) ÷ Test Duration (h)
14. Compare Mean Application Intensity to Soil Infiltration Rate
    - Report as a percentage
    - Application Intensity should be than Soil Infiltration Rate
    - Compare with observations of surface ponding.
15. Calculate Set Flow Rate (m^3/h)
    - Set Flow Rate = Application Intensity (mm/h) x Set Area (ha) x 10.

Field distribution uniformity (FDU_{lq})

16. Estimate overall field distribution uniformity (FDU_{lq})
    - Combine contributing variable factors using the Clemmens-Solomon statistical procedure.

$$FDU_{lq} = \left[1 - \sqrt{(1 - GDU_{lq})^2 + (1 - QDU_{lq})^2 + (1 - F_{ponding})^2 + (1 - F_{drainage})^2}\,\right]$$

Where:

FDU_{lq}	is low quarter field distribution uniformity
GDU_{lq}	is low quarter grid distribution uniformity
QDU_{lq}	is low quarter flow distribution uniformity
$F_{ponding}$	is surface redistribution from ponding
$F_{drainage}$	is uneven drainage factor

Grid distribution uniformity, GDU_{lq}

17. Calculate low quarter grid distribution uniformity, GDU_{lq}
    - First adjust application depths for evaporation and overlap, as described in the *Technical Glossary*.
18. Calculate GDU_{lq}

Flow distribution uniformity, QDU_{lq}

19. Calculate low quarter flow distribution uniformity
    - From measured sprinkler flows along the sprayline length using the low quarter uniformity formula.

NOTE:
This may be replaced by the Pressure Distribution Uniformity.

3.4 Adjust irrigation system settings

APPLIED DEPTH

1. Compare Mean Set Applied Depths to Target Depth
   - Adjust set run time to achieve target applied depth.

Adjusted run time

2. Calculate Adjusted Run Time for each set
   - Adjusted Run Time (h) = Target Depth (mm) ÷ EU ÷ Application Intensity (mm/h)

NOTE: Including EU ensures the Run Time applies sufficient water to adequately irrigate 7/8th plants

Distribution uniformity

3. Identify impact of variables contributing to non-uniformity
   - Repeat Operational Checks (Section 1)
   - Adjust system components to achieve best performance
   - Ensure system is at recommended operating pressure
   - Get professional assistance.

IRRIGATION NEW ZEALAND
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New Zealand Piped Irrigation System Performance Assessment Code of Practice

PART E: Sprayline

Note: This is Part E of a series of nine (Parts A–I).

Part E: Contents

Date of Issue: January 2023

The Code is presented as a series of booklets, each with a defined purpose.

Part A: An Introduction to Performance Assessment
Part A provides an overview of performance assessment, explains the broad philosophy behind assessment approaches taken throughout the Performance Assessment series, and contains specific formulae and reporting standards.

Part B: Compliance and Water Supply Checklists
Part B relates to all system types. It contains recommendations for checks to ensure compliance with regulations, rules and consent conditions, safe effective operation of water supply systems.

Parts C–H: System Performance Assessments
(Part E = this booklet)
Parts C–H contain guidelines and recommendations for Operational Checks, System Calibrations and In-field Performance Assessments specific to a range of irrigation system types.

Part I: Conducting Energy Efficiency Assessments and Seasonal Irrigation Efficiency

IrrigationNZ Technical Glossary
The Glossary and Calculations are common with the NZPIS Design Code of Practice.

Ministry for Primary Industries
Manatū Ahu Matua

Supported by Sustainable Farming Fund

Introduction

Purpose

The *New Zealand Piped Irrigation System Performance Assessment Code of Practice* provides nationally recognised guidelines to measure and benchmark performance of agricultural irrigation.

Part E is specific to sprayline irrigation systems. It makes recommendations for planning and conducting assessments and reporting on the performance of irrigation systems and their management. Its focus is on key performance indicators that are common with the New Zealand Piped Irrigation Systems Design Standards.

It was developed to provide guidelines for irrigators and others undertaking evaluations of such equipment as a 'snapshot exercise' under prevailing field conditions.

SYSTEM PERFORMANCE

The Code recognises different levels of performance assessment depending on purpose. In increasing level of complexity, system performance assessment includes:

- Operational Checks
- System Calibration
- In-field Performance Assessment.

Related documentation

- **New Zealand Piped Irrigation System Performance Assessment Code of Practice:**
  - Part A: An Introduction to Performance Assessment
    Part A provides an overview of performance assessment, explains the broad philosophy behind assessment approaches taken throughout the Performance Assessment series, and contains specific formulae and reporting standards.
  - Part B: Compliance and Water Supply Checklists
    Part B relates to all system types. It makes recommendations for checks to ensure compliance with regulations, rules and consent conditions, safe effective operation of water supply systems and energy efficiency assessments of pumps and delivery systems.
  - Parts C–H: System Performance Assessments
    Parts C–H contains guidelines and recommendations for performance assessments specific to a range of irrigation system types.
- **New Zealand Piped Irrigation Systems Design Code of Practice**
- **New Zealand Piped Irrigation Systems Design Standards**
- **New Zealand Piped Irrigation Systems Installation Code of Practice**
- **New Zealand Water Measurement Code of Practice**
- **New Zealand Irrigation Technical Glossary**

System description

A sprayline irrigation system irrigates a field by sequentially moving a static line of sprinklers to predetermined parallel locations across a field. Water is discharged under pressure from the sprinklers which are set at even intervals along a lateral pipeline.

Irrigated strips overlap at the edges to ensure even coverage. The evenness of application across the irrigated strip, and the evenness of application along the length of the sprayline, both contribute to overall irrigation distribution uniformity.

Sprayline systems make irrigation feasible where other techniques are not suitable. They can be used to irrigate irregularly shaped areas and some types are easily transported between fields. They are readily removed from the field to allow cultivation and other practices to be carried out unhindered.

Recognised categories include hand-move pipes, side-roll systems, and various towable spraylines. They may operate singly or as multiple units.

A. HAND-MOVE PIPES

Hand-move pipes are typically aluminium pipe lengths that clip together with quick couplings to fit field dimensions. A sprinkler is mounted on a riser at one end of each pipe section, so the sprinkler spacing is set.

Shifting is manual, with pipe sections separated, moved and re-joined at each position.

B. SIDE-ROLL SYSTEMS

Side-roll systems consist of sprinklers mounted on aluminium or steel pipeline sections. Each section acts as the spindle of a centrally fitted wheel. Repeating units are joined to form the sprayline to fit field dimensions. The sprinklers are mounted on rotating couplings to ensure horizontal alignment regardless of spindle position. Sprinklers are mounted at pipeline height.

Shifting is done by rolling the complete line sideways to the next position in the irrigation sequence.

C. TOWABLE SPRAYLINES

Towable spraylines consist of sprinklers fitted at set intervals on a polyethylene lateral. The sprayline length is generally set.

Shifting is done by towing the complete sprayline by one end to the next position in the field.

D. MULTIPLE SPRAYLINES

Multiple sprayline systems operate more than one sprayline concurrently from a series of hydrants. Application intensities may vary between individual spraylines, particularly if pressure varies significantly. This can be managed if control systems allow different irrigation event durations.

Special features for analysis

OVERLAPPING STRIPS

The uniformity of water application for an entire field is likely to be increased through the overlapping of adjacent irrigation strips.

Field application uniformity can be estimated by virtual overlays of test data from a single irrigation strip. The sprayline is measured for one set position, and measurements from outer edges mapped on to the corresponding measurements on the opposite side.

WIND EFFECTS

The performance of pressurised spray systems such as spraylines can be greatly affected by wind, particularly when nozzles are used on high angle settings or at high pressures that create smaller droplet sizes. Strong cross winds are likely to have greatest effects.

The uniformity testing should be carried out in conditions representative of those commonly experienced in the field. Wind speed and direction should be measured and recorded.

FIELD VARIABILITY

The performance of irrigation systems may vary at different positions in the field. Contributing factors include topographic variation and elevation changes, lateral pipe lengths, and variable distances from headworks to lateral pipe inlets.

Systems set out in varying topography are subject to pressure effects. In addition, systems that cover large areas may have pressure differences resulting from mainline and sub-main friction losses.

If field elevation varies significantly, consider increasing the number of tests to increase accuracy of distribution uniformity assessments. Record the (relative) elevations of each test site, and draw a profile sketch along a typical lateral if necessary.

OFF-TARGET APPLICATION

Spraylines may be operated with sprinklers set at either end of the strip to ensure at least the target application depth is applied to the whole crop. A variable percentage of water will be applied off target so application efficiency is reduced, more so on short runs.

ALTERNATE SETS

Spraylines may be set in different positions during successive irrigation rotations. If set positions are moved one half of set-width, the compensation can increase overall uniformity.

1. Operational checklist

This is a minimum list of checks of sprayline irrigation systems that should be made.

Be safety conscious – electrical and mechanical hazards may be present.

Every system should be supplied with a System Operation Manual. The manual may include extra checks not listed here. It will give more detail than this checklist including information specific to your system.

SYSTEM OFF CHECKS

Filtration

1. Check condition of filters and filter media
   - No leakage from seals or joints
   - Rings/screens are clean with no holes
   - Pressure gauges are fitted and in good condition.

Fertigation/chemigation

2. Ensure the system is physically sound
   - No signs of corrosion
   - System clean, no blockages
   - No leaks
   - Backflow prevention is installed as required

Control valves and offtakes

3. Ensure wiring and hydraulic lines are secure
4. Ensure manual valves are correctly set
5. Ensure hydrants are secure

Flushing points

6. Check flushing points are accessible
7. Ensure caps are in place

Pipe network

8. Visually inspect sub-mains/headers as possible
9. Visually inspect laterals are undamaged

Laterals

10. Visually check laterals undamaged
11. Check tapping saddles/connections secure
12. Inspect risers for wear or damage

Sprinklers

13. Check sprinklers fitted are as specified in sprinkler chart
14. Inspect for damage or blockage, and moving parts are free
15. Ensure alignment is correct

Control unit

16. Visually inspect electronic controls
17. Check battery charge.

SYSTEM ON CHECKS

Pump

1. Complete checks as specified in *Part B: Water Supply Performance Assessment*

Headworks

2. Complete checks as specified in *Part B: Water Supply Performance Assessment*
3. Check the flow rate of each station

Pipe network

4. Check for leaks along mainline
5. Check for leaks along sub-mains
6. Check for leaks along laterals
7. Check laterals flush clear

System pressure

8. Check pump pressure for each station
9. Check pressure before and after filters
10. Check all off-take pressures correct
11. Check the lateral end-pressure

Offtakes and control points

12. Check hydrants are not leaking

Sprinklers

13. Visually assess application pattern
14. Ensure moving sprinkler parts free.

2. Calibrating sprayline irrigation systems

The Irrigation Calibration method for sprayline irrigation systems assesses the amount of water being applied during an irrigation event. It is based on measurement of water collected in two transects of containers set across the sprayline.

Applied Depth, Application Intensity and Distribution Uniformity are calculated. This allows the manager to determine the maximum depth that can be applied without causing drainage, the time required to apply the target depth, and whether the system is applying the same amount of water across the irrigation area.

By repeating the process at other sprayline positions and in other irrigation stations, a plan to apply target depths in each block across the whole property can be determined.

2.1 What will the testing show?

The main things the calibration test will show are:

Mean station applied depth
The rainfall equivalent depth of water the irrigation system is applying on average to each station. Compare the measured applied depth to target application to calibrate each station. Adjust station run times to correct applied depths.

Soil applied depth
The rainfall equivalent depth of water being applied to the area actually wetted by the irrigation system.

Application intensity
The rainfall equivalent depth of water being applied per hour. If intensity exceeds soil infiltration capacity, ponding, redistribution and runoff will reduce irrigation effectiveness and efficiency.

Distribution uniformity DU
Distribution Uniformity describes the evenness with which water is applied. The higher the DU the better the system is performing. And the higher the uniformity, the more confident you can be that your measurements are truly representative of your system's performance.

Excess water use EWF
The excess water use factor identifies how much extra water is required during a set event because of non-uniformity.

Adjusted station run time
Calculates the irrigation duration to ensure 7/8ths of each sprayline position or irrigation station gets at least the Target Application Depth. It accounts for variations in outlet spacing, flow rate and uniformity.

WHEN SHOULD CALIBRATION BE DONE?
Complete the calibration test if commissioning any new areas and after any major changes. Calibration should be repeated as part of system checks at the start of every season.

NOTE:
Sprayline irrigation system performance can be significantly affected by weather conditions. Consider wind conditions when testing: Calm conditions may give a better assessment of the system's potential performance but if wind is normal for the site, testing may proceed.

NOTE:
Pressure variation will significantly alter performance. Consider testing:

- at different station locations
- different field elevations, or
- when alternative water-takes reduce system pressure.

2.2 Calibration process

Before starting, ensure System Operational Checks (Section 1) have been completed.

Calibration is a four step process:

1. Gathering information about the system
2. Calculating performance indicator values
3. Comparing results with expectations
4. Adjusting irrigation system settings as required to achieve intended performance.

GATHERING INFORMATION

Equipment
Equipment needs are very basic and most should already be available on the property. A suggested list includes:

- 24 containers of same opening diameter (>150mm)
  - 9 Litre buckets have been found suitable
- 1 measuring cylinder
  - 1 or 2 Litre for larger volumes (large containers, long run times)
  - 100mL or 200mL for smaller volumes (small containers, short run times)
- 1 tape measure (50m)
- 1 stop watch
- 1 pen or pencil
- 1 recording sheet.

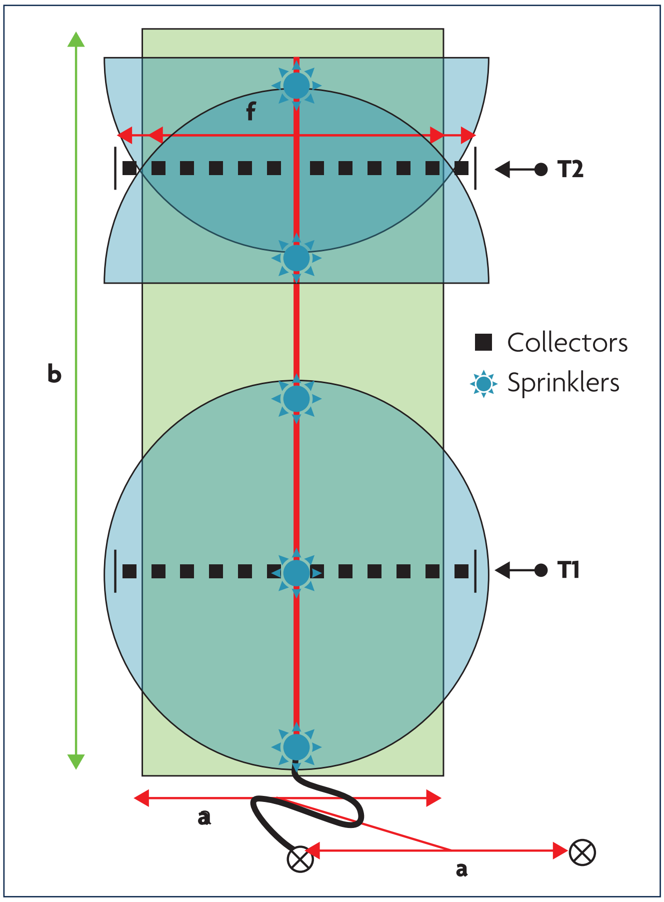

Figure 2.1. Sprayline calibration layout

Sampling method

The calibration check is based on two lines of collectors (transects) placed across representative spraylines. This assesses whether the same depth is applied at the start and end of the sprayline. The calculations give an average value for the whole sprayline based on both transects.

Dealing with overlap

Sprayline irrigation typically has overlap from adjacent sets. This must be taken into account. To account for overlap, buckets are placed in the overlap zone and measured depths combined. The effective depth and evenness is the combined effect of overlapped sets.

Figure 2.2 shows how the two rows of collector buckets are laid out relative to the sprayline wetted strip. This enables the overlap of adjacent spraylines to be included in calibrations.

Testing layout

1. Place a marker half way between two adjacent operating positions or “Sets”
2. Repeat on the other side of the set. The two markers define the Irrigated Strip or Lane (see “a” in Figure 2.1)
3. Mark the extent of obvious wetting when the irrigation runs. This is the “Wetted Width” (f in Figure 2.1)

   NOTE: If the wetted width is greater than the lane width, account for overlap.
4. Place one bucket half way between the edge of the lane and the edge of the wetted width [L6 in Figure 2.2]
5. Mirror this inside the edge of the lane, placing another bucket at the same spacing from the edge of the lane [L5 in Figure 2.2]
6. Arrange four more buckets at even spacing to cover the area back to the centre line (the lateral pipe) [L4–L1 in Figure 2.2]. The spacing may be different to the overlap buckets
7. Repeat Steps 4, 5 & 6 on the right hand side (R1–R6 in Figure 2.2)
8. Then repeat Steps 4 to 7 at position T2 (L7–12 and R7–12 in Figure 2.2).

NOTE:
If the system has no overlap between lanes, leave out buckets L6, L12, R6 and R12. Spread ten buckets at each transect and don’t do overlap calculations.

NOTE:
If the system has more than 25% overlap, this method may not give fair representation of effects.

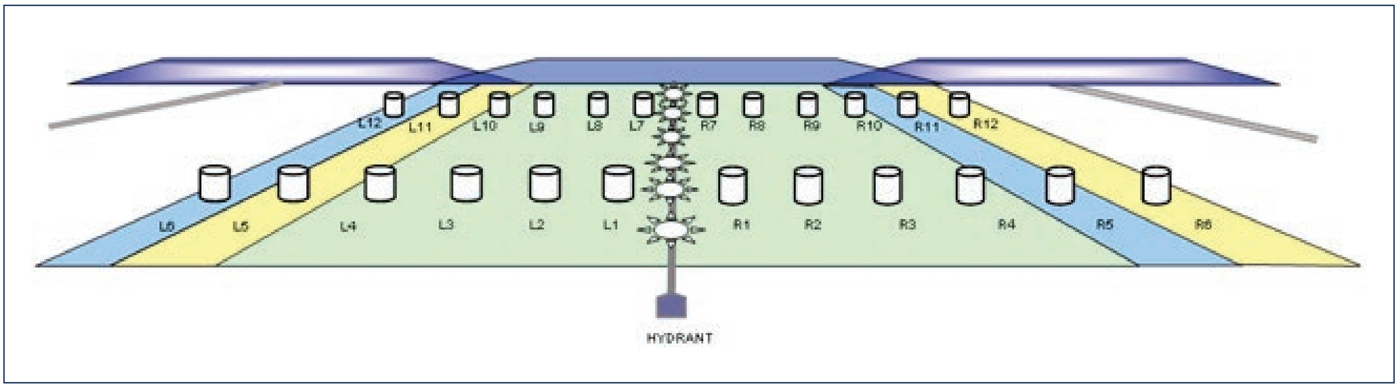

Figure 2.2. Sprayline wetted strip, overlap and collector placement

FIELD MEASUREMENTS

Repeat the following field measurements and calculations in each area of interest.

Management information

1. Record the Target Irrigation Depth
2. Record the Normal Irrigation Event Duration

System measurements

3. Measure the Outlet Pressure at the pump
4. Measure the Pressure at the Entry to the sprayline
5. Measure the system Flow Rate

Sprinkler measurements

6. Measure the distance between sprinklers along a lateral

   NOTE: It is often best to use an average distance between a number of sprinklers.

7. Measure the distance between adjacent sets (sprayline positions)

   NOTE: Take an average spacing between several laterals.

8. Record the number of sets
9. Determine the area for each Block [Lateral length x lateral spacing x lateral number]

Application test

10. Run the system and record the duration

    NOTE: Ensure run time is long enough to collect enough water to measure accurately

11. Measure the collector bucket mouth diameter
12. Measure the volume of water caught in each container and record on the Record Sheet.

    NOTE: Take care to record each reading in the correct position so overlap calculations are correct.

CALCULATE PERFORMANCE INDICATOR VALUES

Complete overlap adjustments

1. Add the volume collected in collector L6 to the volume of R5
2. Add the volume collected in collector R6 to the volume of L5
3. Add the volume collected in collector L12 to the volume of R11
4. Add the volume collected in collector R12 to the volume of L11

   NOTE: Remaining calculations use the twenty overlapped volumes in the two transects.

Applied depth

5. Calculate Applied Depth
   - Applied Depth(mm) = Average Volume collected ÷ Collector opening area
   - Average Volume Collected (mL) = Sum of all collected ÷ number of collectors
   - Collector opening area (m^2) = Pi x (Collector diameter)^2 ÷ 4.

Application intensity

6. Calculate Application Intensity
   - Application Intensity (mm/h) = Applied Depth (mm) ÷ Test Duration (h).
7. Calculate Block Flow Rate (m^3/h)
   - Block Flow Rate = Application intensity (mm/h) x Block Area (ha) x 10.

Distribution uniformity

8. Calculate the Distribution Uniformity (DU_{lq})
   - DU_{lq} = Low quarter average volume ÷ average volume
   - Low Quarter Average Volume (mL) = Average of lowest 5 collected volumes.

Excess water use EWF

9. Calculate Excess Water Use Factor (EWF)
   - EWF (%) = DU Adjusted Depth ÷ Applied Depth x 100
   - DU Adjusted Depth (mm) = (Applied Depth ÷ DU) – Applied Depth.

COMPARE RESULTS WITH EXPECTATIONS

Flow rates

1. Compare calculated System Flow Rate with Water Meter Flow Rate

Applied depth

2. Calculate Target Depth to Applied Depth ratio = Target Depth ÷ Applied Depth
   a. < 1 – under applying
   b. = 1 – correct
   c. > 1 – over applying

   Acceptable variances: 0.90–1.10 (0.95–1.05 is better)

3. Compare Applied Depth with Soil Moisture Deficit
   - Applied Depth < Soil Moisture Deficit ÷ DU.

Application intensity

4. Compare the calculated Application Intensity to Estimated soil infiltration rate
5. Compare with observations of ponding

Distribution uniformity DU

6. Interpret calculated DU value
   - DU > 0.90 Uniformity is very good
     the system is performing very well
   - 0.90 – 0.80 Uniformity is good
     performance better than average
   - 0.80 – 0.70 Uniformity is fair
     performance could be improved
   - 0.70 – 0.60 Uniformity is poor
     system should be investigated
   - DU < 0.60 Uniformity is unacceptable
     system must be investigated

ADJUST IRRIGATION SYSTEM SETTINGS

Check key performance indicators

1. If Applied Depth or Uniformity are unacceptable
   - Repeat Operational Checks
   - Ensure system is at recommended operating pressure
   - Get professional assistance.

Run time

2. Calculate Adjusted Run Time
   - Adjusted Run Time (h)
     = Target Depth ÷ DU ÷ Application Intensity

   NOTE: Including DU ensures the Run Time applies sufficient water to adequately irrigate 7/8th of the field.

3. Performance assessment of sprayline irrigation systems

This schedule presents procedures for conducting efficient and reliable irrigation evaluations of sprayline irrigation systems.

Procedures for planning, conducting, analysing and reporting system performance are described. They are intended to promote efficient work practices and informative reporting that facilitates easy comparison of systems.

NOTE:
Complete Operational Checks (See Section 1) before commencing a system assessment.

TECHNICAL MATERIALS – RELEVANT STANDARDS

Spray Irrigation Performance
ISO 7749-2: 1990 Agricultural irrigation equipment – Rotating sprinklers – Part 2: Uniformity of distribution and test methods

ISO 8026 Agricultural irrigation equipment – Sprayers – General requirements and test methods

ISO 8026:1995/Amd.1:2000 Agricultural irrigation equipment – Sprayers – General requirements and test methods AMENDMENT 1

Overlap Accounting

ISO 8224-1:2002 Traveller irrigation machines – Part 1: Operational characteristics and laboratory and field test methods

ISO 8224/1 – 1985 Traveller irrigation machines – Part 1: Laboratory and field test methods

3.1 Data collection

This schedule outlines procedures to be followed when assessing performance of sprayline irrigation systems under prevailing field conditions.

Because test conditions will vary, key conditions must be measured and recorded to assist any comparisons between subsequent tests of the same system, or when benchmarking against other systems.

NOTE:
To provide farmer general operation/management information, test conditions should be representative of those experienced in normal operation.

NOTE:
For System Commissioning or fulfilling specific purchase contract criteria, adherence to test condition limitations such as wind speed should be ensured.

TEST SITE

Location
Select a test location that is most representative of the system as a whole.

If the irrigation site is not level, conduct the test in an area having elevation differences that are within the design specifications of the sprinkler package.

Site variability
If site elevation varies significantly, consider multiple tests to increase accuracy of distribution uniformity assessments. This may involve several grid uniformity tests or a combination of grid uniformity and pressure flow uniformity tests.

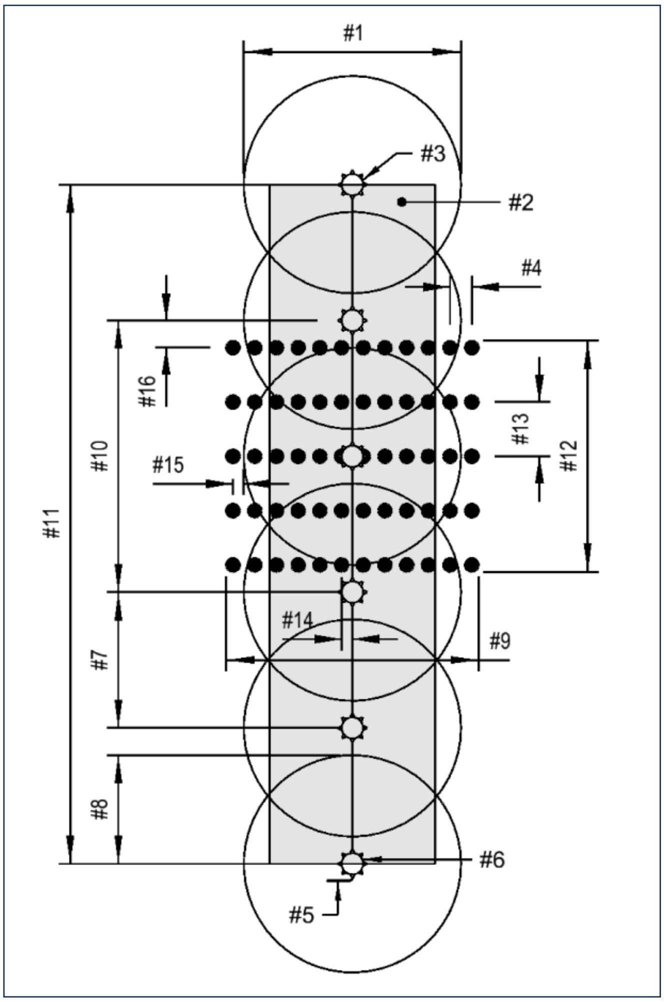

Figure 3.1. Field collector layout for sprayline systems

1. Irrigation strip width, lane width, E
2. Irrigation strip accounting for overlap
3. Sprayline: final sprinkler
4. Collector spacing along the row, s_{cr}
5. Hydrant or end of mainline
6. Sprayline: initial sprinkler
7. Sprinkler spacing D_s
8. Sprinkler wetted radius, r_w
9. Extent of collector columns (columns run parallel to the delivery hose)
10. Transverse line layout zone (= 2 D_s)
11. Length of strip, sprayline length, Lt
12. Extent of collector rows (rows transect the delivery hose)
13. Collector spacing down the column, s_{cc}
14. Distance of the first collector off the delivery half (half row spacing)
15. Distance of the last collector outside the wetted radius (half row spacing)
16. Distance of the first collector in from the end sprinkler (half column spacing).

SYSTEM SURVEY

System layout

1. Prepare a map of the system recording the headworks, mainline, take-off points, sub-mains, manifolds and laterals
2. Mark location of pressure regulators, flush valves and positions where tests are to be conducted (see example Figure 3.1)

Topography

3. Determine elevation differences between test sites and across the station as a whole.
   - Prepare a sketch of the profile along a typical lateral

Irrigation strip

4. Measure the irrigation strip length and width as defined in Figure 3.1
5. Record the number of strips (lanes) per set (operating at once)
6. Record the number of shifts (lanes) per hydrant

Off-target application (F_{TARGET})

7. Estimate the proportion of discharge that falls outside the target area (off the ends of the sprayline or sides of the field as a whole).

SYSTEM OPERATION

System pressure

1. Complete the test at normal operating pressure or as agreed by client and tester
   - Ensure the pressure is maintained during the test
   - Ensure pressure measurements include lowest and highest areas.

Sprinkler package

2. If the water distribution systems allows for different arrangements, use one setting that represents normal operation
   - The number of spraylines and sprinklers operating should remain constant during the test.

Test duration

3. Record the normal operation irrigation set time
4. Record the test duration time
   - Apply sufficient volume for reliable measurements to be obtained.

ENVIRONMENTAL MEASUREMENTS

Wind

1. Record the direction and speed of the wind during the test period, and plot against relevant test locations on a map
    - Wind speed and direction relative to the sprayline should be monitored at intervals of not more than 15 minutes and recorded
    - Wind conditions at the time of the test should be representative of those experienced in normal operation
    - Wind speeds greater than 3m/s can have significant effects on uniformity.

NOTE:
At speeds greater than 3m/s the tester and client must understand the limitations of the test results. The uniformity test should not be used as a valid measure of the sprinkler package if the mean wind velocity exceeds 3m/s.

Evaporation

The uniformity test should be conducted during periods that minimise the effect of evaporation, such as at night or early morning or in winter months

2. Record the time of day, estimated or measured temperature and humidity when the test is conducted
3. Record the temperature and humidity in the test zone during the test period
4. Determine evaporation rates using evaporation collectors identical to those used in uniformity testing
    - Place a control collector in a representative location upwind of the test area
    - Adjust readings for evaporation loss, following the procedures outlined in the *Technical Glossary.*

FIELD OBSERVATIONS

Crop type

1. Record the site's planting history for previous season and year
2. Note crops planted in the area under examination, and stage of growth

Crop appearance

3. Observe the crop for signs of stress or growth difference. Patchiness is indicative of poor system performance
4. Measure or estimate the crop ground cover proportion

Soils

5. Dig or auger several holes within the irrigated area
6. Determine the soil texture and depth of rooting
7. Estimate or otherwise determine soil infiltration rate and soil water holding capacity
8. Assess the depth of water penetration
9. Note any soil features that indicate wetness, poor drainage or related properties and identify causes

Ponding

10. Assess the amount of ponding that occurs within the irrigated area while the system is operating
11. Note if water is ponding, running over the ground, or causing soil movement
12. Estimate the percentage of water lost

Off-target application (F_{TARGET})

13. Estimate the proportion of discharge that falls outside the target area (off the edges of the field as a whole)

Runoff

14. Assess the amount of runoff from the irrigated area as a result of irrigation. Only consider volumes leaving the irrigated area.

SYSTEM CHECKS

Water supply

1. Complete checks of the water supply including pumping system and mainline as specified in *Part B: Compliance and Water Supply Checklists*

Filtration

2. Check filters and note nature and degree of contamination or blockage
3. Identify when the filter was last checked or cleaned
4. Identify if automatic cleaning or back-flushing is fitted and operational
5. Check for presence of contaminants in lines: sand, bacteria/algae, precipitates etc

Sprayline leaks

6. Check for damage to spraylines or misfit connections
7. Assess scale of leakages if any

Sprinklers

8. Record the nozzle type and orifice(s) fitted
    - Verify that the sprinkler package matches the design specifications.
9. Measure sprinkler spacing along the sprayline
10. Measure sprinkler height above canopy
11. Check sprinklers are operating and set correctly (to horizontal)
12. Randomly select at least 12 sprinklers or sprayers along the length of the machine
    - Inspect them for blockages and record the cause of any blockages found
    - Assess orifice wear with a gauge tool or drill bit.

SYSTEM FLOW

Total system flow

1. Record the water flow rate as measured by a fitted water meter with the system operating as normal
    - Wait until flow rates stabilise (up to 15 minutes) before taking readings
    - It may be necessary to take beginning and ending meter readings over a set time period to determine flow rate.

Energy use

2. Obtain energy consumption data for the period covered by flow measurement
    - Enables calculation of irrigation energy costs.

SYSTEM PRESSURE

Headworks pressures

With system operating,

1. Measure pump discharge pressure
2. Measure mainline pressure after filters and control valves

Optionally measure:

3. Filter head loss
4. Pump control valve head loss
5. Throttled manual valve head loss

Mainline pressures

For multiple block solid-set and long lateral systems:

6. Measure Pressure at each hydrant

Sprayline pressure

7. Measure sprinkler pressures:
    - At first available pressure test point or sprinkler downstream of the hydrant
    - At a sprinkler in the middle of the sprayline
    - At the last sprinkler or end of the sprayline.

NOTE:
If pressure is read at a sprinkler, use a pressure gauge with a pitot attachment.

NOTE:
Sprayline pressures cannot be inferred from readings at the sprinkler if pressure regulators are installed.

SPRINKLER PERFORMANCE

Wetted radius

1. Determine the wetted width of the sprayline (sprinkler wetted radius) to the nearest 10cm in at least three locations

Sprinkler pressure / flow

2. Measure the pressures and flows from at least four adjacent sprinklers near the middle of a single lateral
    - Avoid the inlet end if possible as pressure variation will typically be high
    - Ensure sprinklers chosen are of the same specification
    - Capture all flow without flooding the nozzle or affecting pressure
    - Shroud the sprinkler or sprayer with a loose hose and collect discharge for at least 30 seconds or 20 litres
    - Measure and record the volume collected (mL)and time (sec).

Adjusted pressure:flow test

The effect of pressure change on sprinkler discharge is determined using the discharge coefficient. If a manufacturer's value is unavailable, or is queried, the discharge coefficient can be determined from measurements of the same emitters at different operating pressures.

3. Repeat the sprinkler pressure:flow measurements after adjusting the lateral pressure by about 20%

NOTE: After this test, reset the system to its normal operating conditions.

Grid uniformity test

4. Arrange a grid of collectors between three correctly functioning adjacent sprinklers along a representative part of the sprayline (Refer to Figure 3.2)
   - The grid should be 60 collectors. 12 columns and 5 rows (columns are parallel to the delivery hose)
   - Ensure the first and last collectors in the columns are positioned one half spacing from the first and last test sprinklers respectively
   - The first collector in each row must be half a row spacing off the delivery line
   - The last collector In each row must extend to a half row spacing outside the wetted radius of the water distribution system, allowing for any skewing as a result of wind effects. (The grid must extend beyond the sprinkler wetted radius on both sides of the sprayline).

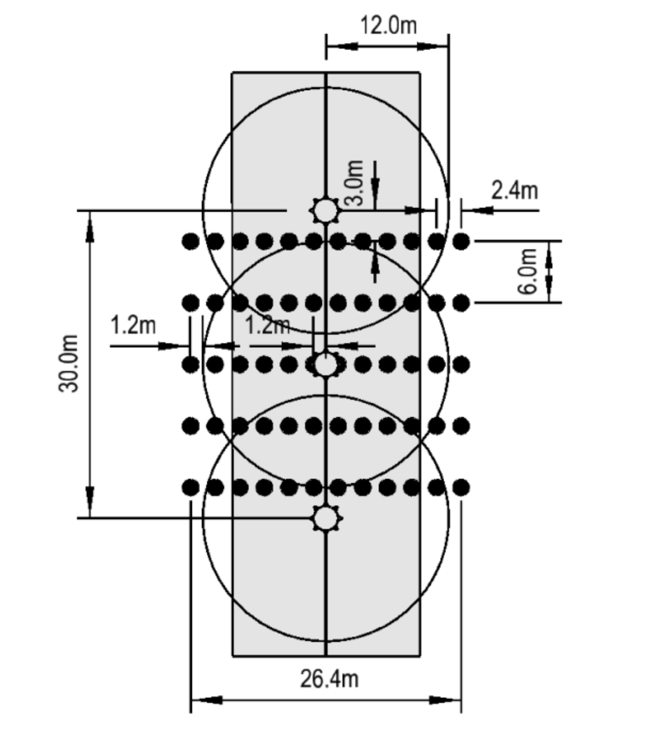

Figure 3.2. Bucket spacing example for a pod system with 15m sprinkler spacings and a 12m throw radius.

5. Measure and record the position of each collector relative to the sprayline
   - Row spacing: 30m/5 = 6m spacing (first row to be a half spacing from the sprinkler (3m)
   - Column spacing: 12m/5 = 2.4m between buckets. The first collector Is a half spacing off the delivery hose (1.2m) and the last collector is 1.2m outside the wetted radius.

Operation

6. Record the test duration time
   - Collect sufficient volume for reliable measurements to be obtained.

NOTE:
The test could run for a complete irrigation set. However, in the interests of time efficiency, a shorter duration may be agreed in consultation with the system owner.

NOTE:
To avoid unequal collection times, shut the system off before reading collectors.

OPTIONAL TESTS

Additional tests

1. Repeat tests as required to determine distribution uniformity under different weather (wind) conditions, or with the sprayline or other spraylines in different field location or fields

NOTE:
On highly variable terrain, a sprinkler pressure:flow test should be considered to establish performance variability across the entire system.

Pressure derived flows

2. Calculate pressure derived flows for each of the pressure measurements taken along the sprayline (see Sprayline Pressure)
   - Use the pressure:flow relationship.

NOTE:
If the emitter discharge exponent and coefficient are not available from manufacturers' data they can be determined as earlier described.

For most sprinklers, the discharge exponent (x) is approximately 0.5.

3.2 Data analysis

SYSTEM

Irrigated area

1. Calculate the irrigated area of the test sprayline
   - Sprayline Area = Sprayline Length x Strip Width
2. Calculate the area irrigated per set
   - Set Area = Sprayline Area x Number of Strips per set
3. Calculate the total area irrigated
   - Total Area = Set Area x Number of Shifts.

PERFORMANCE INDICATORS

Water supply

1. Complete calculations of water supply including pumping system and mainline as specified in *Part B: Compliance and Water Supply Checklists*

Sprayline pressure

2. Calculate the Mean Field Pressure
   - Sum of all pressures / Number of pressure readings
3. Calculate Maximum Hydrant Pressure Variation
   - Highest Hydrant Pressure – Lowest Hydrant Pressure
4. Calculate Maximum Sprayline Pressure Loss
   - Greatest difference between highest and lowest pressure on individual spraylines
5. Calculate the maximum pressure variation among all readings
   - Highest reading – Lowest reading

Pressure derived flows

6. Calculate pressure derived flows
   - For each of the pressure measurements taken across the field using the emitter pressure flow relationship.

NOTE: If the discharge exponent and coefficient are not available from manufacturers' data they must be determined from pressure flow data collected in the field.

Pressure distribution uniformity (PDU_{lq})

NOTE: The pressure distribution uniformity coefficient describes a theoretical uniformity determined from pressure variation across the field, and the pressure:discharge performance characteristics of the emitters.

7. Calculate Pressure Distribution Uniformity (PDU_{lq})
   - Calculated from pressure derived flows, using the low quarter uniformity formula Equation 31.

NOTE:
If used in determining Field DU, PDU_{lq} replaces sprinkler flow uniformity, QDU_{lq}.

Application depth

NOTE:
To make valid assessments of sprayline performance, the depths measured by collectors must be adjusted to account for evaporation losses and for the effect of overlaps from adjacent irrigation sets (strips). This *adjusted application depth* can be compared to a total system application depth.

8. Calculate Adjusted Applied Depth
   - Applied Depth (mm) = Average Volume collected ÷ Collector opening area
   - Average Volume Collected (mL) = Sum of all collected ÷ number of collectors
   - Collector opening area (m^2) = Pi x (Collector diameter (m))^2 ÷ 4.
9. Calculate Equivalent Applied Depth
   - Equivalent Applied Depth (mm) = Adjusted Applied Depth x Set Duration / Test Duration
10. Compare Equivalent Applied Depth to Target Application Depth
    - Report as percentage.
11. Compare Equivalent Applied Depth to soil water holding capacity.

NOTE:
This provides an indication of possible deep percolation, with subsequent impacts on irrigation efficiency, or potential moisture deficit with resultant reduced crop yield.

Total system application depth

12. Calculate application depth based on total system flow, cycle duration and irrigated area

NOTE: This assumes that each strip is overlapped from each side, so each strip receives the full volume of water applied during one irrigation set.

Application intensity

13. Calculate Mean Application Intensity
    - Application Intensity (mm/h) = Adjusted Applied Depth (mm) ÷ Test Duration (h).
14. Compare Mean Application Intensity to Soil Infiltration Rate
    - Report as a percentage
    - Application Intensity should be than Soil Infiltration Rate
    - Compare with observations of surface ponding.
15. Calculate Set Flow Rate (m^3/h)
    - Set Flow Rate = Application intensity (mm/h) x Set Area (ha) x 10.

Field distribution uniformity, FDU_{lq}

16. Estimate overall field distribution uniformity (FDU_{lq})
    - Combine contributing variable factors using the Clemmens-Solomon statistical procedure.

NOTE: Overall uniformity incorporates the distribution pattern of the overlapped sprinklers, and the flow variation from individual sprinklers. It may be adjusted for unequal drainage after system shut-down.

$$FDU_{lq} = \left[1 - \sqrt{(1 - GDU_{lq})^2 + (1 - QDU_{lq})^2 + (1 - F_{ponding})^2 + (1 - F_{drainage})^2}\,\right]$$

Where:

FDU_{lq}	is low quarter field distribution uniformity
GDU_{lq}	is low quarter grid distribution uniformity
QDU_{lq}	is low quarter flow distribution uniformity
$F_{ponding}$	is surface redistribution from ponding
$F_{drainage}$	is uneven drainage factor

Required adjustments

The flow measurements used to assess uniformity are a non-random sample, and cover only part of an irrigation event. Determination of global 'field uniformity' requires that adjustments are made to account for various factors, including pressure variation, flow variation and overlap.

Adjustments are also required to account for evaporative losses from collectors while field data collection is undertaken.

Grid distribution uniformity, GDU_{lq}

17. Calculate low quarter grid distribution uniformity, GDU_{lq}
    - First adjust application depths for evaporation and overlap, as described in the Technical Glossary.
18. Calculate GDU_{lq}.

Flow distribution uniformity, QDU_{lq}

19. Calculate low quarter flow distribution uniformity
    - From measured sprinkler flows along the sprayline length using the low quarter uniformity formula.

NOTE: This may be replaced by the Pressure Distribution Uniformity.

Uniformity from alternate sets

20. Calculate a potential distribution uniformity assuming successive irrigation stagger set positions
    - Determine alternate set uniformity by overlaying left side collector data on the right side data.

3.3 Adjust irrigation system settings

APPLIED DEPTH

1. Compare Mean Set Applied Depths to Target Depth
   - Adjust set run time to achieve target applied depth

Adjusted run time

2. Calculate Adjusted Run Time for each set
   - Adjusted Run Time (h) = Target Depth (mm) ÷ EU ÷ Application Intensity (mm/h)

NOTE: Including EU ensures the Run Time applies sufficient water to adequately irrigate 7/8th plants

DISTRIBUTION UNIFORMITY

3. Identify impact of variables contributing to non-uniformity
   - Repeat Operational Checks (Section 1)
   - Adjust system components to achieve best performance
   - Ensure system is at recommended operating pressure
   - Get professional assistance.

IRRIGATION NEW ZEALAND
WATER | FOOD | FIBRE | LIFE

New Zealand Piped Irrigation System Performance Assessment Code of Practice

PART F: Traveller

Note: This is Part F of a series of nine (Parts A–I).

IRRIGATION NEW ZEALAND

Part F: Contents

Date of Issue: January 2023

The Code is presented as a series of booklets, each with a defined purpose.

Part A: An Introduction to Performance Assessment
Part A provides an overview of performance assessment, explains the broad philosophy behind assessment approaches taken throughout the Performance Assessment series, and contains specific formulae and reporting standards.

Part B: Compliance and Water Supply Checklists
Part B relates to all system types. It contains recommendations for checks to ensure compliance with regulations, rules and consent conditions, safe effective operation of water supply systems.

Parts C–H: System Performance Assessments
(Part F = this booklet)
Parts C–H contain guidelines and recommendations for Operational Checks, System Calibrations and In-field Performance Assessments specific to a range of irrigation system types.

Part I: Conducting Energy Efficiency Assessments and Seasonal Irrigation Efficiency

IrrigationNZ Technical Glossary
The Glossary and Calculations are common with the NZPIS Design Code of Practice.

Ministry for Primary Industries
Manatū Ahu Matua

Supported by Sustainable Farming Fund

Introduction

Purpose

The *New Zealand Piped Irrigation System Performance Assessment Code of Practice* provides nationally recognised guidelines to measure and benchmark performance of agricultural irrigation.

Part F is specific to traveller irrigation systems. It makes recommendations for planning and conducting assessments and reporting on the performance of irrigation systems and their management. Its focus is on key performance indicators that are common with the New Zealand Piped Irrigation Systems Design Standards..

It was developed to provide guidelines for irrigators and others undertaking evaluations of such equipment as a 'snapshot exercise' under prevailing field conditions.

SYSTEM PERFORMANCE

The Code recognises different levels of performance assessment depending on purpose. In increasing level of complexity, system performance assessment includes:

- Operational Checks
- System Calibration
- In-field Performance Assessment.

Related documentation

- **New Zealand Piped Irrigation System Performance Assessment Code of Practice:**
  - Part A: An Introduction to Performance Assessment
    Part A provides an overview of performance assessment, explains the broad philosophy behind assessment approaches taken throughout the Performance Assessment series, and contains specific formulae and reporting standards.
  - Part B: Compliance and Water Supply Checklists
    Part B relates to all system types. It makes recommendations for checks to ensure compliance with regulations, rules and consent conditions, safe effective operation of water supply systems and energy efficiency assessments of pumps and delivery systems.
  - Parts C–H: System Performance Assessments
    Parts C–H contains guidelines and recommendations for performance assessments specific to a range of irrigation system types.
- **New Zealand Piped Irrigation Systems Design Code of Practice**
- **New Zealand Piped Irrigation Systems Design Standards**
- **New Zealand Piped Irrigation Systems Installation Code of Practice**
- **New Zealand Water Measurement Code of Practice**
- **New Zealand Irrigation Technical Glossary**

System description

A traveller irrigation machine irrigates a field sequentially, strip by strip by drawing a 'gun-cart' equipped with a water distribution system across a field.

Water is discharged under pressure from a water distribution system mounted on the gun-cart as it travels across the field. A traveller is intended to be moved to, and operate from, several supply points established in advance in the field.

Irrigated strips overlap at the edges to ensure even coverage. The evenness of application across the irrigated strip, and the evenness of application as the traveller passes across the field both contribute to overall irrigation distribution uniformity.

Three broad categories are recognised each having a structure that includes a reel, spool or winch and a travelling water distribution system.

A. REEL MACHINES (HARD HOSE)

Reel machines have a stationary reel anchored at the run end. The reel acts as a winch, coiling a delivery tube that both supplies water to the distribution system and drags the gun-cart along the field.

B. TRAVELLER MACHINES (SOFT HOSE)

Traveller machines have a cable that is anchored at the run end. The water distribution system and a travelling winch are mounted on the gun-cart. The winch pulls the gun-cart along by coiling the cable on to the reel. The gun-cart drags the delivery hose across the field.

C. SELF PROPELLED REEL MACHINES

Self propelled reel machines carry both a reel and the water distribution system and draw themselves across the field by coiling the anchored delivery tube on to the reel.

In addition, there are three different water distribution mechanisms: big gun, fixed boom and rotating boom.
Each of these requires slightly different evaluation procedures to identify causes on non-uniformity.

Traveller irrigation machines make irrigation feasible in many areas where other techniques are not suitable. They are easily transported between fields even over relatively long distances, and can be used to irrigate irregularly shaped areas.

Special features for analysis

OVERLAPPING STRIPS

The uniformity of water application for an entire field is likely to be increased through the overlapping of adjacent irrigation strips.

Field application uniformity can be estimated by virtual overlays of test data from a single irrigation strip. The machine's performance is measured for one set position, and measurements from outer edges mapped on to the corresponding measurements on the opposite side.

CHANGING TRAVEL SPEED

The speed of a travelling irrigation machine may change as successive layers are laid upon the reel or winch, or because ground conditions create different amounts of drag on the gun-cart.

Field evaluations can estimate the effect of varying travel speeds on distribution uniformity by making multiple transverse measurements and completing a longitudinal speed assessment.

WIND EFFECTS

The performance of a travelling irrigation machine can be greatly affected by wind, particularly when gun-type nozzles are used on high angle settings.

The uniformity testing should be carried out in conditions representative of those commonly experienced in the field. Wind speed and direction should be measured and recorded.

FIELD VARIABILITY

The performance of a travelling irrigation machine may vary at different positions in the field. Contributing factors include topographic variation and elevation changes and soil drag effects.

A machine operating on a relatively flat, homogenous field should have similar performance in all positions. The assessor and client should discuss what testing is desired and the conditions under which any tests should be conducted.

HIGH OPERATING PRESSURES

Relatively high operating pressures, particularly for big guns, minimises the effect of terrain pressure change effects on flow or distribution pattern.

STATIONARY OPERATION

Travelling irrigators may be operated stationary at either end of the strip to ensure at least the target application depth is applied. This increased losses by deep drainage from the section of the wetted area that is 'over watered'. Field uniformity and application efficiency are reduced, more so on short runs.

ALTERNATE SETS

Travellers may be set in different positions during successive irrigation rotations. If set positions are moved one half of set-width, the compensation can increase overall uniformity.

1. Operational checklist

This is a minimum list of checks of travelling irrigators that should be made.

Be safety conscious – electrical and mechanical hazards may be present.

Every system should be supplied with a System Operation Manual. The manual may include extra checks not listed here. It will give more detail than this checklist including information specific to your system.

SYSTEM OFF CHECKS

Hose reel (or cable reel)

1. Visually check structure condition for corrosion or damage
2. Visually check wheel lug bolts, tyre condition and pressure
3. Visually check gearboxes, drive shafts
   - Lubricate as required
4. Check cable winch action and ratchets for wear and freedom of movement
5. Tighten all bolts, check pins
6. Lubricate as specified in manual
7. Visually check seals and flanges

Gun cart

8. Visually check structure condition, corrosion or damage
9. Visually check wheel lug bolts, tyre condition and pressure
10. Tighten all bolts, check pins
11. Visually check condition of other connections
    - Lubricate as specified in manual
12. Visually check seals and flanges
13. Visually check rotating boom turntable not worn, allows free turning

Drag hose

14. Visually check condition for wear, kinks or other damage
15. Visually check boots
    - Tighten bands if necessary

Sprinklers

16. Check sprinklers fitted are as specified in sprinkler chart
17. Inspect nozzle orifice condition
    - Replace if wear detectable
18. Ensure rotating nozzles are free turning and cages not damaged
19. Check splash plate condition, angle and alignment

Gun

20. Check components for looseness, freedom of movement
21. Check outlet nozzle orifice condition
    - Replace if wear detectable

Control unit

22. Visually inspect electronic controls
23. Check battery charge.

SYSTEM ON CHECKS

WARNING:

Before starting ensure nothing is parked in front of the irrigator.

Pump

1. Complete checks as specified earlier in Section 1

Headworks

2. Complete checks as specified earlier in Section 1
3. Check the flow rate of each station

Pipe network

4. Check for leaks along mainline

System pressure

5. Check pump pressure while system operating
6. Check pressure before and after filters

Off-takes/hydrants

7. Check hydrants are not leaking
8. Check all off-take pressures correct

   NOTE: Hydrant must be in use to get valid pressure reading

   NOTE: Check farthest and highest hydrant positions to ensure adequate pressure

Hose reel (or cable reel)

9. Check the reel is turning smoothly
10. Check the hose or cable is winding in correctly
11. Check the inlet pressure gauge
    - Replace if necessary
12. Check the inlet pressure

    NOTE: Check pressure at the furthest hydrant for most extreme situation
13. Check the turbine is functioning correctly

Gun cart

14. Check the cart is moving correctly
15. Check the inlet pressure
    - Replace gauge if necessary
16. Check there are no leaks

Drag hose

17. Check there are no leaks
18. Check the hose is not misshapen

Sprinklers

19. Check each sprinkler is turning correctly and cage not damaged
    - Repair or replace as necessary
20. Check there are no leaks
    - Repair or replace as necessary
21. Check the pressure above last sprinkler, above pressure regulator if fitted

    NOTE: This requires installation of a test point. A ¾" BSP Tee above the pressure regulator is usually suitable. Reduce to ¼" BSP for standard pressure gauge.

Gun

22. Check gun is operating correctly
23. Check gun angles are correct, gun switches direction at correct locations

Control unit

24. Check any control unit is functioning correctly.

2. Calibrating travelling irrigation systems

The Irrigation Calibration method for travelling irrigation systems assesses the amount of water being applied during an irrigation event. It is based on measurements of water collected in a line of containers spaced across the path of travel.

Applied Depth, Application Intensity and Distribution Uniformity are calculated. This allows the manager to determine the speed required to apply the target depth, and whether the system is applying the same amount of water across the irrigation block.

By repeating the process in other irrigation blocks or runs, a plan to apply target depths in each block across the whole property can be determined.

2.1 What will the testing show?

The main things the calibration test will show are:

Applied depth
The 'rainfall equivalent' depth of water the irrigation system is applying on average at the particular travel speed. Compare the measured applied depth to target application to determine machine speed adjustment to correct applied depths.

Application intensity
The rate (mm/hour) at which water is being applied, equivalent to rainfall intensity. If intensity exceeds soil infiltration capacity, ponding, redistribution and runoff will reduce irrigation effectiveness and efficiency.

Distribution uniformity DU
Distribution Uniformity describes the evenness with which water is applied. The higher the DU the better the system is performing. And the higher the uniformity, the more confident you can be that your measurements are truly representative of your system's performance.

Excess water use EWF
The excess water use factor identifies how much extra water is required during a set event because of non-uniformity.

Adjusted machine speed
Calculates the machine speed required to ensure 7/8ths of the area gets at least the Target Application Depth. It accounts for flow rate and uniformity.

WHEN SHOULD CALIBRATION BE DONE?

Complete the calibration test if commissioning a new machine and after any major changes. Calibration should be repeated as part of system checks at the start of every season.

NOTE: Travelling irrigator performance can be significantly affected by weather conditions. Consider wind conditions when testing: Calm conditions may give a better assessment of the system's potential performance but if wind is normal for the site, testing may proceed.

NOTE: Pressure variation will significantly alter performance: consider testing:

- at different hydrant positions
- different field elevations or
- when alternative water-takes reduce system pressure.

2.2 Calibration process

Before starting, ensure System Operational Checks (Section 1) have been completed.

Calibration is a four step process:

1. Gathering information about the system
2. Calculating performance indicator values
3. Comparing results with expectations
4. Adjusting irrigation system settings as required to achieve intended performance.

GATHERING INFORMATION

The calibration check is based on a line of collectors (transects) placed across the traveller run. It can be useful to repeat the test at the start and end of a run to check performance is consistent. Changing terrain, or heavy drag hoses can affect machine performance.

Equipment
Equipment needs are very basic and most should already be available on the property. A suggested list includes:

- 22 containers of same known opening diameter (>150mm)
  - 9 Litre buckets have been found suitable
- 1 measuring cylinder
  - 1 or 2 Litre for larger volumes (large containers, slow speeds)
  - 100mL or 200mL for smaller volumes (small containers, fast speeds)
- 1 tape measure (50m)
- 2 flags or fence standards
- 1 stop watch
- 1 pen or pencil
- 1 recording sheet.

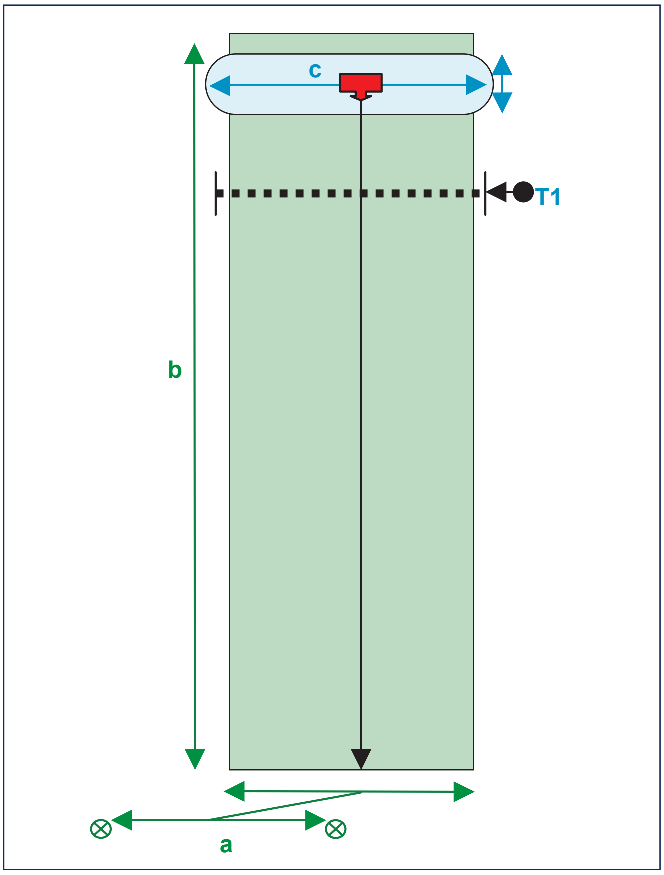

Figure 2.1. Layout of calibration test for travelling irrigators

Dealing with overlap

If irrigation from adjacent runs overlaps, this must be taken into account. To account for overlap, buckets are placed in the overlap zone and measured depths combined. The effective depth and evenness assumes the combined effect of adjacent runs.

1. Place markers half way between the test hydrant and the hydrant to the left (See Figure 2.1)
2. Repeat on the right hand side. The space between the markers is the Run Width (a in Figure 2.1)
3. Mark the extent of obvious wetting when the irrigator runs. This is the "Wetted Width" (c in Figure 2.1)
4. If the Wetted Width is greater than the Run Width, account for overlap.

Sampling method

Set out collectors.

1. Place one bucket half way between the edge of the lane and the edge of the wetted width (see 'L11' in Figure 2.2)
2. Mirror this inside the edge of the run, setting another bucket at the same spacing from the edge of the run (see 'L10 in Figure 2.2)
3. Arrange nine more buckets at even spacing to cover the area back to the centre line (the hose or cable) (see 'L9–L1' in Figure 2.2). The spacing may be different to overlap buckets
4. Repeat 4, 5 and 6 on the right hand side.

   NOTE: If the system has no overlap, leave buckets L11 and R11 out. Spread ten buckets each side of the irrigator and don't do overlaps in the calculations

   NOTE: If the system has more than 25% overlap, this method may not give fair representation of effects

Mark speed test positions

5. Place a marker flag beside the cable or hose, either side of the collector bucket transect
6. Record the distance between the flags

   NOTE: Put flags at least 5m each side of the transect. Ensure marker flags are visible from outside the wetting area so they can be seen during testing

Management information

7. Record the Target Irrigation Depth
8. Record the Normal Irrigation Event Duration
9. Measure the Run Length (b in Figure 2.1)

   NOTE: It is often best to use an average distance for several runs in a paddock

10. Measure the Run Width (often hydrant positions) (a in Figure 2.1)

    NOTE: Take an average spacing between several hydrants

11. Record the number of runs
12. Determine the area of the Block
    (Run length x run spacing x run number).

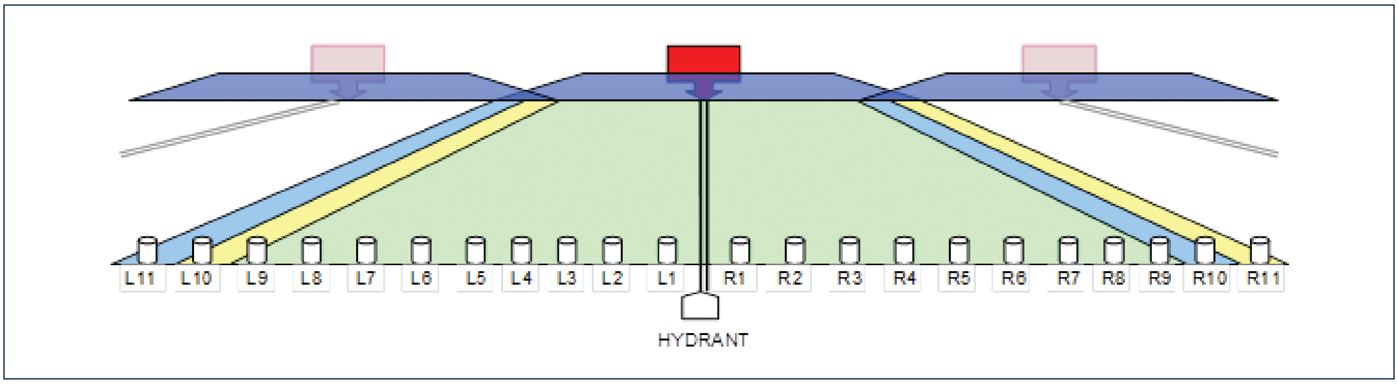

Figure 2.2. Collector bucket positions relative to irrigation lane and wetted width

FIELD MEASUREMENTS

Repeat the following field measurements and calculations in each area of interest.

System measurements

1. Measure the Outlet Pressure at the pump
2. Measure the Pressure at the Entry to the irrigator
3. Measure the system Flow Rate

Application test

4. Run the system and record the duration

   NOTE: Ensure run time is long enough to collect enough water to measure accurately

5. Record the time the traveller passes the first marker flag
6. Record the time the traveller passes the second marker flag
7. Measure the collector bucket mouth diameter
8. Measure the volume of water caught in each container and record on the Record Sheet

   NOTE: Take care to record each reading in the correct position so overlap calculations are correct.

CALCULATE PERFORMANCE INDICATOR VALUES

Irrigator speed

1. Speed (m/min) = Distance travelled ÷ Time taken
   - Distance travelled (m) = distance between marker flags
   - Time taken (min) = Time at second marker flag – Time at first marker flag

Complete overlap adjustments

2. Add the volume collected in collector L11 to the volume of R10
3. Add the volume collected in collector R11 to the volume of L10

   NOTE: Remaining calculations use only twenty volumes

Applied depth

4. Calculate Applied Depth (mm) [Average Volume collected ÷ Collector opening area]
   - Average Volume Collected (mL) = Sum of all collected ÷ number of collectors
   - Collector opening area (m^2) = Pi x Collector diameter (m) x Collector diameter (m) ÷ 4

Application intensity

5. Calculate Application Intensity (mm/h) [Applied Depth (mm) x Irrigator Speed (m/min) x 60 ÷ Wetting Pattern Width (m)]

System flow rate

6. Calculate Flow Rate (L/s)
   - Hydrant/Lane Spacing (m) x Applied Depth (mm) x Irrigator Speed (m/min) / 60]

Distribution uniformity

7. Calculate the Distribution Uniformity DU [Low quarter average volume ÷ average volume]
   - Low Quarter Average Volume (mL) = Average of the lowest five collected volumes

Excess water use EWF

8. Calculate Excess Water Use Factor (%) [DU Adjusted Depth ÷ Applied Depth x 100]
   - DU Adjusted Depth (mm) = (Applied Depth ÷ DU) – Applied Depth

COMPARE RESULTS WITH EXPECTATIONS

Flow rates

1. Compare calculated System Flow Rate with Water Meter Flow Rate

Applied depth

2. Calculate Target Depth to Applied Depth ratio = Target Depth ÷ Applied Depth
   a. < 1 – under applying
   b. = 1 – correct
   c. > 1 – over applying

   Acceptable variances: 0.90–1.10 (0.95–1.05 is better)

3. Compare Applied Depth with Soil Moisture Deficit
   - Applied Depth < Soil Moisture Deficit ÷ DU

Application intensity

4. Compare the calculated Application Intensity to expectations

Distribution uniformity DU

5. Interpret calculated DU value
   - DU > 0.90 — Uniformity is very good; the system is performing very well
   - 0.90 – 0.80 — Uniformity is good; performance better than average
   - 0.80 – 0.70 — Uniformity is fair; performance could be improved
   - 0.70 – 0.60 — Uniformity is poor; system should be investigated
   - DU < 0.60 — Uniformity is unacceptable; system must be investigated

ADJUST IRRIGATION SYSTEM SETTINGS

Check key performance indicators

1. If Applied Depth or Uniformity are unacceptable
   - Repeat Operational Checks
   - Ensure system is at recommended operating pressure
   - Get professional assistance

Irrigator speed

2. Calculate Adjusted Speed (m/min)
   - Irrigator Speed x (Target Depth ÷ DU) ÷ Applied Depth

   NOTE: Including DU ensures the irrigator applies sufficient extra water to adequately irrigate 7/8th plants.

3. Performance assessment of travelling irrigation systems

This schedule presents procedures for conducting efficient and reliable irrigation evaluations of travelling irrigation systems.

Procedures for planning, conducting, analysing and reporting system performance are described. They are intended to promote efficient work practices and informative reporting that facilitates easy comparison of systems.

NOTE:
Complete Operational Checks (See Section 1) before commencing a system evaluation.

TECHNICAL MATERIALS – RELEVANT STANDARDS

Spray Irrigation Performance
ISO 8224-1:2002 Traveller irrigation machines – Part 1: Operational characteristics and laboratory and field test methods Confirmed 2009

ISO 15886-3:2012 Agricultural irrigation equipment – Sprinklers – Part 3: Characterization of distribution and test methods

ISO 8026:2009 Agricultural irrigation equipment – Sprayers – General requirements and test methods

Overlap Accounting

ISO 8224-1:2002 Traveller irrigation machines – Part 1: Operational characteristics and laboratory and field test methods Confirmed 2009.

3.1 Data collection

This schedule outlines procedures to be followed when assessing performance of travelling irrigation systems under prevailing field conditions.

Because test conditions will vary, key conditions must be measured and recorded to assist any comparisons between subsequent tests of the same system, or when benchmarking against other systems.

NOTE:
To provide farmer general operation/management information, test conditions should be representative of those experienced in normal operation.

NOTE:
For System Commissioning or fulfilling specific purchase contract criteria, adherence to test condition limitations such as wind speed should be ensured.

TEST SITE

Location
Select a test location that is most representative of the system as a whole.

If the irrigation site is not level, conduct the test in an area having elevation differences that are within the design specifications of the sprinkler package.

Site variability
If site elevation varies significantly, consider multiple tests to increase accuracy of distribution uniformity assessments. This may involve several grid uniformity tests or a combination of grid uniformity and pressure flow uniformity tests.

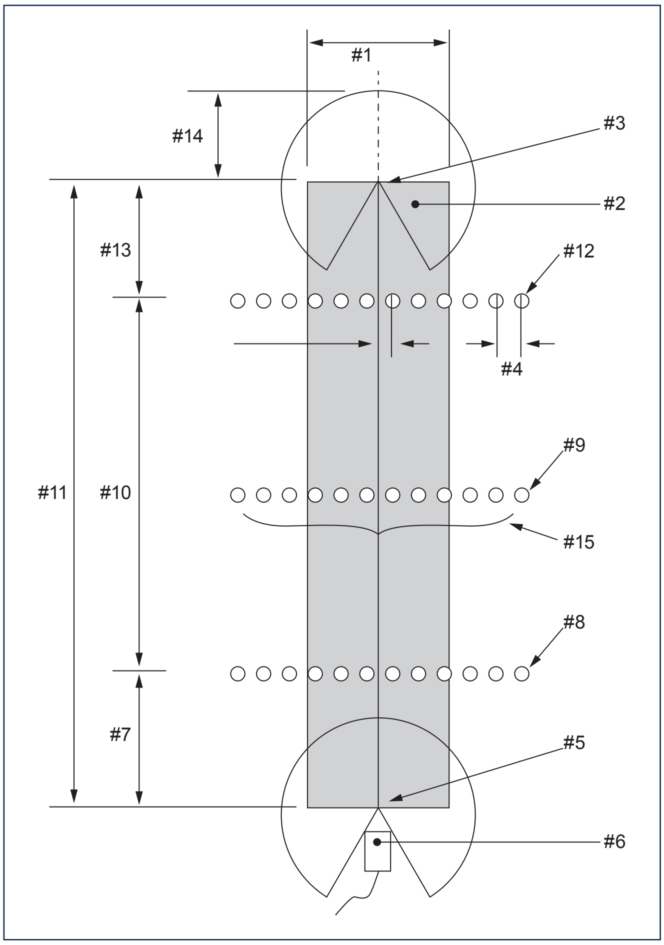

Figure 3.1. Field collector layout (from ISO 8224-1:2002)

1. Irrigation strip width, lane width, E
2. Irrigation strip accounting for overlap
3. Distribution system; initial position
4. Collector spacing, s_c
5. Distribution system: final stop position
6. Fixed end of travelling irrigation machine
7. End guard > wetted radius (14)
8. Position of last line of collectors, n
9. Position of intermediate line of collectors, i
10. Transverse line layout zone (>50% L_t)
11. Length of strip, travel path length, L_t
12. Position of first line of collectors, 1
13. End guard greater than wetted radius 14
14. Distribution system wetted radius, r_w
15. Extent of collector lines

SYSTEM OPERATION

System pressure

1. Complete the test at normal operating pressure or as agreed by client and tester
   - Ensure the pressure is maintained during the test
   - Ensure pressure measurements include lowest and highest areas.

Sprinkler package

2. If the water distribution systems allows for different arrangements, use one setting that represents normal operation

Pressure

3. Run tests at the normal operating pressure, or as mutually agreed upon by client and tester
   - Ensure the pressure is maintained during the test
   - To maintain constant pressure, ensure the system is not affected by other significant system draw-offs such as other irrigation machines or dairy sheds.

Machine speed

4. Select a machine speed for the test that is representative of that normally selected for irrigation, and apply sufficient depth for reliable measurements to be obtained.

ENVIRONMENTAL MEASUREMENTS

Wind

1. Record the direction and speed of the wind during the test period, and plot against relevant test locations on a map
   - Wind speed and direction relative to the sprayline should be monitored at intervals of not more than 15 minutes and recorded
   - Wind conditions at the time of the test should be representative of those experienced in normal operation
   - Wind speeds greater than 3m/s can have significant effects on uniformity.

NOTE:
At speeds greater than 3m/s the tester and client must understand the limitations of the test results. The uniformity test should not be used as a valid measure of the sprinkler package if the mean wind velocity exceeds 3m/s.

Evaporation

The uniformity test should be conducted during periods that minimise the effect of evaporation, such as at night or early morning or in winter months.

2. Record the time of day, estimated or measured temperature and humidity when the test is conducted
3. Record the temperature and humidity in the test zone during the test period
4. Determine evaporation rates using evaporation collectors identical to those used in uniformity testing
   - Place a control collector in a representative location upwind of the test area
   - Adjust readings for evaporation loss.

FIELD OBSERVATIONS

Crop type

1. Record the site's planting history for previous season and year
2. Note crops planted in the area under examination, and stage of growth

Crop appearance

3. Observe the crop for signs of stress or growth difference. Patchiness is indicative of poor system performance
4. Measure or estimate the crop ground cover proportion

Soils

5. Dig or auger several holes within the irrigated area
6. Determine the soil texture and depth of rooting
7. Estimate or otherwise determine soil infiltration rate and soil water holding capacity
8. Assess the depth of water penetration
9. Note any soil features that indicate wetness, poor drainage or related properties and identify causes

Ponding

10. Assess the amount of ponding that occurs within the irrigated area while the system is operating
11. Note if water is ponding, running over the ground, or causing soil movement
12. Estimate the percentage of water lost

Runoff

13. Assess the amount of runoff from the irrigated area as a result of irrigation
    - Only consider volumes leaving the irrigated area

Wheel ruts

14. Assess the presence and degree of wheel or skid rutting in the travel path
    - Assess if machine speed is likely to be affected by ruts.

SYSTEM CHECKS

Water supply

1. Complete checks of the water supply including pumping system and mainline as specified in *Part B: Compliance and Water Supply Checklists*

Filtration

2. Check filters and note nature and degree of contamination or blockage
3. Identify when the filter was last checked or cleaned
4. Identify if automatic cleaning or back-flushing is fitted and operational

System leakages

5. Conduct an overall visual check (as possible) of headworks, mainline, hydrants, connection lines and the distribution system to identify any leakages or other losses from the system

Sprinkler package

6. Before testing a system, verify that the sprinkler package has been installed according to the design specifications, unless specified otherwise by the client

Guns

7. Record the nozzle age, type and orifice(s) fitted
8. Measure the diameter of the orifice and assess for wear
9. Record the vertical and sector angle settings

Fixed booms

10. Record the nozzle age, type(s) and orifice(s) fitted
11. Randomly select a number of sprinklers or sprayers along the length of a fixed boom. Inspect them for blockages and record the cause of any blockages found. Assess orifice wear with a gauge tool or drill bit
12. Check sprinkler height above canopy meets manufacturer's recommendations

Rotating booms

13. Record the nozzle age, type(s) and orifice(s) fitted
14. Assess nozzle orifices for wear
15. Ensure boom rotation is correct and unhindered.
16. Check sprinkler height above canopy meets manufacturer's recommendations

Machine speed

17. The uniformity of speed along the path of travel can affect the field uniformity
18. Measurement of travel speed at intervals along the path can identify a potential cause of non-uniformity, and is needed to compare machine flow rates and measured application rates

Stationary operation (T_S)

19. Measure the time the machine is operated stationary at the beginning and at the end of the strip

Transverse test speeds (S_T)

20. Measure the machine test speed in the field as the machine passes over collectors used for each transverse application uniformity assessment
    - As the wetting zone reaches each line of collectors, mark a point on the delivery tube (hose) or winch cable, and mark the corresponding point in the field with a peg. Record the time
    - When the wetting zone no longer reaches any collectors in the line, place a second peg in the ground corresponding to the mark on the tube, and record the time
    - Measure the distance between the two pegs and calculate the travel speed.

Longitudinal speed uniformity (S_L)

21. Establish a sample of segments, each 5m long, along the travel path
    - There should be at least one segment for each layer of delivery tube or cable on the winch reel.
22. Record the location of each segment as the distance of the gun-cart from the final end point of the strip
23. Calculate segment travel speed for each segment = segment length / time taken
24. Determine the mean travel speed along the travel path from the total time required to travel the strip length
    - Do not include any time operating stationary at either end.

SYSTEM FLOW

Total system flow

1. Record the water flow rate as measured by a fitted water meter with the system operating as normal
   - Wait until flow rates stabilise (up to 15 minutes) before taking readings
   - It may be necessary to take beginning and ending meter readings over a set time period to determine flow rate.

Energy use

2. Obtain energy consumption data for the period covered by flow measurement
   - Enables calculation of irrigation energy costs.

SYSTEM PRESSURE

Headworks pressures

With system operating,

1. Measure pump discharge pressure
2. Measure mainline pressure after filters and control valves

Optionally measure:

3. Filter head loss
4. Pump control valve head loss
5. Throttled manual valve head loss

Mainline pressures

6. Measure pressure at each hydrant
   - If hydrants are on a common mainline, measure pressures at each hydrant while the system is operating at furthest hydrant from the pump/filter.

NOTE: This is an optional test if problems identified or anticipated

Machine pressures

7. Measure pressure at the inlet to the machine
8. Measure pressure at the inlet and outlet to the hydrodynamic drive

Sprinkler pressure

9. Measure pressure at the inlet to the gun or sprinkler package.

SPRINKLER PERFORMANCE

A wide variety of water distribution systems may be fitted to travelling irrigators. Three different types are recognised; guns, fixed booms and rotating booms.

Guns

With machine stationary (system operating)

1. Determine the wetted radius of the water distribution system to the nearest 10cm for three radii: in line with, and at 90° angles left and right of, the direction of travel

Fixed booms

With machine stationary (system operating)

2. Determine the wetted length of the water distribution system to the nearest 10cm
3. Measure the flows from 12 sprinklers chosen at random along the length of the boom.
    - Ensure sprinklers chosen are of the same specifications
    - Capture all flow without flooding the nozzle or affecting pressure
    - Shroud the sprinkler or sprayer with a loose pipe or hose and collect discharge in a container of at least 20 litres
    - Measure and record the time in seconds to fill the container. (Filling to the neck of a bottle or drum container will increase accuracy.

Rotating booms

With machine stationary (system operating)

4. Determine the wetted radius of the water distribution system to the nearest 10cm for three radii: in line with, and at 90° angles left and right of, the direction of travel

NOTE: Because the contribution individual sprinklers make to distribution patterns cannot be distinguished, sprinkler measurements are not made.

TRANSVERSE UNIFORMITY TEST

The transverse uniformity test is of primary importance as it establishes variation across the irrigated strip. Performance is dependent on sprinkler package design and installation, field topography and wind or other disturbances.

Collector placement

1. Arrange three lines of collectors perpendicular to the delivery tube (hose) or tow cable (Figure 3.1)
    - For reel irrigation machines, establish each transverse line such that different numbers of layers of delivery tube are coiled on the reel
    - Ensure the distance between first and last lines is at least 50% of travel length (Lt)
    - Ensure the first line of collectors is positioned ahead of the irrigator, at a distance more than the wetting radius of the water distribution system so the machine is operating normally when the first water reaches the collectors
    - Ensure the last line is positioned at a distance more than the wetting radius of the water distribution system so water stops reaching the collectors before the machine becomes stationary.
2. There Is no set collector number for each line, this should be determined from the following principles.
    - Select collector spacing (sc) such that the half width of the irrigated strip is a multiple of the collector spacing. E.g. If E = 90m, E/2 = 45m. Select a collector spacing of 3.0, 4.5 or 5.0m
    - The maximum spacing between collectors should be 6m for guns and 3m for sprayers or sprinklers
    - The lines of collectors must extend to the full wetted radius of the water distribution system, allowing for any skewing as a result of wind effects
    - Do not place collectors in wheel tracks.
    - Ensure any collectors between wheels will not be knocked over by the machines frame
3. Measure and record the position of each collector relative to centre of the travel path

Evaporation

4. Establish collection times to ensure evaporation losses are minimised.

If the test can be run overnight, a single collection early in the morning may acceptable. Otherwise collect each transverse line as the irrigator passes, resetting the control collector volume each time.

OPTIONAL TESTS

Repeat tests may be run to determine distribution uniformity under different weather (wind) conditions, or with the travelling irrigator in a different field location or locations.

3.2 Data analysis

SYSTEM

Irrigated area

1. Calculate the area irrigated per set (run)
   - Set Area (ha) = Strip Width (m) x (Travel Path Length(m) + 0.75 Wetted Radius(m)) / 10,000
2. Calculate the total area irrigated
   - Total Area = Set Area x Number of Sets

PERFORMANCE INDICATORS

Water supply

1. Complete calculations of water supply including pumping system and mainline as specified in *Part B: Compliance and Water Supply Checklists*

Mainline pressure

2. Calculate the Mean Hydrant Pressure
   - Sum of all pressures / Number of pressure readings
3. Calculate Maximum Hydrant Pressure Variation
   - Highest Hydrant Pressure – Lowest Hydrant Pressure

Fixed boom sprinkler discharge

4. Calculate mean discharge from the 12 measured sprinklers as described in 3.1 Fixed booms.

APPLICATION DEPTHS

Required adjustments

To make valid assessments of travelling irrigator performance, the depths measured by collectors must be adjusted to account for evaporation losses and for the effect of overlaps from adjacent irrigation runs (strips).

Evaporation adjustment

1. Make adjustments for evaporation losses as set out in *Glossary and Calculations: Evaporation from collectors*

Overlap accounting

For water distribution systems intended to operate with areas of overlap, application depths must be adjusted to account for overlap effects.

2. Account for overlap as described in in *Glossary and Calculations: Overlapping systems*

Total machine application depth

3. Calculate Application Depth based on total machine flow, cycle duration and irrigated area
   - This assumes that each strip is overlapped from each side, so each strip receives the full volume of water applied during one travel run.

Transverse line application depth

4. Calculate the mean application depth within the wetted strip for each transverse line, after adjusting for evaporation and overlap
5. Calculate the minimum and maximum application depths after adjustments as above

Wetted strip application depth

6. Calculate mean application depths for the strip as the mean of the transverse line adjusted depths
7. Determine the overall minimum and maximum application depths.

DISTRIBUTION UNIFORMITY

A determination of field DU is a prime output from evaluations. Distribution uniformity from multiple transect tests is adjusted to account for other contributing factors including run-off and off-target application.

NOTE: Distribution uniformity is not an efficiency measurement so is reported as a decimal value.

Uniformity coefficient

The statistical uniformity coefficient based on Christiansen's Uniformity Co-efficient is an alternative measure that can be reported.

NOTE: The uniformity co-efficient is not an efficiency measurement so is reported as a decimal value.

SYSTEM UNIFORMITY

Required adjustments

Determination of global 'field uniformity' requires that adjustments are made to account for various factors, including pressure variation, overlap and unequal system drainage.

Adjustments are also required to account for evaporative losses from collectors while field data collection is undertaken.

Field distribution uniformity, FDU_{lq}

1. Estimate overall field distribution uniformity (FDU_{lq}) by combining contributing variable factors using the Clemmens-Solomon statistical procedure

Overall uniformity incorporates the grid distribution uniformity of the distribution system (gun or boom) assessed from overlapped multiple transect uniformity tests. It may be adjusted for run-off or off-target application.

$$FDU_{lq} = [1 - \sqrt{(1 - GDU_{lq})^2 + (1 - F_{ponding})^2}$$

Where:

FDU_{lq} is low quarter field distribution uniformity

GDU_{lq} is low quarter grid distribution uniformity

$F_{ponding}$ is surface redistribution from ponding

Grid distribution uniformity, GDU_{lq}

2. Calculate GDU_{lq} from all adjusted depths from all transects

NOTE:
Create a virtual grid comprising all transect tests.

Off-target factor

3. Calculate an adjustment factor for off-target application and field runoff from estimates of the percentage of total take represented by these contributing factors

Flow distribution uniformity, QDU_{lq} (fixed boom systems only)

4. Calculate low quarter flow distribution uniformity from measured sprinkler flows along the boom length using the low quarter uniformity formula Equation 30.

APPLICATION INTENSITIES

The Instantaneous Application Intensities under traveller irrigation machines may be very high. High instantaneous application rates can lead to ponding and surface redistribution.

However with guns or rotating booms, any area is watered for only very short periods each rotation, so soil infiltration will often accept these rates. Under fixed booms the area is watered continuously and ponding may be more apparent.

Instantaneous application intensity

1. Calculate the Mean Application Intensity (mm/h) for each transect from Mean Adjusted Applied Depths, Travel Speed and the Wetting Area of the distribution system
   - The maximum application rate at central points will be greater than the average overall application intensity if the intensity reduces toward the edge of the wetted strip.

Wetting area of distribution system

Fixed boom
The wetting area of a fixed boom is mean sprinkler wetted diameter times effective width of the boom.

Rotating boom
The wetting area of a rotating boom is area of a circle based on effective wetting diameter of boom

Big Gun
The wetting area of a big gun can be estimated as half the area of a circle based on the effective wetted radius of the gun trajectory.

MACHINE SPEED

Travel speed at transverse lines

1. Determine the travel speed at each transverse line

Speed of travelling irrigator

2. Calculate the speed at each segment (m/h).
3. Determine the mean speed by dividing the full strip length (m) by the time taken to water the strip (hours) excluding any stationary time at either end
4. Determine the mean, the maximum and minimum speeds

Longitudinal speed uniformity

5. Determine the maximum deviation in travel speed
6. Determine the coefficient of variation in travel speed

3.3 Adjust irrigation system settings

APPLIED DEPTH

1. Compare Mean Set Applied Depths to Target Depth
   - Adjust set run time to achieve target applied depth

Adjusted machine speed

2. Calculate Adjusted Machine Speed
   - Adjusted Machine Speed (m/h) = Machine Test Speed (m/h) x (Target Depth / Distance Adjusted Applied Depth) ÷ DU_{lq}

   NOTE: Including DU_{lq} ensures the Run Time applies sufficient water to adequately irrigate 7/8th plants

Distribution uniformity

3. Identify impact of variables contributing to non-uniformity
   - Repeat Operational Checks (Section 1)
   - Adjust system components to achieve best performance
   - Ensure system is at recommended operating pressure
   - Get professional assistance.

New Zealand Piped Irrigation System Performance Assessment Code of Practice

PART G: Linear Move

Note: This is Part G of a series of nine (Parts A–I).

IRRIGATION NEW ZEALAND

Part G: Contents

Date of Issue: January 2023

The Code is presented as a series of booklets, each with a defined purpose.

Part A: An Introduction to Performance Assessment
Part A provides an overview of performance assessment, explains the broad philosophy behind assessment approaches taken throughout the Performance Assessment series, and contains specific formulae and reporting standards.

Part B: Compliance and Water Supply Checklists
Part B relates to all system types. It contains recommendations for checks to ensure compliance with regulations, rules and consent conditions, safe effective operation of water supply systems.

Parts C–H: System Performance Assessments
(Part G = this booklet)
Parts C–H contain guidelines and recommendations for Operational Checks, System Calibrations and In-field Performance Assessments specific to a range of irrigation system types.

Part I: Conducting Energy Efficiency Assessments and Seasonal Irrigation Efficiency

IrrigationNZ Technical Glossary
The Glossary and Calculations are common with the NZPIS Design Code of Practice.

Ministry for Primary Industries
Manatū Ahu Matua

Supported by Sustainable Farming Fund

Introduction

Purpose

The *New Zealand Piped Irrigation System Performance Assessment Code of Practice* provides nationally recognised guidelines to measure and benchmark performance of agricultural irrigation.

Part G is specific to linear move irrigation systems. It makes recommendations for planning and conducting assessments and reporting on the performance of irrigation systems and their management. Its focus is on key performance indicators that are common with the New Zealand Piped Irrigation Systems Design Standards.

It was developed to provide guidelines for irrigators and others undertaking evaluations of such equipment as a 'snapshot exercise' under prevailing field conditions.

SYSTEM PERFORMANCE

The Code recognises different levels of performance assessment depending on purpose. In increasing level of complexity, system performance assessment includes:

- Operational Checks
- System Calibration
- In-field Performance Assessment.

Related documentation

- **New Zealand Piped Irrigation System Performance Assessment Code of Practice:**
  - Part A: An Introduction to Performance Assessment
    Part A provides an overview of performance assessment, explains the broad philosophy behind assessment approaches taken throughout the Performance Assessment series, and contains specific formulae and reporting standards.
  - Part B: Compliance and Water Supply Checklists
    Part B relates to all system types. It makes recommendations for checks to ensure compliance with regulations, rules and consent conditions, safe effective operation of water supply systems and energy efficiency assessments of pumps and delivery systems.
  - Parts C–H: System Performance Assessments
    Parts C–H contains guidelines and recommendations for performance assessments specific to a range of irrigation system types.
- **New Zealand Piped Irrigation Systems Design Code of Practice**
- **New Zealand Piped Irrigation Systems Design Standards**
- **New Zealand Piped Irrigation Systems Installation Code of Practice**
- **New Zealand Water Measurement Code of Practice**
- **New Zealand Irrigation Technical Glossary**

System description

A linear move irrigation machine consists of a lateral pipeline supported above the field by a series of A-frame towers, each having two driven wheels at the base. The lateral traverses the field in a straight path creating a rectangular wetted area.

Water is discharged under pressure from sprinklers or sprayers mounted on the lateral as it sweeps across the field. As such, the evenness of application at points along the lateral, and the evenness of application as the lateral passes across the field both contribute to overall irrigation distribution uniformity.

Because of the very low labour requirement per irrigation, linear moves allow farmers to apply frequent light irrigations as needed to best fit crop water requirements and maximise production.

Special features for analysis

STOP-START OPERATION

The speed of travel of a linear move irrigation machine is generally controlled by varying the average speed of the end tower.

Stop-start operation can result in non-uniform application along the travel path, especially for single irrigation events. Because the stopping points are effectively random, this is mostly mitigated by subsequent irrigation cycles.

Field evaluation should attempt to minimise effects of single event stop-start effects on distribution measurements which otherwise lead to underestimates of distribution uniformity. For a single lateral test this may require operating the machine at 100% speed to minimise the number and duration of stop-starts. Alternatively, multiple lateral or lateral/linear measurements can be used.

Hydraulically powered linear move irrigation machine run more smoothly but the possibility of erratic movement and potential effects on uniformity should be monitored.

VARIABLE RATE SYSTEMS

Variable rate systems allow different parts of the irrigated area to receive different depths of irrigation. This is achieved by switching individual nozzles on and off in accordance to an application plan or map. Testing such machines requires care to ensure the intended depth at any location is known.

FIELD VARIABILITY

The performance of a linear move irrigation machine may vary at different positions in the field. Contributing factors include topographic variation and elevation changes, wind effects, and the operation of various add-on components such as end guns or corner swing arms.

A machine without add-on equipment, operating on a relatively flat, homogenous field should have similar performance in all positions. The assessor and client should discuss what testing is desired and the conditions under which any tests should be conducted.

WIND EFFECTS

The performance of pressurised spray systems can be greatly affected by wind, particularly when nozzles create smaller droplet sizes. Strong winds blowing perpendicular to the machine are likely to have greatest effect on uniformity.

The uniformity testing should be carried out in conditions representative of those commonly experienced in the field. Wind speed and direction should be measured and recorded.

DIFFERENCES BETWEEN LINEAR MOVES AND CENTRE PIVOTS

The linear move discharges water uniformly along the length of the lateral, whereas the pivot discharges water at an increasing rate with distance from the centre, to account for the increase in area covered.

Linear move irrigation machines may have relatively long rotation times, compared to centre pivots which typically have a return period of only several days. This means the irrigation interval, and therefore the application depth, of a linear move is generally greater than under a pivot.

1. Operational checklist

This is a minimum list of checks of linear (lateral) move irrigation machines that should be made.

Be safety conscious – electrical and mechanical hazards may be present.

Every system should be supplied with a System Operation Manual. The manual may include extra checks not listed here. It will give more detail than this checklist including information specific to your system.

SYSTEM OFF CHECKS

Drag hose (linear moves)

1. Visually check condition for wear, kinks or other damage
2. Visually check Boots
   - Tighten bands if necessary

Tractor unit

3. Visually check Wheel lug bolts, tyre condition and pressure
4. Check engine area for bird nests
5. Check coolant and lubricant levels
6. Check belts and bearings
   - Lubricate as required
7. Visually check Riser and spans

Control unit

8. Visually inspect electronic controls
9. Check battery charge

Towers

10. Check U joints for wear
    - Replace if necessary
11. Visually check Cable and rod connections
12. Visually check Wheel lug bolts, tyre condition and pressure
13. Visually check gearboxes, drive shafts
    - Lubricate as required
14. Visually check Boots
    - Tighten bands if necessary
15. Flanges

End gun, corner arms

16. Check connections
17. Visually check wiring and hydraulic lines

Sand trap

18. Empty and flush

Sprinklers

19. Check sprinklers fitted are as specified in sprinkler chart
    - Replace as necessary

    NOTE: Sprinkler bases are colour coded
20. Inspect nozzle orifice condition
    - Replace if wear detectable
21. Ensure rotating nozzles are free turning and cages not damaged
22. Inspect droppers for wear or damage
    - Replace as necessary

End gun if fitted

23. Check gun components for looseness, freedom of movement
24. Check gun outlet nozzle orifice condition
    - Replace if wear detectable

SYSTEM ON CHECKS

WARNING:
Before starting ensure nothing is parked in front of the irrigator.

Pump

1. Complete checks as specified earlier in Section 1

Pipe network

2. Check for leaks along mainline

System pressure

3. Check pump pressure while system operating
4. Check pressure before and after filters

Off-takes/hydrants

5. Check hydrants are not leaking

Drag hose

6. Check there are no leaks
7. Check the hose is not misshapen

Tractor unit

8. Check engine for noises
9. Check for coolant or lubricant leaks
10. Check belts and bearings

Control unit

11. Check any control unit is functioning correctly

Riser and spans

12. Check inlet pressure gauge with alternative
    - Replace if necessary
13. Check inlet pressure is correct

    NOTE: Hydrant must be in use to get valid pressure reading

    NOTE: Check farthest and highest hydrant positions to ensure adequate pressure
14. Check for leaks along spans and at towers
    - Check flanges: call service company if flanges leaking

Towers

15. Observe motors, gear box and drive shaft operation for noise or vibration

Droppers

16. Check for leaks
    - Repair or replace as necessary

Sprinklers

17. Check each sprinkler is turning correctly and cage not damaged
    - Repair or replace as necessary
18. Check there are no leaks
    - Repair or replace as necessary
19. Check the pressure above last sprinkler, above pressure regulator if fitted

    NOTE: This requires installation of a test point. A ¾" BSP Tee above the pressure regulator is usually suitable. Reduce to ¼" BSP for standard pressure gauge.

Gun

20. Check gun is operating correctly
21. Check gun angles are correct, gun switches direction at correct locations

Corner arm

22. Check arm tracks correctly
23. Check sprinklers turn on and off correctly.

2. Calibrating linear move irrigators

The Irrigation Calibration method for Linear Move irrigators assesses the amount of water being applied during an irrigation event. It is based on measurement water collected in a line of containers spaced across the path of travel. Applied Depth, Application Intensity and Distribution Uniformity are calculated.

This allows the manager to determine the speed required to apply the target depth, and whether the system is applying the same amount of water at all points along the machine. A plan to apply target depths can be determined.

2.1 What will the testing show?

The main things the calibration test will show are:

Applied depth
The 'rainfall equivalent' depth of water the irrigation system is applying on average at the particular travel speed. Compare the measured applied depth to target application to determine machine speed adjustment to correct applied depths.

Application intensity
The rate (mm/hour) at which water is being applied, equivalent to rainfall intensity. If intensity exceeds soil infiltration capacity, ponding, bypass flow, redistribution and runoff will reduce irrigation effectiveness and efficiency.

NOTE: The Application Intensity of Linear move irrigators increases along the length of the machine. Rates are low (gentle) at the inner spans, increases to high (intense) at the end. This protocol calculates Application Intensity at the end tower, the highest rate but one representing a large proportion of the irrigated area.

Distribution uniformity DU
Distribution Uniformity describes the evenness with which water is applied. The higher the DU the better the system is performing. And the higher the uniformity, the more confident you can be that your measurements are truly representative of your system's performance.

Excess water use EWF
The excess water use factor identifies how much extra water is required during a set event because of non-uniformity.

Adjusted machine speed
Calculates the machine speed required to ensure 7/8ths of the area gets at least the Target Application Depth. It accounts for flow rate and uniformity.

WHEN SHOULD CALIBRATION BE DONE?

Complete the calibration test if commissioning a new machine and after any major changes.

Calibration should be repeated as part of system checks at the start of every season.

NOTE: Linear Move irrigator irrigation depth is controlled by machine speed. Checking at 100% speed may give best results. If the machine stops for long periods it may affect bucket collected volumes.

NOTE: Linear Move irrigator performance can be significantly affected by weather conditions. Consider wind conditions when testing: Calm conditions may give a better assessment of the system's potential performance but if wind is normal for the site, testing may proceed.

NOTE: The flow and uniformity of a linear move will not normally change much if adequate pressure is supplied. Check end sprinkler pressure:

- at different hydrant positions
- different field elevations or
- when alternative water-takes reduce system pressure.

2.2 Calibration process

Before starting, ensure System Operational Checks (Section 1) have been completed.

Calibration is a four step process:

1. Gathering information about the system
2. Calculating performance indicator values
3. Comparing results with expectations
4. Adjusting irrigation system settings as required to achieve intended performance.

GATHERING INFORMATION

Equipment

Equipment needs are very basic and most should already be available on the property. A suggested list includes:

- 24 containers of same known opening diameter (>150 mm)
  - 9 Litre buckets have been found suitable
- 1 measuring cylinder
  - 1 or 2 Litre for larger volumes (large collectors, higher application depths)
  - 100mL or 200mL for smaller volumes (small collectors, lower application depths)
- 1 tape measure (20m)
- 2 flags or fence standards
- 1 stop watch
- 1 pen or pencil
- 1 recording sheet.

Sampling method

The calibration check is based on a line of collectors (transects) placed across the travel path. It can be useful to repeat the test at different positions around the circle to check performance is consistent. Changing terrain or end-guns turning on and off can affect machine performance.

Testing layout

1. Set 24 collector buckets in a row along the length of the irrigator
2. Arrange eight collector buckets at even spacing under the first span or two of the machine (see 1–8 in Figure 2.1).
3. Arrange eight more collector buckets at even spacing in the middle of the machine (see 9–16 in Figure 2.1).
4. Arrange eight more collector buckets under the last span or two of the machine (see 17–24 in Figure 2.1).

   NOTE: If there is an end gun, arrange the last two collector buckets at even spacing between the end wheel track and the extent of significant wetting (see 23 and 24 in Figure 2.1).

Mark speed test positions

5. Place two marker flags along the line of travel, either side of the collector bucket transect
6. Record the distance between the flags

   NOTE: Put flags at least 5m either side of the line of collector buckets near the wheel track at the machine centre-tower.

   NOTE: Ensure flags are easily visible during testing.

Management information

7. Record the Target Irrigation Depth
8. Record the Normal Irrigator Speed
9. Measure the Run Length (b in Figure 2.2)

   NOTE: It is often best to use an average distance for several runs in a paddock.
10. Measure the Run Length (may be hydrant positions) (a in Figure 2.2)

    NOTE: Take an average spacing between several hydrants.
11. Record the number of runs
12. Determine the area of the Block (Run length x run spacing x run number)

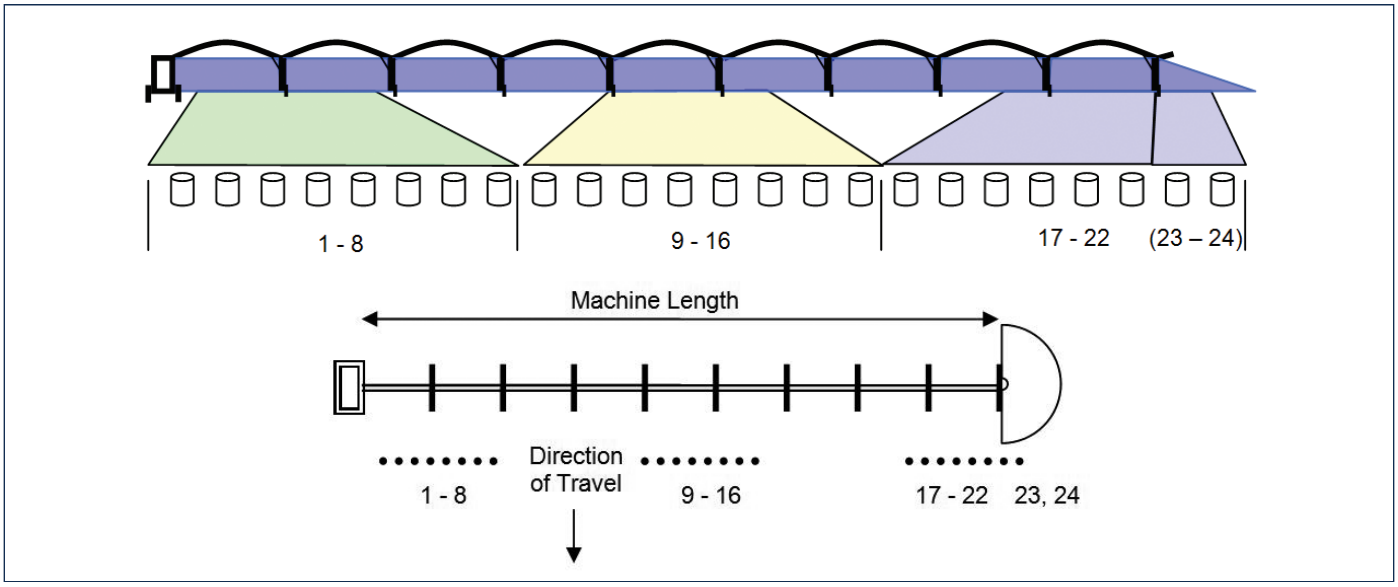

Figure 2.1. Layout of collectors along length of linear move irrigator

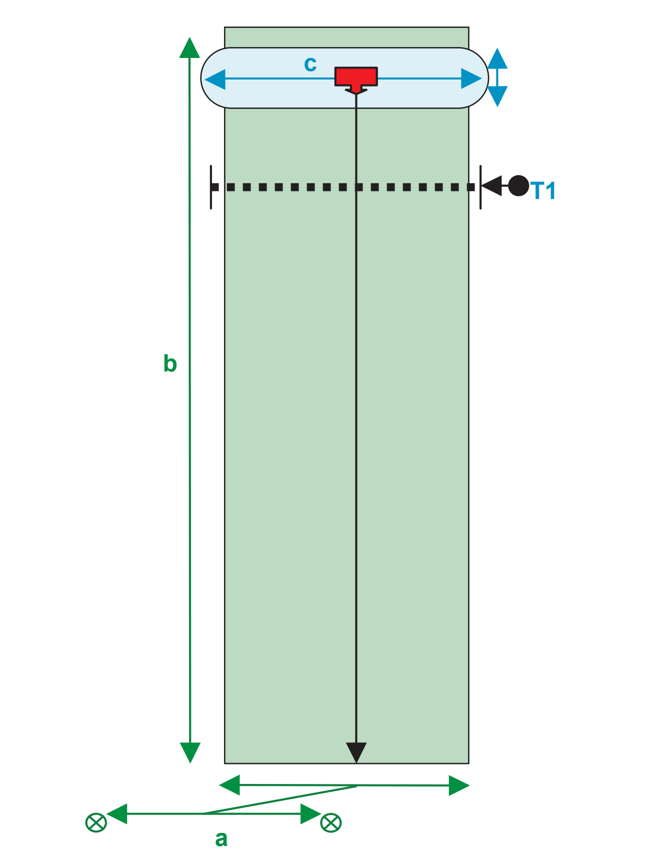

Figure 2.2. Layout of calibration test of linear move irrigators

FIELD MEASUREMENTS

System measurements

1. Measure the system Flow Rate
2. Measure the Outlet Pressure at the pump
3. Measure the Pressure at the Entry to the irrigator
4. Measure the Pressure the last tower

   NOTE: Take pressure measurement above any pressure regulator at the nozzle at the tower

Application test

5. Record the time for the machine to pass between the speed test marker flags
6. Measure the collector bucket mouth diameter
7. Measure the volume of water caught in each container and record on the Record Sheet

   NOTE: Take care to record each reading in the correct position

CALCULATE PERFORMANCE INDICATOR VALUES

Irrigator speed

1. Speed (m/min) = Distance travelled ÷ Time taken
   - Distance travelled (m) = distance between marker flags
   - Time taken (min) = Time at second marker flag – Time at first marker flag

Applied depth

2. Calculate Average Applied Depth (mm) [Average Volume collected ÷ Collector opening area]
   - Average Volume Collected (mL) = Sum of all collected ÷ number of collectors
   - Collector opening area (m^2) = Pi x Collector diameter (m) x Collector diameter (m) ÷ 4
3. Calculate Applied Depth (mm) of eight collected depths in first span
4. Calculate Applied Depth (mm) of eight collected depths in middle span
5. Calculate Applied Depth (mm) of eight collected depths in last span
6. If present; Calculate Applied Depth (mm) of two collected depths of end span/end gun

Application intensity

7. Calculate Application Intensity (mm/h)
   = Applied Depth (mm) x Irrigator Speed (m/min) x 60
   ÷ Wetting Pattern Width (m)

System flow rate

8. Calculate Flow Rate (L/s)
   = (Machine Length + EndGun Extra Length) (m) x Applied Depth (mm) x Irrigator Speed (m/min) ÷ 60

Distribution uniformity

9. Calculate the Distribution Uniformity DU
   = Low quarter average volume ÷ average volume
   - Low Quarter Average Volume (mL) = Average of five lowest volumes collected

Excess water use EWF

10. Calculate Excess Water Use Factor (%) [DU Adjusted Depth ÷ Applied Depth x 100]
    - DU Adjusted Depth (mm) = (Applied Depth ÷ DU) – Applied Depth

COMPARE RESULTS WITH EXPECTATIONS

Flow rates

1. Compare calculated System Flow Rate with Water Meter Flow Rate

Applied depth

2. Calculate Target Depth to Applied Depth ratio
   = Target Depth ÷ Applied Depth
   a. < 1 – under applying
   b. = 1 – correct
   c. > 1 – over applying

   Acceptable variances: 0.90–1.10 (0.95–1.05 is better)
3. Compare Applied Depth with Soil Moisture Deficit
   - Applied Depth < Soil Moisture Deficit ÷ DU

Application intensity

4. Compare the calculated Application Intensity to expectations

Distribution uniformity DU

5. Interpret calculated DU value
   - DU > 0.90 Uniformity is very good
     the system is performing very well
   - 0.90 – 0.80 Uniformity is good
     performance better than average
   - 0.80 – 0.70 Uniformity is fair
     performance could be improved
   - 0.70 – 0.60 Uniformity is poor
     system should be investigated
   - DU < 0.60 Uniformity is unacceptable
     system must be investigated

ADJUST IRRIGATION SYSTEM SETTINGS

Check key performance indicators

1. If Applied Depth or Uniformity are unacceptable
   - Repeat Operational Checks
   - Ensure system is at recommended operating pressure
   - Get professional assistance

Irrigator speed

2. Calculate Adjusted Speed (m/min)
   - Irrigator Speed x (Target Depth ÷ DU) ÷ Applied Depth

   NOTE: Including DU ensures the irrigator applies sufficient extra water to adequately irrigate 7/8th plants.

3. Performance assessment of linear move irrigation machines

This schedule outlines procedures to be followed when assessing distribution uniformity of a linear move irrigation machine fitted with overlapping sprayers or sprinklers. It was developed to provide guidelines for irrigators and others undertaking evaluations of such equipment as a 'snapshot exercise' under prevailing field conditions.

NOTE:
Complete Operational Checks (See Section 1) before commencing a system evaluation.

TECHNICAL MATERIALS – RELEVANT STANDARDS

ANSI/ASAE S436.1 DEC01 Test procedure for determining the uniformity of water distribution of center pivot and lateral move irrigation machines equipped with spray or sprinkler nozzles (ANSI)

ISO 11545: 2001 Agricultural irrigation equipment – Centre-pivot and moving lateral irrigation machines with sprayer or sprinkler nozzles – Determination of uniformity of water distribution (ISO)

ISO 8224/1 – 1985 Traveller irrigation machines – Part 1: Laboratory and field test methods

ISO 7749-2: 1990 Irrigation equipment – Rotating sprinklers – Part 2: Uniformity of distribution and test methods

TECHNICAL REFERENCES

Allen, R.G., J. Keller and D. Martin. 2000. *Center Pivot System Design*. The Irrigation Association. Falls Church, VA. (CPD)

3.1 Data collection

This schedule outlines procedures to be followed when assessing performance of linear move irrigation machines under prevailing field conditions.

Because test conditions will vary, key conditions must be measured and recorded to assist any comparisons between subsequent tests of the same machine, or when benchmarking against other systems.

NOTE:
To provide a farmer with general operation/management information, test conditions should be representative of those experienced in normal operation.

NOTE:
For System Commissioning or fulfilling specific purchase contract criteria, adherence to test condition limitations such as wind speed should be ensured.

TEST SITE

Location

Select a test location that is most representative of the system as a whole.

If the irrigation site is not level, conduct the test in an area having elevation differences that are within the design specifications of the sprinkler package.

Site variability

If site elevation varies significantly, consider multiple tests to increase accuracy of distribution uniformity assessments. This may involve several radial uniformity tests in different parts of the field.

NOTE:
Some protocols recommend a "Longitudinal Uniformity Test" performed by arranging a line of collectors along the path of travel. This protocol instead recommends multiple lateral uniformity tests if performance at different positions is suspect. Check pressure is adequate in all machine positions and monitor machine speed.

SYSTEM SURVEY

System layout

1. Prepare a map of the system recording the headworks, mainline, take-off points (hydrants) (Figure 3.1)
2. Mark position of tests

Topography

If the field is not level, conduct the test in an area having elevation differences that are within the design specifications of the sprinkler package.

3. Measure the elevation difference and prepare a sketch of the ground surface profile along and across the test position
4. Record elevation at each tower

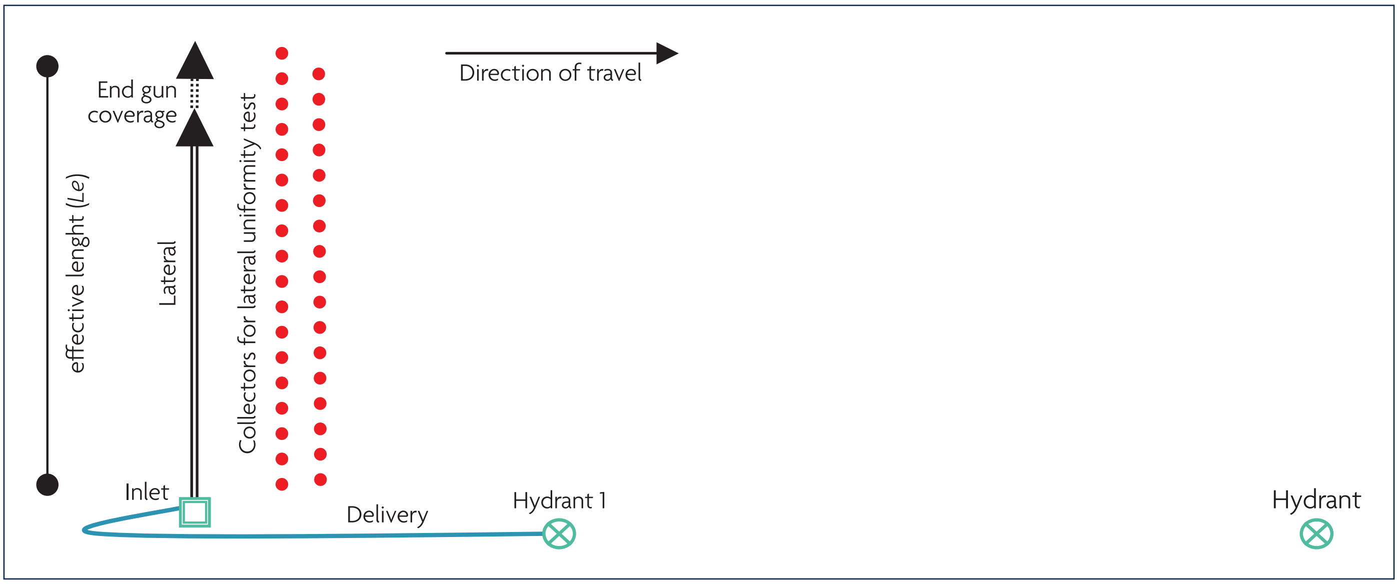

Figure 3.1. Layout of test site for linear move application testing

Irrigated area

5. Measure irrigation strip length
6. Measure the machine length and the length of each span, measuring between towers
7. Determine the length of any sections of the machine excluded from irrigation
8. Determine the effective wetted radius of any end gun (or guns) fitted to the machine

Off-target application (F_{TARGET})

9. Estimate the proportion of discharge that falls outside the target area (off the ends of the sprayline or sides of the field as a whole).

SYSTEM OPERATION

Water quality

The water used for the test should be the same as that normally used for irrigation unmodified for the purpose of the test by any additional filtration, injection of chemicals or other processes unless specifically requested by the client.

NOTE:
For personal health and safety reasons, particular caution is necessary if water contains chemical treatments or biological wastes.

System pressure

1. Complete the test at normal operating pressure or as agreed by client and tester
   - Ensure the pressure is maintained during the test
   - Ensure the system is not affected by other significant system draw-offs such as other irrigation machines or dairy sheds
   - Ensure pressure measurements include lowest and highest areas.

Machine speed

2. Operate the machine as near to 100% speed while ensuring a reasonable average application depth for accurate collector volume measurements.
   - Minimise the effect of stop-start effects on distribution patterns
   - Apply sufficient volume for reliable measurements to be obtained (ISO recommend 15mm).

End gun

3. If the sprinkler package is designed with an end-gun, perform the test with the end gun operating. The number of sprinklers or sprayers operating should remain constant during the test.
4. If desired the test may also be performed with the end gun not operating in order to evaluate the water distribution under those conditions

Corner system wetted radius

5. If desired the test may also be performed with the corner system (not) operating in order to evaluate the water distribution under those conditions

Field variability

6. If field elevation varies significantly, consider multiple uniformity tests.

ENVIRONMENTAL MEASUREMENTS

Wind

1. Record the direction and speed of the wind during the test period, and plot against relevant test locations on a map
    - Wind speed and direction relative to the sprayline should be monitored at intervals of not more than 15 minutes and recorded
    - Wind conditions at the time of the test should be representative of those experienced in normal operation
    - Wind speeds greater than 3 m/s can have significant effects on uniformity.

NOTE:
At speeds greater than 3m/s the tester and client must understand the limitations of the test results. The uniformity test should not be used as a valid measure of the sprinkler package if the mean wind velocity exceeds 3m/s.

Evaporation

By preference, the uniformity test should be conducted during periods that minimise the effect of evaporation, such as at night or early morning or in winter months.

2. Record the time of day, estimated or measured temperature and humidity when the test is conducted
3. Record the temperature and humidity in the test zone during the test period.
4. Determine evaporation rates using evaporation collectors identical to those used in uniformity testing
    - Place a control collector in a representative location upwind of the test area
    - Adjust readings for evaporation loss, following the procedures outlined in the *Technical Glossary.*

FIELD OBSERVATIONS

Crop type

1. Record the site's planting history for previous season and year
2. Note crops planted in the area under examination, and stage of growth

Crop appearance

3. Observe the crop for signs of stress or growth difference. Patchiness is indicative of poor system performance
4. Measure or estimate the crop ground cover proportion

Soils

5. Dig or auger several holes within the irrigated area
6. Determine the soil texture and depth of rooting
7. Estimate or otherwise determine soil infiltration rate and soil water holding capacity
8. Assess the depth of water penetration
9. Note any soil features that indicate wetness, poor drainage or related properties and identify causes

Wheel ruts

10. Assess the presence and degree of wheel rutting in tower tracks. Note if water is running down wheel tracks
11. Note if 'boom backs' are used or if directional sprayers are installed either side of the tower

Ponding

12. Assess the amount of ponding along the length of the machine
13. Note if water is ponding, running over the ground, or causing soil movement.
14. Estimate the percentage of water lost

Runoff

15. Assess the amount of runoff from the irrigated area as a result of irrigation. Only consider volumes leaving the irrigated area.

SYSTEM CHECKS

Water supply

1. Complete checks of the water supply including pumping system and mainline as specified in *Part B: Compliance and Water Supply Checklists*

Filtration

2. Check filters and note nature and degree of contamination or blockage
3. Identify when the filter was last checked or cleaned
4. Identify if automatic cleaning or back-flushing is fitted and operational
5. Check for presence of contaminants in lines: sand, bacteria/algae, precipitates etc

System leakages

6. Visually check (where possible) headworks, mainline, hydrants and the distribution system to identify any leakages or other losses from the system
7. Assess scale of leakages if any

Sprinklers

8. Record the nozzle type and orifice(s) fitted
   - verify that the sprinkler package matches the design specifications.
9. Measure sprinkler spacing along the sprayline
10. Measure sprinkler height above canopy
11. If sprayers are installed, check alternate spray heads are at different elevations to avoid stream interference
12. Check sprinklers are operating and set correctly (to horizontal)
13. Randomly select at least 12 sprinklers along the length of the machine
    - Inspect them for blockages and record the cause of any blockages found
    - Assess orifice wear with a gauge tool or drill bit.

Normal speed (S_N)

14. Determine the typical time required to make one full rotation of the irrigated area during periods of peak water use
    - This may be from farmer information or design specifications.

SYSTEM FLOW

Total system flow

1. Record the water flow rate as measured by a fitted water meter with the system operating as normal
   - Wait until flow rates stabilise (up to 15 minutes) before taking readings
   - It may be necessary to take beginning and ending meter readings over a set time period to determine flow rate
   - Record flow with end gun operating and not operating.

Energy use

2. Obtain energy consumption data for the period covered by flow measurement
   - enables calculation of irrigation energy costs.

SYSTEM PRESSURE

Headworks pressures

1. Measure pump discharge pressure
2. Measure mainline pressure after filters and control valves

Optionally measure:

3. Filter head loss
4. Pump control valve head loss
5. Throttled manual valve head loss

Mainline pressures

NOTE: This is an optional test if problems are identified or anticipated

6. Measure pressure at each hydrant with irrigator operating
   - If hydrants are on a common mainline, measure pressures at each hydrant while the irrigator is operating at furthest hydrant from the pump/filter.

Machine pressure

7. Measure lateral pressures upstream of any sprinkler pressure regulators:
   - At the first available pressure test point or outlet downstream of the elbow or tee at the top of the inlet structure
   - At the last outlet or end of the pipeline. If an end-gun with booster pump is fitted, ensure the pressure reading is taken upstream of the pump
   - If pressure is read at a sprinkler, use a pressure gauge with a pitot attachment. Depending on sprinkler design, this may require dismantling the units
   - Lateral pressures cannot be inferred from readings at the sprinkler if pressure regulators are installed.

Sprinkler pressure (pressure regulator function)

8. Measure pressures of eight sprinklers using a pitot tube or in-line gauge downstream of any pressure regulator
   - First sprinkler
   - Last sprinkler (before end-gun)
   - Highest sprinkler
   - Lowest sprinkler
   - Four other sprinklers randomly along the lateral

NOTE: This may require dismantling of the sprinkler unit to fit a temporary test point, or for access to the nozzle jet-stream.

SPRINKLER PERFORMANCE

For a centre pivot, the only direct measurement of uniformity that conforms to international conventions for uniformity testing comes from catch can collectors. The wide variety of sprinkler spacings and flow rates used in pivots (and linears) require more detailed direct testing and analysis to determine they are functioning correctly. That can be time consuming and expensive but could be a useful supplement to uniformity measurement

APPLICATION TEST

For a linear move machine with overlapping sprayers or sprinklers, useful measurements of uniformity comes from both individual sprinkler flows and catch can collectors. Linear systems have uniform sprinkler spacings and flow rates, and the subsequent analysis allows determination of the cause of any non-uniformity.

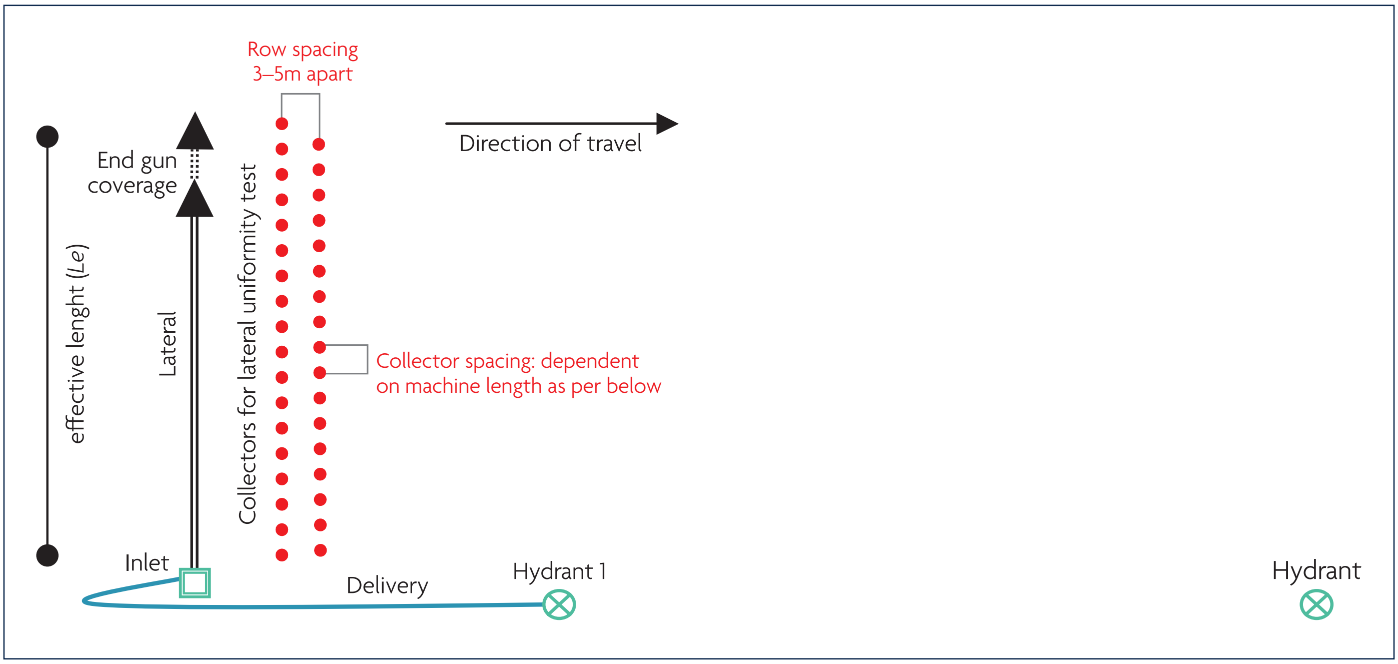

Figure 3.2. Layout of test site for linear move application testing

Machine uniformity

The machine uniformity test is of primary importance as it establishes variation along the length of the machine. Performance is dependent on sprinkler package design and installation, field elevation and wind or other disturbances.

Sprinkler discharge rate

1. Measure the pressures and discharges from 12 sprinklers chosen at random along the length of the sprayline. Ensure sprinklers chosen are of the same specifications
   - Capture all flow without flooding the nozzle or affecting pressure
   - Shroud the sprinkler or sprayer with a loose hose and collect discharge in a container of at least 20 litres
   - Measure and record the time in seconds to fill the container. (Filling to the neck of a bottle or drum container will increase accuracy.)

Pressure regulators

2. Randomly select several pressure regulators along the length of the machine and assess for cause and degree of blockages
   - This may require dismantling the units

Collector placement

3. Arrange two rows of collectors 3–5m apart

NOTE: Machines < 450m effective length:
Use a total of 80 collectors staggered to ensure the spacing between cans does not match sprinkler spacing. Arrange 40 collectors spaced up to 10m apart in each row.

NOTE: Machines > 450m effective length:
Increase the number of collectors proportionally so mean collector spacing is about 5m.

NOTE:
If an end-gun is used, the rows of collectors should be extended to just inside the wetted radius.

NOTE:
Position collectors ahead of the irrigator, at a distance more than the wetting radius of the sprinklers so the machine is operating normally when the first water reaches the collectors.

NOTE:
Do not place collectors in wheel tracks

Wetted radius

4. Determine the average wetted width of the sprayline (sprinkler wetted radius) to the nearest 10cm in at least three locations

Test speed (S_T)

5. Place two marker flags on a 15–30m test track along the line of travel, either side of the collector bucket transect
6. Record the distance between the flags

NOTE:
Put flags at least 5m either side of the line of collector buckets near the wheel track at the machine centre-tower.

NOTE:
Ensure flags are easily visible during testing.

7. Time how long it takes the machine to pass over the test track, and all intermediate start and stop times (IEP)
   - Repeat test where speeds may be reduced because of serious rutting or other factors.

Water collection

NOTE:
Collection and measurement can begin once the first row is no longer being wetted, while the second row is still being wetted.

OPTIONAL TESTS

Travel uniformity test

Some protocols suggest testing uniformity of application along the path of travel. Travel uniformity test recommendation is not recommended in these protocols. Much variability will be due to variation along the machine rather than along the travel path. Effort is better used checking machine speed and pressure or repeating machine uniformity tests at different positions in the field.

Travel speed and pressure tests

Monitoring machine travel speeds and sprinkler pressures can provide useful information about machine performance and variability.

If the machine has sprinkler pressure regulators fitted and pressure is sufficient at all locations, flows should remain uniform. If travel speeds are also uniform around the circle, distribution uniformity should be constant unless sprinkler heights vary due to undulating topography.

Repeat tests

Repeat tests to determine distribution uniformity with and without the end-gun operating, or with the lateral in a different field location or locations. In particular, consider up slope regions where machine pressures may be reduced.

If sprinkler heights or system pressures vary, additional radial uniformity tests will give most reliable uniformity assessments.

3.2 Data analysis

SYSTEM

Irrigated area

1. Calculate the total area irrigated
   - Total Area (ha) = Effective machine length (m) x run length (m) / 10,000.

PERFORMANCE INDICATORS

Water supply

1. Complete calculations of water supply including pumping system and mainline as specified in *Part B: Compliance and Water Supply Checklists*

Mean system applied depth

2. Calculate application depth based on total machine flow, event duration and irrigated area

Application depth

3. Calculate Evaporation Adjusted Applied Depth (AD_{Adj})
   - Make adjustments to account for evaporation losses.
4. Determine the minimum and maximum adjusted application depths

Application intensity

5. Calculate Instantaneous Application
6. Compare Application Intensities to Soil Infiltration Rate
   - Report as a percentage
   - Application Intensity should be less than Soil Infiltration Rate
   - Compare with observations of surface ponding.

DISTRIBUTION UNIFORMITY

System uniformity

Distribution uniformity is determined using the low quarter distribution uniformity coefficient, DU_{lq}.

NOTE:
Determine global 'field uniformity' accounting for contributing factors, including distribution pattern, off-target application and run-off.

Machine uniformity coefficient, CU_R

1. Calculate the Christiansen's Uniformity Co-efficient

Machine distribution uniformity, DU_{LQ}

2. Determine machine low quarter distribution uniformity from evaporation adjusted collector depths using the Distance adjusted DU_{lq}

Field distribution uniformity, FDU_{LQ}

3. Estimate overall field distribution uniformity (FDU_{lq})

NOTE:
If system pressure is adequate at all points, and machine speed is uniform, the Machine DU value will suffice.

NOTE:
If multiple radial test uniformities are included, all depths must be pooled, and a new uniformity calculation performed with the pooled data.

Sprinkler discharge uniformity

4. Calculate low quarter flow distribution uniformity from sprinkler discharges measured along the machine length
5. Determine the discharge uniformity of the sprinklers measured using the low quarter uniformity formula.

PRESSURE VARIATION

Mainline pressures

1. Calculate the percentage pressure variation between hydrants

Machine pressure loss

2. Calculate machine pressure loss HL
   - $HL = P_{first} - P_{last}$
   - P_{first} is the pressure before the first sprinkler and P_{last} is the pressure before the last sprinkler (excluding the end-gun)

NOTE:
As a general rule, total friction loss of a 400m system on flat to moderately sloping ground should not exceed 70kPa

3. Check minimum pipeline pressure is at least 20kPa higher than the pressure regulator setting

Pressure regulators

Pressure regulators have performance variability of about 6%. They are only recommended where pressure changes due to changes in elevation, end-gun operation or pumping lift exceed regulator variability by an amount that varies with design pressure.

In general terms, regulators are recommended if design pressure (P_d) is less than pressure variation due to elevation, pumping or end-gun operation (P_v) as given by the equation:

Fit regulators if: $P_d < (3.5\ P_v) + 3.5$

Sprinkler pressures

4. Determine mean pressure from measurements
5. Identify any sprinklers where pressure is more than 10% different to the mean pressure.

SPRINKLER PERFORMANCE

For a linear move, the only direct measurement of uniformity that conforms to international conventions for uniformity testing comes from catch can collectors. The wide variety of sprinkler spacings and flow rates used in linears (and pivots) require more detailed direct testing and analysis to determine they are functioning correctly. That can be time consuming and expensive but could be a useful supplement to uniformity measurement.

3.3 Adjust irrigation system settings

APPLIED DEPTH

1. Compare Mean Set Applied Depths to Target Depth
   - Adjust set run time to achieve target applied depth

Adjusted machine speed

2. Calculate Adjusted Machine Speed
   - Adjusted Machine Speed (m/h) = Machine Test Speed (m/h) x (Target Depth / Distance Adjusted Applied Depth) ÷ DU_{lq}

   NOTE: Including DU_{lq} ensures the Run Time applies sufficient water to adequately irrigate 7/8th plants.

Distribution uniformity

3. Identify impact of variables contributing to non-uniformity
   - Repeat Operational Checks (Section 1)
   - Adjust system components to achieve best performance
   - Ensure system is at recommended operating pressure
   - Get professional assistance.

New Zealand Piped Irrigation System Performance Assessment Code of Practice

PART H: Pivot

Note: This is Part H of a series of nine (Parts A–I).

Part H: Contents

Date of Issue: January 2023

The Code is presented as a series of booklets, each with a defined purpose.

Part A: An Introduction to Performance Assessment
Part A provides an overview of performance assessment, explains the broad philosophy behind assessment approaches taken throughout the Performance Assessment series, and contains specific formulae and reporting standards.

Part B: Compliance and Water Supply Checklists
Part B relates to all system types. It contains recommendations for checks to ensure compliance with regulations, rules and consent conditions, safe effective operation of water supply systems.

Parts C–H: System Performance Assessments
(Part H = this booklet)
Parts C–H contain guidelines and recommendations for Operational Checks, System Calibrations and In-field Performance Assessments specific to a range of irrigation system types.

Part I: Conducting Energy Efficiency Assessments and Seasonal Irrigation Efficiency

IrrigationNZ Technical Glossary
The Glossary and Calculations are common with the NZPIS Design Code of Practice.

Ministry for Primary Industries
Manatū Ahu Matua

Supported by Sustainable Farming Fund

Introduction

Purpose

The *New Zealand Piped Irrigation System Performance Assessment Code of Practice* provides nationally recognised guidelines to measure and benchmark performance of agricultural irrigation.

Part H is specific to centre pivot irrigation systems. It makes recommendations for planning and conducting assessments and reporting on the performance of irrigation systems and their management. Its focus is on key performance indicators that are common with the New Zealand Piped Irrigation Systems Design Standards..

It was developed to provide guidelines for irrigators and others undertaking evaluations of such equipment as a 'snapshot exercise' under prevailing field conditions.

SYSTEM PERFORMANCE

The Code recognises different levels of performance assessment depending on purpose. In increasing level of complexity, system performance assessment includes:

- Operational Checks
- System Calibration
- In-field Performance Assessment.

Related documentation

- **New Zealand Piped Irrigation System Performance Assessment Code of Practice:**
  - Part A: An Introduction to Performance Assessment
    Part A provides an overview of performance assessment, explains the broad philosophy behind assessment approaches taken throughout the Performance Assessment series, and contains specific formulae and reporting standards.
  - Part B: Compliance and Water Supply Checklists
    Part B relates to all system types. It makes recommendations for checks to ensure compliance with regulations, rules and consent conditions, safe effective operation of water supply systems and energy efficiency assessments of pumps and delivery systems.
  - Parts C–H: System Performance Assessments
    Parts C–H contains guidelines and recommendations for performance assessments specific to a range of irrigation system types.
- **New Zealand Piped Irrigation Systems Design Code of Practice**
- **New Zealand Piped Irrigation Systems Design Standards**
- **New Zealand Piped Irrigation Systems Installation Code of Practice**
- **New Zealand Water Measurement Code of Practice**
- **New Zealand Irrigation Technical Glossary**

System description

A centre pivot machine consists of a lateral circulating around a fixed pivot point. The lateral is supported above the field by a series of A-frame towers, each having two driven wheels at the base. Depending on field layout, the pivot may complete a full circle or only part segments.

Water is discharged under pressure from sprinklers or sprayers mounted on the lateral as it sweeps across the field. As such, the evenness of application at points along the lateral, and the evenness of application as the lateral passes across the field both contribute to overall irrigation distribution uniformity.

Because of the very low labour requirement per irrigation, centre pivots allow farmers to apply frequent light irrigations as needed to best fit crop water requirements and maximise production.

Special features for analysis

DISCHARGE RATES ALONG THE LATERAL

The unique and critical feature of a centre pivot machine is how it moves across the field. The centre pivot lateral moves at increasing ground-speed with distance for the centre, so the application *intensity* must increase further out along the lateral to give the same application *depth*.

Any point-measurement, such as collector (catch-can) volume, is representative of a much larger area of the entire field. Under a centre pivot, the collector measurements at the outer end represent a very much larger area of the field than those near the centre.

STOP-START OPERATION

The speed of rotation of a centre pivot is generally controlled by varying the average speed of the end tower. For electric machines, this is achieved by cycling the power on and off using a percentage timer mounted at the pivot end. Typically the cycle time is one minute. A 25% speed is achieved by turning the end-tower drive-motor on for 15 seconds every minute.

Irrigator alignment is maintained by operating inner towers for proportionally shorter times, so the forward movement of these machines is unsteady. This stop-start operation can result in non-uniform application along the travel path, especially for single irrigation events. Because the stopping points are effectively random, this is mostly mitigated by subsequent irrigation cycles (CPD).

Field evaluation should attempt to minimise effects of single event stop-start effects on distribution measurements which otherwise lead to underestimates of distribution uniformity. For a single radial test this may require operating the machine at 100% speed to minimise the number and duration of stop-starts. Alternatively, multiple radial measurements can be used.

Hydraulically powered centre pivot machines should run more smoothly but assessors are advised to still pay attention to the possibility of erratic movement and potential effects on uniformity.

VARIABLE RATE SYSTEMS

Variable rate systems allow different parts of the irrigated area to receive different depths of irrigation. This is achieved by switching individual nozzles on and off in accordance to an application plan or map. Testing such machines requires care to ensure the intended depth at any location is known.

FIELD VARIABILITY

The performance of a centre pivot irrigation machine may vary at different positions in the field. Contributing factors include topographic variation and elevation changes, wind effects, and the operation of various add-on components such as end guns or corner swing arms.

A machine without add-on equipment, operating on a relatively flat, homogenous field should have similar performance in all positions. The assessor and client should discuss what testing is desired and the conditions under which any tests should be conducted.

WIND EFFECTS

The performance of pressurised spray systems can be greatly affected by wind, particularly when nozzles create smaller droplet sizes. Strong cross winds are likely to have greatest effects.

The uniformity testing should be carried out in conditions representative of those commonly experienced in the field. Wind speed and direction should be measured and recorded.

1. Operational checklist

This is a minimum list of checks of centre pivot irrigation machines that should be made.

Be safety conscious – electrical and mechanical hazards may be present.

Every system should be supplied with a System Operation Manual. The manual may include extra checks not listed here. It will give more detail than this checklist including information specific to your system.

SYSTEM OFF CHECKS

Pivot point

1. Check condition of seals
2. Pressure gauge fitted and in good condition
    - Lubricate as specified in manual.

Towers

3. Check U joints for wear
    - Replace if necessary
4. Visually check Cable and rod connections
5. Visually check Wheel lug bolts, tyre condition and pressure
6. Visually check Gearboxes, drive shafts
    - Lubricate as required.
7. Visually check Riser and spans
8. Visually check Boots
    - Tighten bands if necessary.
9. Flanges

End gun, corner arms

10. Check connections
11. Visually check wiring and hydraulic lines

Sand trap

12. Empty and flush

Sprinklers

13. Check sprinklers fitted are as specified in sprinkler chart
    - Replace as necessary.

NOTE:
Sprinkler bases are colour coded.

NOTE:
LINEAR MOVES – all sprinklers are usually identical.
CENTRE PIVOTS – all sprinklers are usually different.

14. Inspect nozzle orifice condition
    - Replace if wear detectable
15. Ensure rotating nozzles are free turning and cages not damaged
16. Inspect droppers for wear or damage
    - Replace as necessary.

Gun

17. Check gun components for looseness, freedom of movement
18. Check gun outlet nozzle orifice condition
    - Replace if wear detectable.

Control unit

19. Visually inspect electronic controls
20. Check battery charge.

SYSTEM ON CHECKS

WARNING:
Before starting ensure nothing is parked in front of the irrigator.

Pump

1. Complete checks as specified earlier in Section 1

Pipe network

2. Check for leaks along mainline

System pressure

3. Check pump pressure while system operating
4. Check pressure before and after filters

Off-takes/hydrants (linear moves and towable pivots)

5. Check hydrants are not leaking

Drag hose

6. Check there are no leaks
7. Check the hose is not misshapen

Pivot point

8. Check for leaks, movement

Riser and spans

9. Check inlet pressure gauge with alternative
    - Replace if necessary.
10. Check inlet pressure is correct

    NOTE: Hydrant must be in use to get valid pressure reading.

    NOTE: Check farthest and highest hydrant positions to ensure adequate pressure.
11. Check for leaks along spans and at towers
    - Check flanges: call service company if flanges leaking.

Towers

12. Observe motors, gear box and drive shaft operation for noise or vibration

Droppers

13. Check for leaks
    - Repair or replace as necessary.

Sprinklers

14. Check each sprinkler is turning correctly and cage not damaged
    - Repair or replace as necessary.
15. Check there are no leaks
    - Repair or replace as necessary.
16. Check the pressure above last sprinkler, above pressure regulator if fitted

NOTE:
This requires installation of a test point. A ¾" BSP Tee above the pressure regulator is usually suitable. Reduce to ¼" BSP for standard pressure gauge.

Gun

17. Check gun is operating correctly
18. Check gun angles are correct, gun switches direction at correct locations

Corner arm

19. Check arm tracks correctly
20. Check sprinklers turn on and off correctly

Control unit

21. Check any control unit is functioning correctly

2. Calibrating centre pivot irrigators

The Irrigation Calibration method for Centre Pivot irrigators assesses the amount of water being applied during an irrigation event. It is based on measurement water collected in a line of containers spaced across the path of travel. Applied Depth, Application Intensity and Distribution Uniformity are calculated.

This allows the manager to determine the speed required to apply the target depth, and whether the system is applying the same amount of water at all points along the machine. A plan to apply target depths can be determined.

2.1 What will the testing show?

The main things the calibration test will show are:

Applied depth
The 'rainfall equivalent' depth of water the irrigation system is applying on average at the particular travel speed. Compare the measured applied depth to target application to determine machine speed adjustment to correct applied depths.

Application intensity
The rate (mm/hour) at which water is being applied, equivalent to rainfall intensity. If intensity exceeds soil infiltration capacity, ponding, bypass flow, redistribution and runoff will reduce irrigation effectiveness and efficiency.

NOTE: The Application Intensity of Centre Pivot irrigators increases along the length of the machine. Rates are low (gentle) at the inner spans, increases to high (intense) at the end. This protocol calculates Application Intensity at the end tower, the highest rate but one representing a large proportion of the irrigated area.

Distribution uniformity DU
Distribution Uniformity describes the evenness with which water is applied. The higher the DU the better the system is performing. And the higher the uniformity, the more confident you can be that your measurements are truly representative of your system's performance.

Excess water use EWF
The excess water use factor identifies how much extra water is required during a set event because of non-uniformity.

Adjusted machine speed
Calculates the machine speed required to ensure 7/8ths of the area gets at least the Target Application Depth. It accounts for flow rate and uniformity.

WHEN SHOULD CALIBRATION BE DONE?

Complete the calibration test if commissioning a new machine and after any major changes.

Calibration should be repeated as part of system checks at the start of every season.

NOTE: Centre pivot irrigator irrigation depth is controlled by machine speed. Checking at 100% speed may give best results. If the machine stops for long periods it may affect bucket collected volumes.

NOTE: Centre pivot irrigator performance can be significantly affected by weather conditions. Consider wind conditions when testing: Calm conditions may give a better assessment of the system's potential performance but if wind is normal for the site, testing may proceed.

NOTE: The flow and uniformity of a centre pivot will not normally change much if adequate pressure is supplied. Check end sprinkler pressure:

- at different hydrant positions
- different field elevations or
- when alternative water-takes reduce system pressure.

2.2 Calibration process

Before starting, ensure System Operational Checks (Section 1) have been completed.

Calibration is a four step process:

1. Gathering information about the system
2. Calculating performance indicator values
3. Comparing results with expectations
4. Adjusting irrigation system settings as required to achieve intended performance.

GATHERING INFORMATION

Equipment

Equipment needs are very basic and most should already be available on the property. A suggested list includes:

- 24 containers of same known opening diameter (>150 mm)
  - 9 Litre buckets have been found suitable
  - 1 or 2 Litre for larger volumes (large collectors, higher application depths)
  - 100mL or 200mL for smaller volumes (small collectors, lower application depths)
- 1 tape measure (20m)
- 2 flags or fence standards
- 1 stop watch
- 1 pen or pencil
- 1 recording sheet.

Sampling method

The calibration check is based on a line of collectors (transects) placed across the travel path. It can be useful to repeat the test at different positions around the circle to check performance is consistent. Changing terrain or end-guns turning on and off can affect machine performance.

Testing layout

1. Set 24 collector buckets in a row along the length of the irrigator, starting a fifth of the way along the length of the irrigator
2. Arrange twelve collector buckets at even spacing from this point to two thirds of the irrigator length (see 1–12 in Figure 2.1).
3. Arrange ten more buckets at even spacing from two thirds of the irrigator length to the end wheels (see 13–22 in Figure 2.1). The spacing will be different to the first twelve buckets.
4. Arrange two buckets at even spacing between the end wheel track and the extent of significant wetting (see 23–24 in Figure 2.1).

   NOTE: The end section may be a part span or an end-gun or both. Avoid the very end where application drops quickly away.

Mark speed test positions

5. Place two marker flags along the line of travel, either side of the collector bucket transect
6. Record the distance between the flags

   NOTE: Put flags at least 5 m either side of the line of collector buckets near the machine end-tower.

   NOTE: Ensure marker flags are visible from outside the wetting area so they can be seen during testing.

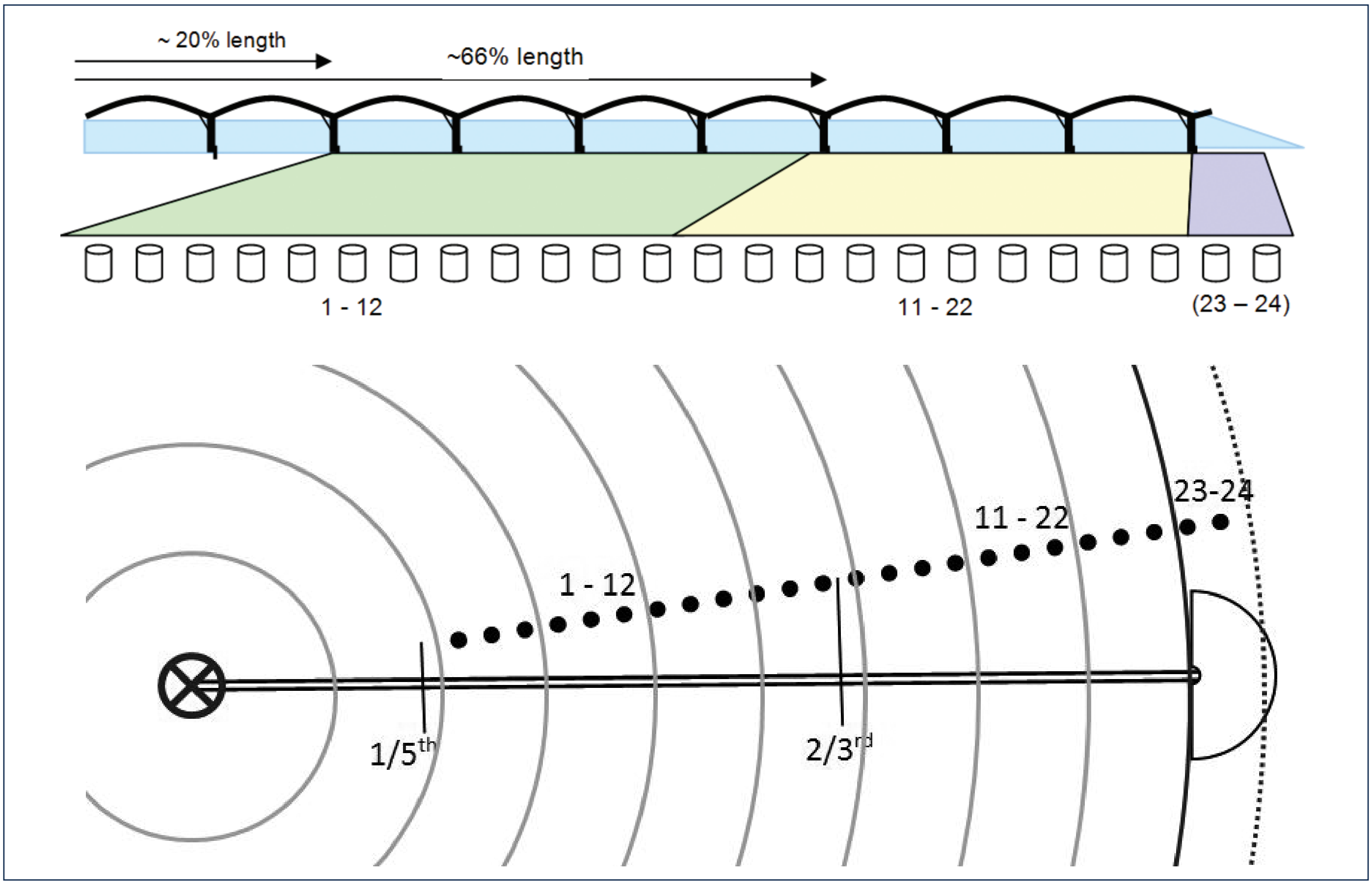

Figure 2.1. Layout of collectors along length of centre pivot irrigator.

FIELD MEASUREMENTS

Management information

1. Record the Target Irrigation Depth
2. Record the Irrigator Speed Setting
3. Record the number of Circles or Part Circles

System measurements

4. Measure the system Flow Rate
5. Measure the Outlet Pressure at the pump
6. Measure the Pressure at the Entry to the irrigator
7. Measure the Pressure the last tower

   NOTE: Take pressure measurement above any pressure regulator at the nozzle at the tower.

Application test

8. Record the time for the machine to pass between the speed test marker flags
9. Measure the collector bucket mouth diameter
10. Measure the volume of water caught in each container and record on the Record Sheet.

    NOTE: Take care to record each reading in the correct position.

CALCULATE PERFORMANCE INDICATOR VALUES

Irrigator speed

1. Speed (m/min) = Distance travelled ÷ Time taken
   - Distance travelled (m) = distance between marker flags
   - Time taken (min) = Time at second marker flag – Time at first marker flag

Applied depth

2. Calculate Average Applied Depth (mm) [Average Volume collected ÷ Collector opening area]
   - Average Volume Collected (mL) = Sum of all collected ÷ number of collectors
   - Collector opening area (m^2) = Pi x Collector diameter (m) x Collector diameter (m) ÷ 4
3. Calculate Applied Depth (mm) of twelve inner collected depths 1–12
4. Calculate Applied Depth (mm) of twelve outer collected depths 13–24
5. If present; Calculate Applied Depth (mm) of two collected depths under end span/end gun

Application intensity

6. Calculate Application Intensity at End Wheels (mm/h) [Applied Depth (mm) x Irrigator Speed at End Wheels (m/min) x 60 ÷ Wetting Pattern Width at End Wheels (m)]

System flow rate

7. Calculate Flow Rate (L/s) [(Machine Length + End Gun Extra Length) (m) x Applied Depth (mm) x Irrigator Speed (m/min) ÷ 60]

Distribution uniformity

8. Calculate the Distribution Uniformity DU [Low quarter average volume ÷ average volume]
   - Low Quarter Average Volume (mL) = Average of the lowest five collected volumes

Excess water use EWF

9. Calculate Excess Water Use Factor (%) [DU Adjusted Depth ÷ Applied Depth x 100]
   - DU Adjusted Depth (mm) = (Applied Depth ÷ DU) – Applied Depth.

COMPARE RESULTS WITH EXPECTATIONS

Flow rates

1. Compare calculated System Flow Rate with Water Meter Flow Rate

Applied depth

2. Calculate Target Depth to Applied Depth ratio
   = Target Depth ÷ Applied Depth
   a. < 1 – under applying
   b. = 1 – correct
   c. > 1 – over applying

   Acceptable variances: 0.90–1.10 (0.95–1.05 is better)

3. Compare Applied Depth with Soil Moisture Deficit
   - Applied Depth < Soil Moisture Deficit ÷ DU

Application intensity

4. Compare the calculated Application Intensity to expectations

Distribution uniformity DU

5. Interpret calculated DU value
   - DU > 0.90 Uniformity is very good
     the system is performing very well
   - 0.90 – 0.80 Uniformity is good
     performance better than average
   - 0.80 – 0.70 Uniformity is fair
     performance could be improved
   - 0.70 – 0.60 Uniformity is poor
     system should be investigated
   - DU < 0.60 Uniformity is unacceptable
     system must be investigated

ADJUST IRRIGATION SYSTEM SETTINGS

Check key performance indicators

1. If Applied Depth or Uniformity are unacceptable
   - Repeat Operational Checks
   - Ensure system is at recommended operating pressure
   - Get professional assistance.

Irrigator speed

2. Calculate Adjusted Speed (m/min)
   - Irrigator Speed x (Target Depth ÷ DU) ÷ Applied Depth.

   NOTE: Including DU ensures the irrigator applies sufficient extra water to adequately irrigate 7/8th plants.

3. Performance assessment of centre pivot irrigation machines

This schedule outlines procedures to be followed when assessing distribution uniformity of a centre pivot irrigation machine fitted with overlapping sprayers or sprinklers. It was developed to provide guidelines for irrigators and others undertaking evaluations of such equipment as a 'snapshot exercise' under prevailing field conditions.

The guidelines presented in this schedule are not intended for evaluations of centre pivots without overlapping sprinklers, such as the LEPA system which is not used in New Zealand.

NOTE:
Complete Operational Checks (See Section 1) before commencing a system evaluation.

TECHNICAL MATERIALS – RELEVANT STANDARDS

ANSI/ASAE S436.1 DEC01 Test procedure for determining the uniformity of water distribution of center pivot and lateral move irrigation machines equipped with spray or sprinkler nozzles (ANSI)

ISO 11545: 2001 Agricultural irrigation equipment – Centre-pivot and moving lateral irrigation machines with sprayer or sprinkler nozzles – Determination of uniformity of water distribution (ISO)

ISO 8224/1 – 1985 Traveller irrigation machines – Part 1: Laboratory and field test methods

ISO 7749-2: 1990 Irrigation equipment – Rotating sprinklers – Part 2: Uniformity of distribution and test methods

TECHNICAL REFERENCES

Allen, R.G., J. Keller and D. Martin. 2000. *Center Pivot System Design*. The Irrigation Association. Falls Church, VA. (CPD)

3.1 Data collection

This schedule outlines procedures to be followed when assessing performance of centre pivot irrigation machines under prevailing field conditions.

Because test conditions will vary, key conditions must be measured and recorded to assist any comparisons between subsequent tests of the same machine, or when benchmarking against other systems.

NOTE:
To provide a farmer with general operation/management information, test conditions should be representative of those experienced in normal operation.

NOTE:
For System Commissioning or fulfilling specific purchase contract criteria, adherence to test condition limitations such as wind speed should be ensured.

TEST SITE

Location
Select a test location that is most representative of the system as a whole.

If the irrigation site is not level, conduct the test in an area having elevation differences that are within the design specifications of the sprinkler package.

Site variability
If site elevation varies significantly, consider multiple tests to increase accuracy of distribution uniformity assessments. This may involve several radial uniformity tests in different parts of the field.

NOTE:
Some protocols recommend a "Circular Uniformity Test" performed by arranging a circle of collectors around the pivot. This protocol instead recommends multiple lateral uniformity tests if performance at different positions is suspect. Check pressure is adequate in all machine positions and monitor machine speed.

SYSTEM SURVEY

System layout

1. Prepare a map of the system recording the headworks, mainline, pivot centre and position of test

Topography

2. Determine elevation differences between test sites and across the station as a whole.
   - Prepare a sketch of the profile along a typical lateral.

Machine length

3. Measure the machine length and the length of each span, measuring between towers

Un-irrigated length

4. Determine the length of any sections of the machine excluded from irrigation

End gun wetted radius

5. Determine the effective wetted radius of any end gun (or guns) fitted to the machine

Effective radius (R_E)

6. Measure the effective radius from pivot centre (Figure 2.1 Layout of collectors along length of centre pivot irrigator)

Corner system wetted radius

7. Determine the effective wetted radius at full extension of any corner system fitted to the machine. Determine where it may be operative.

Off-target application (F_{TARGET})

8. Estimate the proportion of discharge that falls outside the target area (off the ends of the sprayline or sides of the field as a whole).

SYSTEM OPERATION

Water quality

The water used for the test should be the same as that normally used for irrigation unmodified for the purpose of the test by any additional filtration, injection of chemicals or other processes unless specifically requested by the client.

NOTE:
For personal health and safety reasons, particular caution is necessary if water contains chemical treatments or biological wastes.

System pressure

1. Complete the test at normal operating pressure or as agreed by client and tester
   - Ensure the pressure is maintained during the test
   - Ensure the system is not affected by other significant system draw-offs such as other irrigation machines or dairy sheds
   - Ensure pressure measurements include lowest and highest areas.

Machine speed

2. Operate the centre pivot machine as near to 100% speed while ensuring a reasonable average application depth for accurate collector volume measurements
   - Minimise the effect of stop-start effects on distribution patterns
   - Apply sufficient volume for reliable measurements to be obtained
     (ISO recommend 15mm).

End gun

3. If the sprinkler package is designed with an end-gun, perform the test with the end gun operating. The number of sprinklers or sprayers operating should remain constant during the test
4. If desired the test may also be performed with the end gun not operating in order to evaluate the water distribution under those conditions

Corner system wetted radius

5. If desired the test may also be performed with the corner system (not) operating in order to evaluate the water distribution under those conditions

Field variability

6. If field elevation varies significantly, consider multiple radial uniformity tests.

ENVIRONMENTAL MEASUREMENTS

Wind

1. Record the direction and speed of the wind during the test period, and plot against relevant test locations on a map
   - Wind speed and direction relative to the sprayline should be monitored at intervals of not more than 15 minutes and recorded
   - Wind conditions at the time of the test should be representative of those experienced in normal operation
   - Wind speeds greater than 3m/s can have significant effects on uniformity.

NOTE:
At speeds greater than 3m/s the tester and client must understand the limitations of the test results. The uniformity test should not be used as a valid measure of the sprinkler package if the mean wind velocity exceeds 3m/s.

Evaporation

By preference, the uniformity test should be conducted during periods that minimise the effect of evaporation, such as at night or early morning or in winter months.

2. Record the time of day, estimated or measured temperature and humidity when the test is conducted
3. Record the temperature and humidity in the test zone during the test period
4. Determine evaporation rates using evaporation collectors identical to those used in uniformity testing
   - Place a control collector in a representative location upwind of the test area
   - Adjust readings for evaporation loss, following the procedures outlined inn the *Technical Glossary.*

Topography

If the field is not level, conduct the test in an area having elevation differences that are within the design specifications of the sprinkler package.

5. Measure the elevation difference and prepare a sketch of the ground surface profile along and across the test position
   - Record elevation at each tower.

FIELD OBSERVATIONS

Crop type

1. Record the site's planting history for previous season and year
2. Note crops planted in the area under examination, and stage of growth

Crop appearance

3. Observe the crop for signs of stress or growth difference. Patchiness is indicative of poor system performance
4. Measure or estimate the crop ground cover proportion

Soils

5. Dig or auger several holes within the irrigated area
6. Determine the soil texture and depth of rooting
7. Estimate or otherwise determine soil infiltration rate and soil water holding capacity
8. Assess the depth of water penetration
9. Note any soil features that indicate wetness, poor drainage or related properties and identify causes

Wheel ruts

10. Assess the presence and degree of wheel rutting in tower tracks. Note if water is running down wheel tracks
11. Note if 'boom backs' are used or if directional sprayers are installed either side of the tower

Ponding

12. Assess the amount of ponding particularly toward the end of the pivot where application intensity is highest
13. Note if water is ponding, running over the ground, or causing soil movement.
14. Estimate the percentage of water lost

Runoff

15. Assess the amount of runoff from the irrigated area as a result of irrigation. Only consider volumes leaving the irrigated area.

SYSTEM CHECKS

Water supply

1. Complete checks of the water supply including pumping system and mainline as specified in *Part B: Compliance and Water Supply Checklists*

Filtration

2. Check filters and note nature and degree of contamination or blockage
3. Identify when the filter was last checked or cleaned.
4. Identify if automatic cleaning or back-flushing is fitted and operational
5. Check for presence of contaminants in lines: sand, bacteria/algae, precipitates etc

System leakages

6. Visually check (as possible) headworks, mainline and the distribution system to identify any leakages or other losses from the system
7. Assess scale of leakages if any

Sprinklers

8. Record the nozzle type and orifice(s) fitted
    - Verify that the sprinkler package matches the design specifications.
9. Measure sprinkler spacing along the sprayline
10. Measure sprinkler height above canopy
11. Check sprinklers are operating and set correctly (to horizontal)
12. Randomly select at least 12 sprinklers along the length of the machine
    - Inspect them for blockages and record the cause of any blockages found
    - Assess orifice wear with a gauge tool or drill bit.

Pressure regulators

13. Randomly select several pressure regulators along the length of the machine and assess for cause and degree of blockages
    - This may require dismantling the units.

Normal speed (S_N)

14. Determine the typical time required to make one full-circle pass during periods of peak water use
    - This may be from farmer information or design specifications.

Test speed (S_T)

15. Measure the machine speed at 2/3rds effective radius – the centre point for mass discharge of the machine
    - This greatly simplifies comparisons between total machine flow and measured application depths from uniformity measurements.
16. Measure the machine test speed at the end tower
    - Time how long it takes the machine to pass over the test track, and all intermediate start and stop times.

SYSTEM FLOW

Total system flow

1. Record the water flow rate as measured by a fitted water meter with the system operating as normal
    - Wait until flow rates stabilise (up to 15 minutes) before taking readings
    - It may be necessary to take beginning and ending meter readings over a set time period to determine flow rate
    - Record flow with end gun operating and not operating.

Energy use

2. Obtain energy consumption data for the period covered by flow measurement
    - Enables calculation of irrigation energy costs.

SYSTEM PRESSURE

Headworks pressures

1. Measure pump discharge pressure
2. Measure mainline pressure after filters and control valves

Optionally measure:

3. Filter head loss
4. Pump control valve head loss
5. Throttled manual valve head loss

Pivot lateral pressure

6. Measure lateral pressures upstream of any sprinkler pressure regulators:
    - At the first available pressure test point or outlet downstream of the elbow or tee at the top of the inlet structure
    - At the last outlet or end of the pipeline. If an end-gun with booster pump is fitted, ensure the pressure reading is taken upstream of the pump
    - If pressure is read at a sprinkler, use a pressure gauge with a pitot attachment. Depending on sprinkler design, this may require dismantling the units
    - Lateral pressures cannot be inferred from readings at the sprinkler if pressure regulators are installed.

Sprinkler pressure (pressure regulator function)

7. Measure pressures of eight sprinklers using a pitot tube or in-line gauge downstream of any pressure regulator
   - First sprinkler
   - Last sprinkler (before end-gun)
   - Highest sprinkler
   - Lowest sprinkler
   - Four other sprinklers randomly along the lateral.

NOTE: This may require dismantling of the sprinkler unit to fit a temporary test point, or for access to the nozzle jet-stream.

SPRINKLER PERFORMANCE

For a centre pivot, the only direct measurement of uniformity that conforms to international conventions for uniformity testing comes from catch can collectors. The wide variety of sprinkler spacings and flow rates used in pivots (and linears) require more detailed direct testing and analysis to determine they are functioning correctly. That can be time consuming and expensive but could be a useful supplement to uniformity measurement.

Radial uniformity test

The radial uniformity test is of primary importance as it establishes variation along the length of the pivot lateral. Performance is dependent on sprinkler package design and installation, field elevation and wind or other disturbances.

The easiest location for this test is along the pivot access track, provided that area is representative of the field.

Collector placement

1. Arrange two rows of collectors either side of a radial line starting 20% of the way along the machine
   - The inner span represents a small proportion of irrigated area and flow rates are very low.

NOTE: Machines < 450m effective length:
Use a total of 80 collectors staggered to ensure the spacing between cans does not match sprinkler spacing. Arrange 40 collectors spaced up to 10m apart in each row.

NOTE: Machines > 450m effective length:
Increase the number of collectors proportionally so mean collector spacing is about 5m.

NOTE:
If an end-gun is used, the rows of collectors should be extended to just inside the wetted radius.

NOTE:
Position collectors ahead of the irrigator, at a distance more than the wetting radius of the sprinklers so the machine is operating normally when the first water reaches the collectors.

NOTE:
Do not place collectors in wheel tracks

2. Measure and record the position of each collector relative to the pivot centre
   - Rows should be 3m apart at the inner-most collector (Figure 2.1).

Wetted radius

3. Determine the average wetted width of the sprayline (sprinkler wetted radius) to the nearest 10cm in at least three locations.

Water collection

NOTE:
Collection and measurement can begin at the outer collector in the first wetted row, then progress in to the centre and back out again. This allows collection to begin as soon as possible, and while the last collector in the second row is still being wetted.

OPTIONAL TESTS

Circular uniformity test

The Circular Uniformity test recommendation is not recommended in these protocols. Much variability will be due to radial (along the pivot length) variation rather than around the circle. Effort is better used checking machine speed and pressure or repeating radial uniformity tests at different positions in the field.

Travel speed and pressure tests

Monitoring machine travel speeds and sprinkler pressures can provide useful information about machine performance and variability.

If the machine has sprinkler pressure regulators fitted and pressure is sufficient at all locations, flows should remain uniform. If travel speeds are also uniform around the circle, distribution uniformity should be constant unless sprinkler heights vary due to undulating topography.

Repeat tests

Repeat tests to determine distribution uniformity with and without the end-gun operating, or with the pivot lateral in a different field location or locations. In particular, consider up slope regions where machine pressures may be reduced.

If sprinkler heights or system pressures vary, additional radial uniformity tests will give most reliable uniformity assessments.

3.2 Data analysis

SYSTEM

Irrigated area

1. Calculate the irrigated area of the machine
   - For Full Circle machine
     Irrigated Area = Pi x Machine Length (radius)^2
   - For part Circle machine
     Irrigated Area = Pi x Machine Length (radius)^2 x (angle irrigated / 360)
   - For Circle machine with unirrigated centre zone
     Irrigated Area = Pi x Machine Length (radius)^2 – Pi x Unirrigated Inner Length^2.
2. Calculate the total area irrigated (Towable machines)
   - Total Area = Sum of individual irrigated areas.

PERFORMANCE INDICATORS

Water supply

1. Complete calculations of water supply including pumping system and mainline as specified in *Part B: Compliance and Water Supply Checklists*

Application depth

NOTE:
To make valid assessments of pivot performance, the depths measured by collectors must be weighted according to distance from the pivot centre. This accounts for the greater field area represented by collectors more distant from the pivot centre.

NOTE:
Make adjustments to account for evaporation losses.

2. Calculate Distance Adjusted Applied Volume (V_a)
3. Calculate Distance Adjusted Applied Depth (AD_{DAdj})
4. Determine the minimum and maximum distance adjusted application depths

Total machine flow application depth

5. Calculate application depth based on total machine flow, event duration and irrigated area

Application intensity

Application Intensity varies along the length of a centre pivot machine, as speeds are higher at greater radii.

6. Calculate Instantaneous Application Intensity at 2/3rd effective radius
7. Calculate Instantaneous Application Intensity at the end of the pivot
8. Calculate Instantaneous Application Intensity at the end of the effective radius if using a gun or corner arm

NOTE:
The average application rate occurs at approximately 2/3rd the full radius. Half the total machine flow is discharged in the first 2/3rd and the remainder in the outer 1/3rd.

9. Compare Application Intensities to Soil Infiltration Rate
   - Report as a percentage
   - Application Intensity should be less than Soil Infiltration Rate
   - Compare with observations of surface ponding.

DISTRIBUTION UNIFORMITY

System uniformity

Distribution uniformity is determined using the low quarter distribution uniformity coefficient, DU_{lq}.

NOTE:
Because the lowest quarter relates to a proportion of total field area, calculations must be made to determine which collectors are representing the lowest quarter.

NOTE:
Determining global 'field uniformity' requires adjustments to account for contributing factors, including distribution pattern, off-target application and run-off.

Radial uniformity coefficient, CU_R

1. Calculate the Uniformity Coefficient using the Heermann and Hein modified formula
   - This adjusts for the relative area represented by each collector.

Radial distribution uniformity, $R_{AD}DU_{LQ}$

2. Determine radial low quarter distribution uniformity from evaporation adjusted collector depths using the Distance adjusted DU_{lq}

Field distribution uniformity, FDU_{LQ}

3. Estimate overall field distribution uniformity (FDU_{lq}).

NOTE:
If system pressure is adequate at all points, and machine speed is uniform, the radial DU value will suffice.

NOTE:
If multiple radial test uniformities are included, all depths must be pooled, and a new uniformity calculation performed with the pooled data.

PRESSURE VARIATION

Mainline pressures

For towable centre pivots:

1. Calculate the percentage pressure variation between hydrants

Lateral pressure loss

2. 2. Calculate lateral pressure loss HL
   - HL = $P_{first} - P_{last}$
   - P_{first} is the pressure before the first sprinkler and P_{last} is the pressure before the last sprinkler (excluding the end-gun)

NOTE:
As a general rule, total friction loss in the pivot lateral of a 400m system on flat to moderately sloping ground should not exceed 70kPa

3. Check minimum pipeline pressure is at least 20kPa higher than the pressure regulator setting.

Pressure regulators

Pressure regulators have performance variability of about 6%. They are only recommended where pressure changes due to changes in elevation, end-gun operation or pumping lift exceed regulator variability by an amount that varies with design pressure.

In general terms, regulators are recommended if design pressure (P_d) is less than pressure variation due to elevation, pumping or end-gun operation (P_v) as given by the equation:

Fit regulators if: $P_d < (3.5\ P_v) + 3.5$

Sprinkler pressures

4. Determine mean pressure from measurements
5. Identify any sprinklers where pressure is more than 10% different to the mean pressure.

3.3 Adjust irrigation system settings

APPLIED DEPTH

1. Compare Mean Set Applied Depths to Target Depth
   - Adjust set run time to achieve target applied depth

Adjusted machine speed

2. Calculate Adjusted Machine Speed
   - Adjusted Machine Speed (m/h) = Machine Test Speed (m/h) x (Target Depth / Distance Adjusted Applied Depth) ÷ DU_{lq}

   NOTE: Including DU_{lq} ensures the Run Time applies sufficient water to adequately irrigate 7/8th plants.

Distribution uniformity

3. Identify impact of variables contributing to non-uniformity
   - Repeat Operational Checks (Section 1)
   - Adjust system components to achieve best performance
   - Ensure system is at recommended operating pressure
   - Get professional assistance.

Appendices

PART H: Pivot

Appendix 1: Centre pivot case study

A centre pivot was tested as part of system commissioning and found to have lower than expected performance. The primary causes were incorrect system pressure and nozzle selection at the machine towers. The problems were increased by field topography. Additional problems were indicated. Correcting the pressure will improve performance. Replacing half-circle nozzles at towers would enable very high uniformity to be achieved.

SYSTEM INFORMATION

The towable centre pivot irrigator operates over two river terraces 25m above the river. Water is pumped from a river bed gallery to the pivot via a variable speed drive pump. A steep terrace scarp intersects the circle. The lowest part of the 60ha irrigated area is 5m below the pivot centre and the highest 10m above.

The 407m, 8 span machine is fitted with 24 pressure regulated spinner sprinklers per span and an end gun giving an overall effective length of 430m.

The machine has closely spaced sprinklers set at 2m above flat ground. While crossing the terrace edge the sprinklers were much lower, including one area where they dragged on the ground. Pressure regulators set pressure to 70kPa. Directional sprinklers either side of each tower keep water of the wheel tracks.

Machine speed, pump performance, sprinkler performance, catch-can and system pressure measurements were taken while the machine was irrigating a sector including the top terrace.

METHODOLOGY

The test was undertaken with the machine in the highest section of the irrigated area. This is the most severe test, where pressure is most likely to be limiting.

Catch cans were laid out in two radial rows as specified in the Evaluation section of the Performance Assessment Code. The rows started after the first tower and extended to the edge of the area wetted by the end-gun.

The machine was run across the catch cans at 75% of full speed and the speed measured. The volume of water collected was measured and the applied depth determined. Pressure was measured above the pressure regulators before the last tower, away from interference by the end-gun pump.

RESULT SUMMARY

For testing, the machine was operated at 75% speed which would enable it to complete one revolution in 10.7 hours. With a rapid shift, this would just enable two circles to be irrigated per day.

The end-gun was not reaching the boundary fence that had been erected around the circle.

Table 1

Indicator	Actual	Recommended
Water meter flow	78.3L/s	
Pump discharge pressure	1,180kPa	
Pressure at the pivot centre	200kPa	
Pressure at pivot end sprinkler	75kPa	110kPa+
Target Depth		6.0mm
Measured Depth	4.7mm	
Distribution Uniformity	0.75	0.85+
Christiansen Uniformity	0.84	0.90+
Application Intensity 2/3rd radius	100mm/h	<70mm/h
Application Intensity end tower	126mm/h	<70mm/h

APPLICATION DATA

System pressure readings showed the Variable Speed Drive had been set low to save energy costs, but too low for correct pressure regulator function. Pressure above the regulator should typically be 40kPa higher than the regulated pressure to ensure correct functioning.

The mean applied depth along the machine was 4.7mm, with a range of 1.8mm to 7.2mm. This was less than the 6mm target depth.

The Low quartile Distribution Uniformity (DU_{lq}) was 0.72 which is poor for a centre pivot.

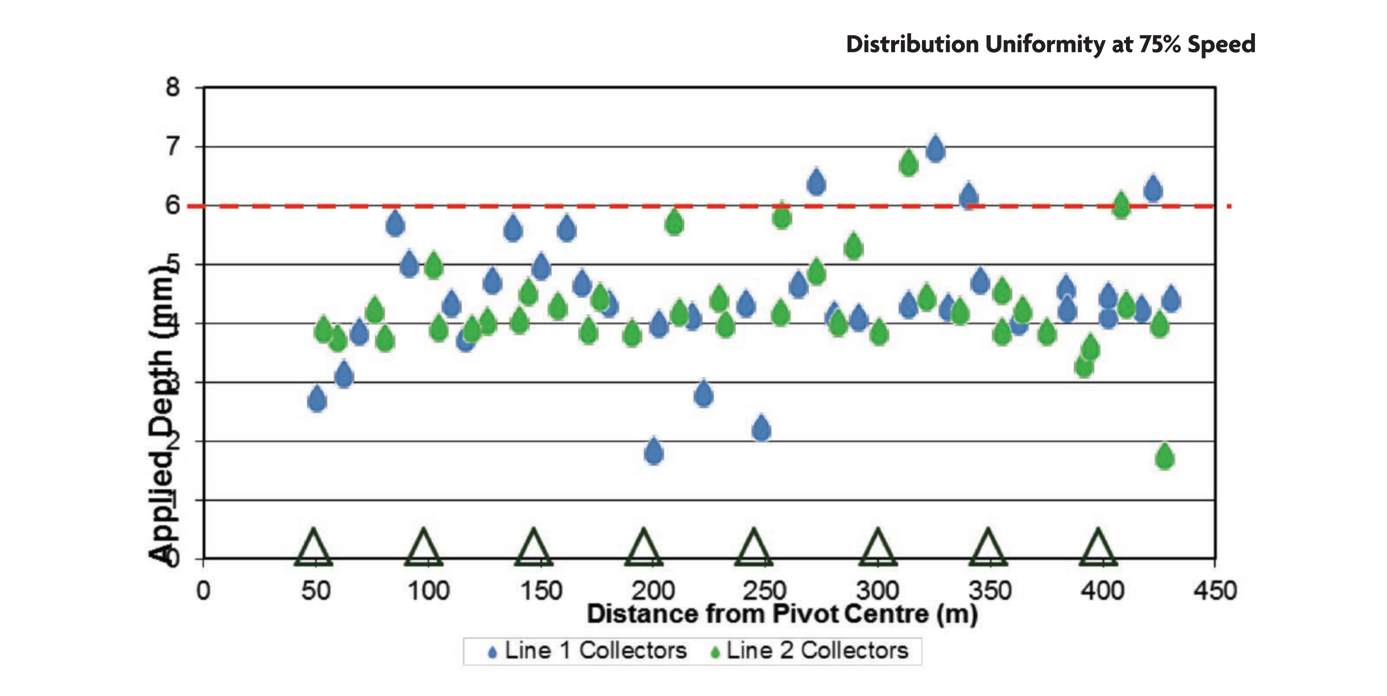

Figure 1. The recorded Irrigation Applied Depths along Centre Pivot starting from the centre (0) moving outwards. The elevation of each tower is also shown with the triangles. Red line denotes target depth.

The major reason for poor performance is sprinkler choice. The data collected from catch cans indicate an issue at the towers (Figure 1) which is where fixed half-circle sprays are fitted. When data from all spans are overlaid and graphed the effect of this is clearly seen (Figure 2).

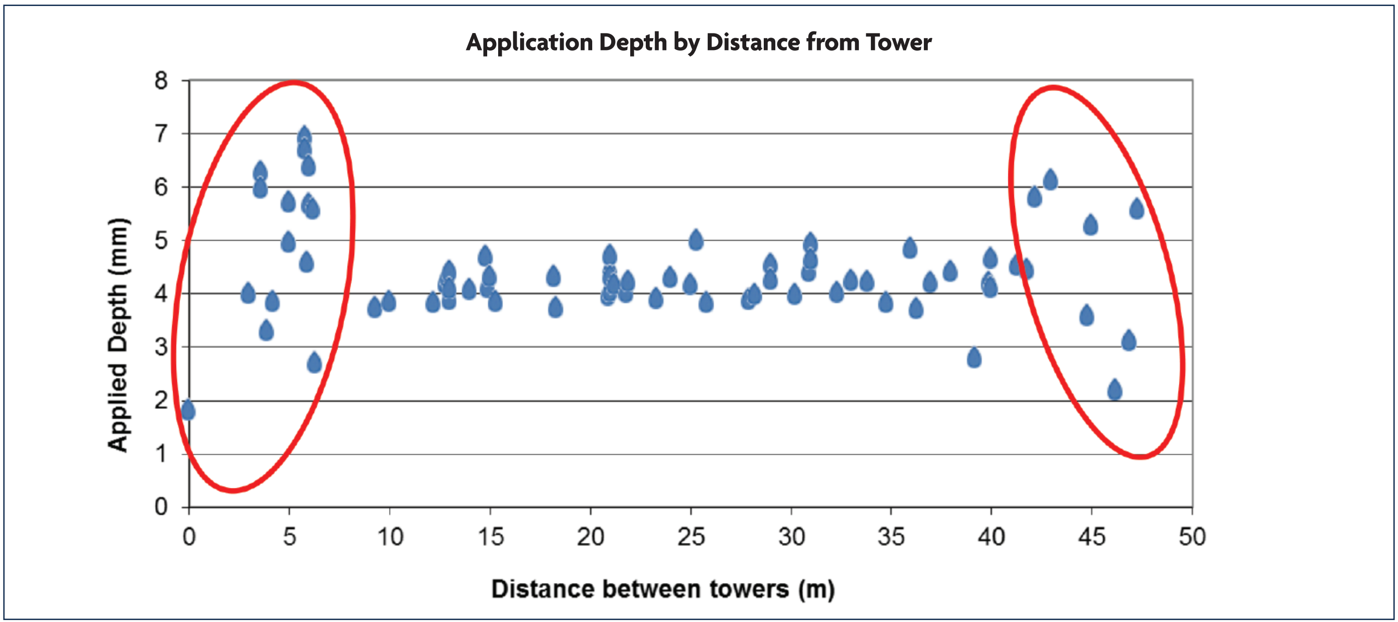

Figure 2. Application depth with all spans overlaid – catch can measurements relative to distance from towers.

Figure 2 shows that in the mid-section of the pivot spans the applied depth is very uniform (DU_{lq} = 0.96). However there is wide spread at the towers as indicated by the red rings in Figure 2. Investigation showed this was caused by half circle sprays directing water away from the wheel tracks shown in Figure 3.

Figure 3. Half-circle sprays direct water away from pivot tower.

The use of half-circle sprays did keep water off the tracks but also created a band almost 7m wide at every tower where irrigation was under-applied (the red zone in Figure 3). Outside that was an area where excessive application was made (the blue zone in Figure 3). Altogether along the total length of the pivot, the half-circle sprays left almost a quarter of the area incorrectly irrigated.

OTHER ISSUES TO MONITOR

Ponding and run-off

The Irrigation Design Code of Practice recommends maximum Application Intensities on sandy loam soils of 20mm/hour (slope 0–8˚), 17mm/hour (slope 9–12.5˚) and 13mm/hour (slope over 12.5˚). While some of the irrigated area is within the 0–8˚ limit, some is significantly greater.

Because a drier soil can accept water somewhat faster, application intensities can be about three times the stated intensity. While on flat areas, this machine may be able to apply at about 70mm/hour with minimal ponding and run-off. The steeper areas should still be kept below about 40mm/hour to avoid losses.

The application intensity of the machine is very high (100mm/h at 2/3rd radius) so ponding and run-off can be assumed particularly on sloping areas. At the end of the machine this problem is even greater.

Machine wear

The machine is operating on steep terrain with harsh angles at tower pipe joints. The wheels were observed to slip on steeper sections, leaving gearboxes subject to heavy loads. Strategic ground contouring can lessen these problems.

Figure 4. Very steep areas exacerbate surface run-off and apply high loads to machine components including gearboxes.

Sprinkler damage

Some sprinklers were damaged even though the machine was very new. They main cause was from being dragged along the ground as the spans passed over the terrace edge (Figure 5).

Figure 5.

RECOMMENDATIONS

Pressure

The pumping pressure was increased after a first test. This ensured pressure regulators would have satisfactory intake pressure along the machine to the end sprinklers.

Sprinkler selection

The rotators fitted along the machine performed very well. The half-circle sprays fitted at the towers caused major problems and should be replaced.

Replacing the half-circle sprays with standard spinners or rotators would give greatly improved application uniformity and increased irrigation effectiveness and efficiency. Water running down the towers into wheel tracks should not be excessive. A cautionary alternative would fit spinners to boom-backs so the machine has passed over the track before water is applied.

An interim measure would be turning the half-circle sprays to about 45° so they apply water after the wheels have passed. This would more evenly to the strips either side of the tower.

Ground shaping

Ground shaping areas to mediate grade where the towers climb very steeply would reduce the load on gearboxes and other structural parts. This would prevent early failure. Correctly designed, this would also elevate the mid-span sections so the sprinklers were off the ground, avoiding damage and improving application uniformity.

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New Zealand Piped Irrigation System Performance Assessment Code of Practice

PART I: Conducting Energy Efficiency Assessments and Seasonal Irrigation Efficiency

Note: This is Part I of a series of nine (Parts A–I).

Part I: Contents

Date of Issue: January 2023

The Code is presented as a series of booklets, each with a defined purpose.

Part A: An Introduction to Performance Assessment
Part A provides an overview of performance assessment, explains the broad philosophy behind assessment approaches taken throughout the Performance Assessment series, and contains specific formulae and reporting standards.

Part B: Compliance and Water Supply Checklists
Part B relates to all system types. It contains recommendations for checks to ensure compliance with regulations, rules and consent conditions, safe effective operation of water supply systems.

Parts C–H: System Performance Assessments
Parts C–H contain guidelines and recommendations for Operational Checks, System Calibrations and In-field Performance Assessments specific to a range of irrigation system types.

Part I: Conducting Energy Efficiency Assessments and Seasonal Irrigation Efficiency
(This booklet)

IrrigationNZ Technical Glossary
The Glossary and Calculations are common with the NZPIS Design Code of Practice.

Ministry for Primary Industries
Manatū Ahu Matua

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1. Conducting energy efficiency assessments

This section provides protocols for assessing energy efficiency in irrigation systems. They are intended to be used by irrigation managers and operators to check that energy use and loss are within expected boundaries.

The two largest areas of energy consumption in irrigation are pressurising and moving water by pumping, and losing energy through hydraulic friction. Therefore two related protocols are presented:

1.1 Assessing pump efficiency

1.2 Assessing delivery system efficiency

These protocols are suited to relatively simple systems. Complex multi-pump systems or ring main systems often require a detailed engineering analysis undertaken by experienced engineers with specialised software.

1.1 Assessing pump efficiency

The purpose of Pump Efficiency Test is to determine the energy efficiency of the motor and pump combination feeding the irrigation system.

The test is designed so irrigation managers can do measurement and calculations themselves. Supporting guidelines and worksheets are in the Appendices. Calculation software is available from IrrigationNZ. If findings are unexpected, or suggest low performance, consider getting professional advice.

A full or complex pump performance test must be performed by a trained service provider with appropriate testing equipment.

Why check pump efficiency?

Incorrectly sized or physically deteriorated pumps will waste energy and money. Efficient pumping minimises energy use and carbon emissions.

Pump and motor selection are important system design considerations. Incorrectly sized pumps and/or motors will not operate at their most efficient points. So they will waste energy.

The pump must provide adequate pressure and flow to ensure the system operates as designed. Low pressure is a common cause of poor irrigation uniformity which reduces overall system effectiveness and efficiency.

Excessive pressure affects performance and wastes energy. Pump selection will usually allow about 5% extra pressure capacity to allow for slippage with time. But excessively oversized pumps waste considerable amounts of energy.

The presence of deliberate pressure reducing components or partially closed valves at the headworks indicates a need for careful assessment.

What will the testing show?

The main things the calibration test will show are:

- **Energy consumed**
  The kWh of electricity or diesel energy used to run the system; hourly and annually.
- **Pump efficiency**
  How much of the energy consumed (and paid for) is used to do useful 'work' driving the irrigation system.
- **Pump performance**
  How well the pump compares with typical values for that type and size of equipment.
- **Annual energy cost and savings**
  How much energy and money would be saved if the pump was operating at typical performance levels.

When should testing be done?

Complete the efficiency test when commissioning a new system and after any major changes to the pump or irrigation system.

The system operation should be 'typical' when the test is performed to ensure results are meaningful. If system flow or pressure changes when different parts of the irrigation system are operating, Delivery Efficiency will change.

Testing should be repeated as part of system checks at the start of every season. Compare with past results to identify slippage or failures.

What are the test's limitations?

The irrigation pump efficiency test will only provide information for the conditions measured, running at a given flow and pressure with a given depth to water. The energy use and efficiency will change if system pressure or flow changes or if the water table moves up or down.

The efficiency value determined is for the motor and pump combination. It is not easy to separate the individual performance of the motor or the pump. By looking at typical values, some indication is possible.

Results that show low efficiency indicate a need for detailed professional analysis.

ENERGY EFFICIENCY ASSESSMENT PROCESS

To assess pump efficiency, measured flow rates are combined with energy consumption information. This allows calculation of the energy efficiency of the motor and pump combination, operating as tested.

The process should be repeated if there are significantly different operating conditions, essentially varying system flow and/or required pressure.

NOTE:
Using this method, the intake pipe efficiency is included as part of the overall pump efficiency calculated.

NOTE:
In multiple pump systems, it can be possible to analyse each pump separately if pressures between pumps can be measured.

What needs to be done?

1. Gather information about the system
2. Calculate performance indicator values
3. Compare results with expected values
4. Determine if changes are justified.

GATHERING INFORMATION

The effective efficiency of a pump and motor combination can be estimated from power readings, flow rates and pressures. The information should be easy to obtain, and calculations needed are set out below.

NOTE:
Endeavour to record energy consumption and water use at the same time to ensure they are closely related.

NOTE:
Field recording sheets to assist are provided in the Appendices.

Equipment

Equipment needs are very basic and most should already be available on the property. A suggested list includes:

- 1 stop watch
- 1 pen or pencil
- 1 recording sheet
- 1 measuring jug (for fuel tank topping)
- pressure gauge(s) – rating depends on system pressures
- vacuum gauge(s) – rating depends on system pressures
- way to determine elevation difference between water level and pump outlet.

FIELD MEASUREMENTS

System measurements

1. Record motor details including power rating
2. Determine the mean energy cost of electricity and fuel
3. Determine the typical pump operating hours per year
4. Determine the change in elevation between the water surface (when pumping) and the centre of the pump outlet

NOTE:
This may require survey equipment and/or a method to measure water level in a bore or well

NOTE:
Information may be available from other sources such as design or construction information

Measure energy use

5. Determine the rate of energy use in kilowatts (kW)
   - *For electric pumps*
     - Run the system and record the duration
     - Record the power meter reading at start
     - Record the power meter reading at finish
     - Record any "multiplier" factor value.
   - *For fuel pumps*
     - Fill the tank to the lip if possible
     - Run the system and record the duration
     - Measure volume of fuel required to refill tank
     - Record volume consumed.

Measure water consumption

6. Determine system flow rate (m^3/h)

   NOTE: If a correctly calibrated water meter is fitted to the system, record and calculate water use.

   NOTE: If necessary:

   - Record the water meter reading (m^3) at start
   - Record any "multiplier" factor value
   - Run for a defined period consistent with electricity or fuel use recording
   - Record the duration
   - Record the water meter reading again (m^3) at finish
   - Record volume pumped.

   NOTE: If no meter is fitted, determine flow rate from field measurements by doing an irrigation calibration.

Measure system pressures

NOTE:
Ensure pressure gauges are in good condition

7. Measure water intake pressure (kPa)
8. Measure pump inlet pressure (kPa) (record a suction as negative pressure)
9. Measure the pump outlet pressure (kPa).

NOTE:
The water intake is usually not pressured. (Water depth above intakes or submerged pumps is included as the water surface level to the pump difference for Elevation Head.)

NOTE:
If there is positive head on the intake from a primary pump, subtract that pressure to get the increase in pressure generated by the pump being tested.

CALCULATE PERFORMANCE INDICATOR VALUES

Energy consumed

1. Calculate Pump Efficiency (%)
   = Work Done (kW) ÷ Total Power (kW) x 100
2. Calculate Total Power = Sum of all power used
3. Calculate Total Energy Cost = Sum of all energy costs.

NOTE:
Whether the pump runs on electricity or fuel or both, the kilowatt consumption must be calculated.

NOTE:
If there is more than one pump, add the energy use rates to get a total. Calculate energy use rate in the same units (kW) for both electric and diesel.

For electric pumps
Electricity meters show energy consumption in kilowatt hours (kWh) – the combination of energy use rate (kW) and time (hours).

4. Calculate Power (kW) = Energy Use Rate = Energy Used (kWh) ÷ Test Duration (h)
   - Energy Used (kWh) = Meter Difference (kWh) x Meter Multiplier Factor (fM)
   - Meter Difference = Meter reading (kWh) at end – Meter reading (kWh) at start
5. Calculate Annual Energy Use (kWh/year) = Use Rate x Annual Operating Time
6. Calculate Annual Energy Cost ($/year) = Annual Energy Use (kWh/year) x Energy Cost ($/kWh)

For fuel pumps
Convert fuel energy to kWh equivalent values.

7. Calculate Power (kW) = Energy Use Rate = Energy Used (kWh) ÷ Test Duration (h)
   - Energy Used (kWh) = Fuel Consumed (L) x Fuel Energy Factor (fFE)

   NOTE: Multiply fuel used by relevant factor from Table 1.1 (Lh x kWhL = kW)
8. Calculate Annual Energy Use (kWh/year) = Use Rate x Annual Operating Time
9. Calculate Annual Energy Cost ($/year) = Annual Fuel Use (L/year) x Fuel Cost ($/L)
   - Annual Fuel Use (L/year) = Fuel Use Rate (L) x Annual Operating Time
   - Fuel Use Rate (L/h) = Fuel Consumed (L) ÷ Test Duration (h)

Work done

10. Calculate Work Done (kW) = Total Dynamic Head (kPa) x Water Flow Rate (m^3/h)
    - Total Dynamic Head (kPa) = Elevation Head + Pressure Head + Inlet Friction Head
    - Elevation Head (kPa) = Elevation Change (m) x Specific Gravity (~ 9.8)
    - Pressure Head (kPa) = Pump Outlet Pressure (kPa) – System Intake Pressure (kPa)
    - Inlet-side Friction Head (kPa) = Inlet-side Pressure Loss

NOTE:
Inlet-side Pressure Loss may be determined using the Delivery Efficiency Assessment protocols.

NOTE:
Elevation head refers to the lift from the source water level to the pump discharge. It is the lift from the actual water level when the pump is running (drawn down) to the centre of the pump outlet.

NOTE:
Elevation head is usually positive, but if the water level is higher than the pump (e.g. a dam) the elevation change is recorded as a negative value.

NOTE:
Specific Gravity (SG ~ 9.8) accounts for the force of gravity.

NOTE:
The pump is working to overcome friction in the intake side of the headworks. To account for this, add the friction in the intake pipe. This can be determined using the Delivery System Efficiency protocols.

COMPARE RESULTS WITH EXPECTED VALUES

Relative pump efficiency

1. Calculate Relative Performance % = Calculated Pump Efficiency ÷ Reasonable Efficiency x 100
2. Calculate Potential Savings ($/year)
   = Annual Cost – Reasonable Cost
   - Reasonable Cost ($/year)
     = Annual Cost x Relative Performance ÷ 100

NOTE:
Pump efficiency shows how much of the energy consumed does useful work. It is usually given as a percentage.

NOTE:
Select a Reasonable Efficiency value for the test system from Table 1.1 and compare it with the calculated efficiency for the actual pumping plant. The relative performance is usually given as a percentage.

NOTE:
The cost of energy for a pumping plant with 48.6% efficiency is 44% more than a typical plant running at 70% efficiency.

NOTE:
Table 1.1 gives guidelines for expected efficiencies, based on motor size and assuming the pump is matched appropriately to the motor.

Table 1.1 Typical electric motor and pumping plant efficiencies by motor size

Electric motor kW	Efficiency % of full load motor	Efficiency % of correctly matched pump	Overall efficiency % pump & motor
2 – 4	80 – 86	55 – 65	44 – 56
5 – 7.5	85 – 89	60 – 70	51 – 62
10 – 22	86 – 90	65 – 75	56 – 68
30 – 45	88 – 92	70 – 80	62 – 74
> 55	90 – 93	75 – 85	68 – 79

Source: North Carolina Cooperative Extension Service, Publication Number: AG 452-6

Notes to Table 1.1

Pump-type variations

1. Values shown are typical for centrifugal pumps.
   NOTE: < 55 kW submersible pumps range 3–5% higher and turbine pumps range 5–10% higher.
   NOTE: > 55 kW centrifugal pumps may approach efficiencies of 88%, whereas large submersible and turbine pump efficiencies peak at about 90%.
2. Overall Pump Efficiency ranges are obtained by multiplying the Full Load Motor Efficiency range by the Matched Pump Efficiency range e.g. 80% x 55% = 44% (on a calculator 0.80 x 0.55 = 0.44)

Converting values for typical fossil fuels to usable energy values:

3. New Zealand Diesel contains 10.4 kWh/L but only about 3.5 – 4.0 kWh/L of useful energy is generated
4. New Zealand 91 Petrol contains 9.69 kWh/L but only about 2.5 – 2.8 kWh/L of useful energy is generated.

NOTE:
The usable energy values for diesel and petrol above are already adjusted for engine efficiency.

If using them as 'Power Conversion' factors, use values from the Matched Pump Efficiency column rather than the Overall Pump Efficiency column as the 'Typical' Pumping Plant Efficiency.

DETERMINE IF CHANGES ARE JUSTIFIED

Cost benefit

1. Determine costs of potential system change options
   - Larger intake pipes
   - Replacement pump/motor.
2. Estimate proportion of Potential Savings from each change option
3. Compare Potential Savings ($/year) with costs of change options.

NOTES:

- The pressure at the nozzle (the end nozzle if there is more than one) gives best guidance to adequacy of system pressure. Generating more pressure than required is wasteful and costly.
- Using an oversized pump will result in higher operating costs. New pumps may have spare capacity to allow for wear. However, if the system pressure is more than 5% over the sprinkler operating requirement, or if partially closed gate valves or pressure regulators are installed to 'burn-off' pressure, it is likely energy and money are being wasted.
- It is usually more economical in the long term to select the most efficient pump, even if it requires higher initial outlay. Replacing incorrectly sized motors or pumps can often have a quick payback.
- The efficiencies of the pump itself and the motor are combined for overall efficiency. For example, a 90% efficient motor on a 70% efficient pump is only 63% efficient overall (0.9 x 0.7 = 0.63).
- Check manufacturer's data sheets to determine the expected efficiency of the pump-motor combination. They should be selected to operate at or near their maximum efficiency points as much as possible.

Why does efficiency change?

There are two basic reasons for a pump being inefficient:

1. It has physically deteriorated
2. It is not suitable for the required operating conditions (i.e. required flow and pressure).

NOTES:

- Most irrigation systems are powered by electric motors or internal combustion engines, sometimes both. In general, electric motors are more energy efficient than diesel engines, which are usually more efficient than petrol engines.
- Differences in potential efficiencies between standard electric motors are generally small (1 5%), but as the motor is at the start of the drive train the savings achieved by an efficient motor and motor operating at its best efficiency point can be substantial.
- Changing flow or pressure requirements will change the pump operating point, and can move from its optimum to a less efficient performance.
- If pump loads fluctuate widely or if pumps are often run at partial loads, adding a variable speed drive may be cost effective since it closely matches output to actual demand. An alternative is to use multiple pumps turning on or off to optimise to different operating conditions.

1.2 Assessing delivery system efficiency

The purpose of this test is to determine the energy efficiency of the headworks and pipelines feeding the irrigation system. See also the guidelines for assessing the efficiency of the pumping system.

The test is designed so irrigation managers can do measurement and calculations themselves. Supporting guidelines and worksheets are in the Appendices. Calculation software is available from IrrigationNZ. If findings are unexpected, or suggest low performance, consider getting professional advice.

Why check delivery system efficiency?

Incorrectly sized or physically deteriorated components can waste energy and money. Energy efficient irrigation minimises energy use and carbon emissions. A good system saves money and the environment.

Pipe and component selection are important system design considerations. Selecting smaller options may reduce up front capital cost, but increases ongoing energy costs as bigger pumps are required. The correct selections optimise the necessary trade-offs.

A separate protocol deals with pumping system efficiency. The two should be used together.

What will the testing show?

The test will show water velocities in and energy losses from the irrigation system. These are described using 'performance indicators' which apply regardless of system type:

- **Headworks efficiency**
  How much of the energy consumed (and paid for) is lost at the headworks
- **Hydraulic (mainline) velocity and efficiency**
  How fast water is moving along the pipeline and the amount of friction loss
- **Suction line lift and velocity**
  The maximum suction and speed in the intake pipeline; important for safe pump operation
- **Annual energy cost and savings**
  How much energy and money would be saved if the delivery system was operating at typical performance levels.

When should testing be done?

Complete the efficiency test when commissioning a new system and after any major changes to the pumping or irrigation systems. It should also be repeated as part of annual maintenance.

The system operation should be 'typical' when the test is performed to ensure results are meaningful. If system flow or pressure changes when different parts of the irrigation system are operating, Delivery Efficiency will change.

Testing should be repeated as part of system checks at the start of every season. Compare with past results to identify slippage or failures.

What are the test's limitations?

The irrigation delivery system efficiency test will only provide information for the conditions measured. The energy use and efficiency will change if system flow changes.

The more accurate your input values, the more accurate your results. Take care reading pressure and determining elevation changes. Use good equipment in good order.

If pressure and suction gauges are not already in place, it may take a little setting up the first time this testing is done. Next time, the equipment will already be in place.

The efficiency value determined is based on guidelines in the New Zealand Piped Irrigation Systems Standards.

Get professional help if testing shows unexpected results.

ENERGY EFFICIENCY ASSESSMENT PROCESS

The Delivery System Efficiency Test is based on measurements collected on farm. Key information is pressure, elevation and flow rate so a process to accurately determine these at critical system points is required.

Combining flow, pressure and elevation allows calculation of the energy losses from friction as water flows through the system, operating under the conditions when tested.

Significant changes to flow rate will change the outcomes. If different irrigators, combinations of irrigators or permanent irrigation systems with blocks of significantly different sizes are used, the process should be repeated for each different combination.

What needs to be done?

1. Gather information about the system
2. Calculate performance indicator values
3. Compare results with expected values
4. Determine if changes are justified.

GATHERING INFORMATION

The efficiency of your delivery system can be estimated from flow rates, pressures and elevation changes. The information should be easy to obtain, and calculations needed are set out below.

NOTE:
Endeavour to record energy consumption and water use at the same time to ensure they are closely related.

NOTE:
Field recording sheets to assist are provided in the Appendices.

Equipment required

- Stop watch
- Pen or pencil
- Recording sheet
- pressure gauge(s)
  - rating depends on system pressures
- vacuum gauge(s)
  - rating depends on system pressures
- way to determine elevation difference between:
  - water level and pump outlet
  - pump outlet and mainline entry
  - mainline entry and mainline exit

FIELD MEASUREMENTS

1. Record motor details including power rating
2. Determine the mean energy cost of electricity and fuel
3. Determine the typical pump operating hours per year
4. Determine the change in elevation between the water surface (when pumping) and the centre of the pump outlet

NOTE:
This may require survey equipment and/or a method to measure water level in a bore or well

NOTE:
Information may be available from other sources such as design or construction information

Measure energy use

5. Determine the rate of energy use in kilowatts (kW).

NOTE:
Refer to Assessing Pump Efficiency for process to determine Energy Use

Measure water consumption

6. Determine System Flow Rate (m^3/h)

   NOTE: Refer to Assessing Pump Efficiency for process to determine System Flow Rate

7. Determine the typical pump operating hours per year

Measure system elevations

8. Measure Water Intake elevation (kPa)
9. Measure Pump (Outlet) elevation (kPa)
10. Measure the Mainline Entry elevation (kPa)
11. Measure the Mainline Exit elevation (kPa)

NOTE:
This may require survey equipment and/or a method to measure water level in a bore or well.

NOTE:
Information may be available from other sources such as design or construction information.

NOTE:
Elevation accuracy is important! Work to the nearest tenth of a metre. Remember: 0.1m is about 1kPa. You can use actual elevations above sea level, or assume the pump shed floor 100.0m and determine all other elevations relative to that.

NOTE:
Water Intake elevation is the surface level of the water, NOT the position of the actual intake itself which must be under water. The level in a well may drop when the system is running.

SYSTEM MEASUREMENTS

Measure system pressures

NOTE:
Ensure pressure gauges are in good condition

12. Measure Water Intake pressure (kPa)
13. Measure Pump Inlet pressure (kPa)
    (record a suction as negative pressure)
14. Measure the Pump Outlet pressure (kPa)
15. Measure the Headworks Exit pressure (kPa)
16. Measure the Mainline Entry pressure (kPa)
17. Measure the Mainline Exit pressure (kPa)

NOTE:
Intake pressure is 0kPa unless there is a pre-pump or community pipe providing pressure. The water intake is usually not pressured. (Water depth above intakes or submerged pumps is accounted for in Elevation Head calculations.)

NOTE:
A vacuum gauge fitted at the pump inlet is needed to accurately determine intake side losses.

NOTE:
With no inlet suction gauge, only the headworks efficiency from the pump outlet can be calculated. (When the pump efficiency test is completed, the intake efficiency will be included as part of the overall pumping plant efficiency calculated.)

NOTE:
If there is positive head on the intake from a primary pump, subtract that pressure to get the increase in pressure generated by the pump being tested.

NOTE:
Mainline entry is the point where the headworks stop. It will be after control valves, filters, meters and injection points etc. It is the same as the Headworks Exit.

NOTE:
Mainline exit may be a block offtake or hydrant, or in the case of a centre pivot, the entry to the irrigator itself. In systems with multiple offtakes or hydrants, the first offtake may be considered, or each may be assessed.

Measure system dimensions

18. Measure Mainline length (m)
19. Determine Intake Pipe internal diameter (mm)
20. Determine Mainline internal diameter (mm).

NOTE:
The internal pipe diameter must be accurate and in most cases is not the 'nominal diameter' of the pipe. Either measure a sample or check with the supplier to confirm the right value. Small diameter errors cause big velocity errors.

CALCULATE PERFORMANCE INDICATOR VALUES

Headworks efficiency

Headworks efficiency is a measure of the hydraulic performance of the intake structure, pump and headworks (excluding pump pressure and elevation differences).
It considers pressure loss in the system between the water take point and the mainline entry.

NOTE:
Pressure in the system is the result of pump input and pipeline friction losses, and changes in elevation.

NOTE:
Elevation effects are discounted to focus on the efficiency of pipes and components.

NOTE:
Use consistent measurement units:

- Measure pressures in kPa
- Convert elevations from metres to kPa (multiply by specific gravity).

1. Calculate Headworks Efficiency (%) = (Residual Pressure Head ÷ Total Pressure Head) x 100
   - Residual Pressure Head (kPa) = Total Pressure Head – Total Friction Head Loss
   - Total Pressure Head (kPa) = Inlet Side Pressure Head + Outlet Side Pressure Head
   - Total Friction Head Loss (kPa) = Inlet Side Friction Loss + Outlet Side Friction Loss

Inlet side friction head loss

2. Calculate Friction Head Loss (kPa) = Change in Pressure Head – Change in Elevation Head
   - Change in Pressure Head (kPa) = Pump Outlet Pressure – System Intake Pressure
   - Change in Elevation Head (kPa) = Elevation Change (m) x Specific Gravity
   - Elevation Change (m) = Pump elevation – System Intake elevation

NOTE:
Elevation head refers to the lift from the source water level to the pump discharge. It is the lift from the actual water level when the pump is running (drawn down) to the centre of the pump outlet.

NOTE:
Elevation head is usually positive, but if the water level is higher than the pump (e.g. a dam) the elevation change is recorded as a negative value.

NOTE:
Specific Gravity (SG ~ 9.8) accounts for the force of gravity.

Intake pipe velocity

3. Calculate Intake Pipe Velocity (m/s) = (System Flow Rate (m^3/h) ÷ 3,600) ÷ Pipe Section Area (m^2)
   - Pipe Section Area (m^2) = Pipe Internal Diameter (mm) ÷ $2{,}000)^2$ x Pi

Outlet side efficiency

4. Calculate Friction Head Loss (kPa) = Change in Pressure Head – Change in Elevation Head
   - Change in Pressure Head (kPa) = Mainline Entry pressure – Pump Outlet Pressure
   - Change in Elevation Head (kPa) = Elevation Change (m) x Specific Gravity
   - Elevation Change (m) = Mainline Entry elevation – Pump elevation

Hydraulic (mainline) efficiency

Hydraulic efficiency refers to the proportion of energy lost carrying water from the headworks to the entry to the 'irrigator' itself. The 'irrigator' might be a traveller, a pivot or a block of micro-irrigation. Hydraulic efficiency is an assessment of mainline performance. It can be determined from pressure readings and knowledge of elevation changes.

5. Calculate Mainline Friction Head Loss (kPa) = Change in Pressure Head – Change in Elevation Head
   - Change in Pressure Head (kPa) = Mainline Entry Pressure – Mainline Exit pressure
   - Change in Elevation Head (kPa) = Elevation Change (m) x Specific Gravity
   - Elevation Change (m) = Mainline Exit elevation – Mainline Entry elevation

Mainline pipe velocity

6. Calculate Mainline Pipe Velocity (m/s) = (System Flow Rate (m^3/h) ÷ 3,600) ÷ Pipe Section Area (m^2)
   - Pipe Section Area (m^2) = (Pipe Internal Diameter (mm) ÷ $2{,}000)^2$ x Pi

COMPARE RESULTS WITH EXPECTED VALUES

The maximum lift, including elevation gain and friction losses, must not exceed the practical limits for pumps. High water velocities or high pressure losses through suction lines can create major problems including cavitation and complete failure of centrifugal pumps.

Headworks efficiency

1. Calculate Excess Headworks Head Loss
   Guideline:
   - Basic headworks including water meter, clean filters and gate valves, but excluding pressure control valves
   - Acceptable friction head loss < 30kPa.

NOTE:
Unclean filters may cause extra 10–50+ kPa head loss

NOTE:
Query the use of headworks pressure regulators. They are designed to burn off excess pressure. Unless you have changing conditions and need to protect your system, regulators are probably wasteful.

Intake side/suction line

2. Calculate Excess Intake Pipe Velocity (m/s)
   = Intake Pipe Velocity – Acceptable Intake Pipe Velocity

   NOTE:
   Excess velocity is the difference between the recommended maximum value and test results. A positive answer means excess velocity.

   Guideline:
   - Acceptable Intake Suction < 60kPa
   - Acceptable Intake Pipe Velocity < 1.5m/s (where pipe sizes are not determined by pressure variation or velocity requirements).

Excess energy cost

3. Calculate Annual Energy Loss Cost ($ p.a.)
   = Annual Energy Cost x Excess Friction Ratio
   - Annual Energy Cost (from Pump Efficiency Test Protocol)
   - Excess Friction Ratio = Excess Headworks Friction Loss ÷ Total Pressure Head
   - Excess Headworks Friction Loss (kPa)
     = Total Friction Head Loss – 30

Hydraulic (mainline) efficiency

1. Calculate Excess Mainline Friction (kPa)
   = Mainline Friction Head Loss – Acceptable Mainline Friction Loss
   - *Guideline:*
     Acceptable Mainline friction loss* < 100kPa
     *unless there is need to burn off pressure, such as in gravity supplied systems.
2. Calculate Excess Mainline Friction (kPa/100m)
   = Mainline Friction Loss – Acceptable Mainline friction loss
   - Mainline Friction Loss (kPa/100m)
     = Friction Head Loss ÷ Mainline Length (m) x 100
   - *Guideline:*
     Acceptable Mainline friction loss* 4–12 kPa/100m pipe
     *unless there is need to burn off pressure, such as in gravity supplied systems.
3. Calculate Excess Mainline Pipe Velocity (m/s)
   = Mainline Velocity – Standard Max Velocity

   NOTE:
   Excess velocity is the difference between the recommended maximum value and test results. A positive answer means excess velocity.

   NOTE:
   Higher speeds cause higher friction losses and increase the risk of damage through surges and water hammer. In high sediment conditions, minimum velocities may be needed to avoid blockages.

   NOTE:
   Large diameter pipes subject to uncontrolled starting and stopping are particularly sensitive. *The New Zealand Piped Irrigation System Code of Practice for Irrigation Design* recommends maximum water velocities:

Table 1.2

	Condition / location	Max velocity
< 150mm diameter pipe	open end, controlled start and stop	< 3.0m/s
	uncontrolled start and stop	< 1.5m/s
> 150mm diameter pipe	open end, controlled start and stop	< 2.0m/s
	uncontrolled start and stop	< 1.0m/s

DETERMINE IF CHANGES ARE JUSTIFIED

Cost benefit

1. Determine costs of potential system change options
   - Larger pipes
   - Larger headworks components.
2. Estimate proportion of Potential Savings from each change option
3. Compare potential savings ($/year) with costs of change options.

Why does efficiency change?

There are two basic reasons why a system is inefficient:

- it has physically deteriorated, and/or
- it is not suitable for the required operating conditions (i.e. required flow).

If the losses are higher than expected, assess the cost of efficiency improvement. In some cases, relatively minor changes can give considerable on-going energy savings.

2. Assessment of seasonal irrigation efficiency

This section outlines procedures for estimating measures of seasonal irrigation efficiency (SIE).

The indicators estimate the effectiveness and efficiency of irrigation scheduling on a seasonal basis. They are calculated using soil moisture budgets; tracing inputs and outputs from a conceptual reservoir of some set size.

The schedule identifies varying levels of analysis ranging from very simplistic to highly detailed. The simplest is a quick estimate of seasonal irrigation efficiency based on comparing total seasonal irrigation and rainfall with total estimated seasonal evapotranspiration.

A more detailed process is recommended where information is available. Therefore the schedule outlines a process for more detailed analysis, requiring knowledge of soil water properties, seasonal weather, potential crop water use, and irrigation system performance and management.

DETERMINE SEASONAL EFFICIENCY

1. Process questionnaire responses to assess the adequacy and efficiency of irrigations for the preceding season
2. Estimate yield losses and values resulting from inadequate irrigation.

Purpose

This schedule presents procedures for estimating measures of seasonal irrigation efficiency (SIE). A wide range of efficiency measures may be used, depending on scale, timeframe and issues under consideration. Commonly used indicators include irrigation efficiency, irrigation adequacy and drainage.

Seasonal irrigation efficiency overview

The indicators below relate to estimates of efficiency across an irrigated growing season or year. They provide information relating to economic or environmental implications of in efficient irrigation systems or management. The indicators are calculated using soil moisture budgets; tracing inputs and outputs from a conceptual reservoir of some set size.

The simplest indicator of Seasonal Irrigation Efficiency compares total seasonal irrigation and rainfall with total estimated seasonal evapotranspiration. A more detailed process is recommended where information is available.

This schedule outlines a process for more detailed analysis, requiring knowledge of soil water properties, seasonal weather, potential crop water use, and irrigation system performance and management.

The quality of results from such exercises is dependent on input data, the quality of which should be recorded.

SEASONAL APPLICATION EFFICIENCY

Seasonal Irrigation Efficiency (SIE) is an estimate, calculated for a whole season or full year, of how much irrigation water that is applied is likely to have been used beneficially.

Beneficial uses include meeting evapotranspiration requirements, frost protection and salinity management. The prime consideration is crop evapotranspiration need. Frost protection is not included in these calculations.

The main indicator calculated is Seasonal Application Efficiency (SAE), the ratio of crop water use to applied irrigation, net of changes in soil moisture storage.

SEASONAL IRRIGATION ADEQUACY

Irrigation Adequacy is an estimate of whether sufficient irrigation is applied to meet the needs of a given proportion of the field. A commonly used indicator is low-quarter adequacy, which takes the average low-quarter applied depth as the scheduling criterion and typically considers a single irrigation event.

Potential soil moisture deficit is used as the seasonal equivalent indicator, because summing individual-event irrigation adequacy results over the course of a season gives a false indication of adequacy.

Deep percolation (often referred to as drainage) resulting from irrigation (SDP_i), quantifies the amount of water that is lost to groundwater through non-uniformity or improper scheduling.

OTHER EFFICIENCY INDICATORS

Drought induced yield loss (YL_{di}) and energy and water costs related to over-watering describe the financial implications of irrigation in-efficiencies.

Sources of information

Determination of irrigation efficiency indicators requires knowledge of beneficial water use, total water inputs and the soil's 'reservoir' capacity.

Typically seasonal irrigation efficiency will be calculated on the basis of the last complete season, using records of actual irrigation volumes, calculated estimates of water need, and knowledge of soil moisture storage at the beginning and end of the season.

The source of data used, and assessments of their reliability, should be recorded.

WATER USE

Because the key drivers of water use (PET) vary little within a district, water use by a given crop can usually be determined from district weather records and crop factors.

If on-site crop monitoring records allow, actual measured water use data should be used.

WATER INPUTS

Water inputs require knowledge of irrigation quantities and rainfall, both adjusted to equivalent water depths. Irrigation is obviously field-specific. Because rainfall is so variable, information should relate to that received on-site.

SOIL WATER HOLDING CAPACITY

Unless on-site data is known (e.g. from moisture monitoring records) soil water holding capacity (WHC) and readily available water (RAW) must be estimated.

Standard data for soils and crops in question may be available from published sources. On-site textural analysis may provide a reasonable estimate of WHC.

Plant rooting depth should be determined on-site. Text book values are widely variable and unreliable.

Determination of input data

ACCURACY OF INPUT DATA AND RESULTS

Many of the inputs can be entered with considerable precision, but are of limited or unknown accuracy. Therefore output results are of limited or unknown accuracy. Levels of confidence will be difficult to ascertain, but the precision of generated results should not be taken to imply a level of accuracy.

SOIL MOISTURE CHARACTERISTICS

The water holding potential of the soil should be calculated from the estimated soil WHC and the plant rooting depth. It is convenient to express water holding as a depth (mm).

The readily available water is estimated from WHC and some crop factor, typically management allowed depletion (MAD) or critical deficit (usually also a percentage).

For annual or new crops, root depth will increase with plant growth, so WHC and RAW will typically change over the season.

ESTIMATING CROP WATER REQUIREMENT

Crop water requirement is dependent on climatic conditions, crop characteristics and plant available soil moisture. In a simple estimate, only the climatic and crop factors are considered.

Reference potential evapotranspiration values (PET) should be obtained on-site or from relevant local climate station values. PET is then adjusted to account for crop specific water use factors (K_{crop}) and the ground cover fraction ($K_{ground\ cover}$). These may be combined into a single factor (K_c) the crop water use co-efficient.

The crop water requirement calculated is described as crop-adjusted evapotranspiration (ET_{crop})

In most cases it is satisfactory to assume plant water use stops when Critical Deficit (maximum allowable deficit, MAD) is reached. For very detailed analyses, some reduced rate of consumption should be allowed in calculating soil moisture balances.

SYSTEM PERFORMANCE (DU_{LQ})

No irrigation system applies water perfectly evenly, so under a full irrigation regime, some areas will receive more water than required while others do not receive enough.

In calculating many indicators, it is helpful to consider distribution uniformity. For example, the volume of water required to adequately meet the needs of most (7/8ths) of the crop is determined by adjusting the theoretical water requirement by the low quarter distribution uniformity coefficient (DU_{lq}).

ROOT AREA WETTED

Drip and micro sprinkler irrigation efficiency needs particular consideration, because only a fraction of the total soil area is actually watered.

Calculations must account for reduced soil reservoir capacity. This may be done by adjusting the effective AWC and RAW proportionally, or considering the zones separately.

BENEFICIAL WATER REQUIREMENTS

Additional water may be required for particular purposes other than replacing ET. Alternative beneficial uses include frost protection, any leaching requirement, and pre-plant irrigations for weed germination or other reasons.

Such water use should be accounted for in determining irrigation efficiency. If water applied (e.g. for frost protection or soil conditioning) is retained and available for later plant use it should be included in calculations as irrigation.

If water applied for frost protection or soil conditioning drains (or causes other irrigation to drain) from the profile, it should be omitted from irrigation efficiency calculations, but may be included in a seasonal water use efficiency estimate (SWUE). This may include excess water applied to manage salinity (leaching), although this is rare in New Zealand.

CROP VALUE

Financial losses can be estimated if potential yield and price are known, and a suitable drought response factor is available.

For field crops, in lieu of better data, a drought response factor, F_{dr} of 0.1% of potential yield per mm potential soil moisture deficit can be used for C4 plants (maize and sweetcorn) and a value of 0.2%/mm PSMD for other field crops.

Analysis detail

Decisions must be made about which factors to include and the detail with which soil moisture budgets and other calculations will be undertaken. Variables include climatic, crop and soil variables, and the irrigation system and its management.

The level of detail possible depends in part on the availability of reliable input information and in part on the purpose for which the analysis is being undertaken. The division of time periods and spatial zones for analyses also have significant effects on the results generated.

TIME PERIOD

The size or number of time-steps considered influences results generated. The greater the division of any time period (the finer the time-steps) the more closely estimates can reflect reality. Wider time-steps integrate more events; summing rainfall, irrigation, ET and deep percolation. This typically underestimates certain factors such as the degree of drought and drainage.

If reliable information is available, a more detailed assessment will provide better information for future decision making. Weekly or daily weather and irrigation records provide a good or very good level of information.

SPATIAL VARIATION

Analyses can be based on average values for variables such as applied depth. However, inclusion of distribution uniformity factors in calculations further increases the quality of analysis.

Typically three ‘virtual spaces’ can be considered: the area that receives the mean depth of application, and those receiving the low quarter and high quarter mean depths. Use weighted results when recombining data.

In drip or micro-irrigation systems, where only part of the area is wetted, soil moisture trends in the irrigated and un-irrigated zones should also be considered separately.

Constructing independent soil moisture budgets for each area identifies where drought and drainage are occurring more accurately. The calculated indicator values can then be combined to give a value for the system as a whole.

SIMPLE ANALYSES

The most simple analysis uses total seasonal values to estimate an approximate efficiency. This level of analysis can be a useful starting point, easily calculated by hand or with a simple calculator.

Soil moisture storage capacity is not considered, except as change in status between the start and end of the season. Neither is consideration given to the timing of irrigation or rain, or the relationship of these events to water use (ET) in any particular time period. While this estimate can identify major problems, it does not provide the detail needed to make recommendations for improving system management.

Considerable experience in New Zealand, Australia and the United States shows that many irrigators do not have sufficient system performance knowledge, or maintain sufficient records, to allow even rough estimates to be made.

DETAILED ANALYSIS

More detailed analyses involve soil moisture budgets with calculations based on periodic time steps. The desirability of computer programs to perform the calculations increases with the number of periods and detail of calculations. This level of analysis does permit increasingly accurate establishment of overall irrigation efficiency. It can be used to highlight ways in which system management, particularly scheduling and application quantities, can be adjusted to increase efficiency.

Data inputs include weather, soil moisture storage properties, crops and crop coefficients, irrigation events and system performance (distribution uniformity).

Estimates of performance rely on historic weather and management data. The quality of records of rainfall, PET and past irrigation practices determines the accuracy with which more detailed analyses of irrigation efficiency can proceed.

Efficiency calculations

SEASONAL APPLICATION EFFICIENCY

Seasonal application efficiency (SAE) is given by the ratio of water retained in the root zone to water applied to the field, over a full irrigation season or year.

In more detailed calculations, the amount of water retained from each irrigation event should be summed to determine a seasonal result.

For greater accuracy, soil moisture balance calculations may be completed in each of three conceptual irrigated zones: the zone receiving the average application depth, and those receiving the average low quarter and high quarter depths.

The overall SAE is a weighted average of these calculated values.

EVENT IRRIGATION ADEQUACY

Irrigation adequacy typically applies to an individual irrigation event. It measures the degree to which the soil moisture in some proportion of the field is restored to a level that meets or exceeds target soil water content.

A simple determinant is low quarter irrigation adequacy, IA_{lq} which is the ratio of the mean low quarter depth applied to the mean target depth required across the field as a whole.

This assumes it is reasonable to adequately irrigate 7/8ths of a field, leaving 1/8th under irrigated. IA_{lq} can be used to determine 'correct' irrigation scheduling:

$IA_{lq} < 1.0$	under-irrigation
$IA_{lq} = 1.0$	target irrigation
$IA_{lq} > 1.0$	over-irrigation

SEASONAL IRRIGATION ADEQUACY

If the adequacy of irrigation is summed over the course of a season over- and under-irrigations may cancel out. This will give a false indication of adequacy, and fails to provide useful information for decision making.

For a seasonally relevant value of irrigation adequacy, potential soil moisture deficit (PSMD) gives a better indication of adequacy (lack of moisture stress). The equivalent indicator is therefore the low quarter potential soil moisture deficit ($PSMD_{lq}$). Alternatively, a PSMD for the field as a whole may be presented based on low, mean and high quarter estimates.

Seasonal deep percolation resulting from irrigation (SDP_i) is a measure of the amount of irrigation water applied that drains from the soil profile. It is therefore the equivalent indicator for excess irrigation over a season.

POTENTIAL SOIL MOISTURE DEFICIT

Potential soil moisture deficit (PSMD) is a measure of moisture stress experienced by a crop, and is correlated with yield loss.

SEASONAL POTENTIAL SOIL MOISTURE DEFICIT

Seasonal PSMD is calculated from soil moisture budgets by summing all deficits greater than the critical deficit (or MAD). Seasonal PSMD assumes any rain or irrigation is immediately available to plants, so is not the same as an aggregation of period SMD's.

To correspond to low quarter irrigation adequacy, a budget would be calculated using data for the low quarter zone. A potential soil moisture deficit in the low quarter zone ($PSMD_{lq}$) > 0.0mm equates to a seasonal irrigation adequacy (SIA_{lq}) < 1.0, as plants have experienced stress conditions.

To determine PSMD across the whole area, weighted values from each of the low, mean and high application zones can be summed.

SEASONAL DEEP PERCOLATION (SDP)

Seasonal deep percolation SDP includes all drainage whether from irrigation or precipitation. It is estimated from the balance of water not retained in the root zone, calculated after any surface losses have been accounted for.

SEASONAL IRRIGATION DEEP PERCOLATION

Seasonal deep percolation resulting from irrigation (SDP_i) is a measure of the amount of irrigation water applied that drains from the soil profile. It is, in effect, seasonal application in-efficiency.

SDP_i > 0.0 in the low quarter zone equates to seasonal irrigation adequacy > 1.0 as drainage has occurred.

To determine deep percolation across the whole area, weighted values from each of the low, mean and high application zones can be summed.

DROUGHT INDUCED YIELD LOSS

For most field crops, yield loss resulting from drought stress follows potential soil moisture deficit (PSMD) regardless of when in the season the stress occurs.

NOTE:
A possible exception is fruit trees and grape vines where deficit irrigation practices may be deliberately employed to control vegetative growth and or enhance crop quality without compromising yield.

VALUE OF LOST YIELD

The value of lost yield (cost of not irrigating correctly) is determined from the value of the crop and the amount of lost yield.

Note that no account is made for loss of quality in the remaining crop.

VALUE OF WASTED WATER

Estimate the cost of water non beneficially used from the amount of irrigation water lost through deep percolation, runoff and off-target application by the price paid for the water.

Because SDP_i is calculated as a depth, a conversion is needed if water is charged by the cubic metre. Typically in New Zealand there is no charge on water itself, but any cost associated with its procurement, delivery or treatment may be included.

VALUE OF WASTED ENERGY

The value of energy unnecessarily consumed is calculated from 'wasted' water, volumetric energy consumption and system efficiency factors. This integrates all energy losses, including those from poor headworks and mainline design.

Excess energy consumption can be reported in units of kWhr/mm/ha. Similarly, meaningful units for value of wasted energy is $/mm/ha.

IRRIGATION REQUIREMENT

Irrigation requirement is given by crop water requirement plus any additional beneficial water requirement less received precipitation and stored soil moisture.

Appendices

PART I: Conducting Energy Efficiency Assessments and Seasonal Irrigation Efficiency

Delivery system efficiency guidelines

What is the test about?

The purpose of this test is to determine the energy efficiency of the headworks and pipelines feeding the irrigation system. See also the guidelines for assessing the efficiency of the pumping system.

The test is designed so irrigation managers can do testing and calculations themselves. As well as this guideline, a worksheet is available to assist. If findings are unexpected, or suggest low performance, consider getting professional advice.

Why check delivery system performance?

Profitability – Incorrectly sized or physically deteriorated components can waste energy and money. A good system saves money!

Sustainability – energy efficient irrigation minimises energy use and carbon emissions. A good system saves the environment!

Pipe and component selection are important system design considerations. Selecting smaller options may reduce up front capital cost, but increases ongoing energy costs as bigger pumps are required. The correct selections optimise the necessary trade-offs.

A separate guideline deals with pumping system efficiency. The two guides should be used together.

What is involved?

The delivery system efficiency test is based on measurements collected on farm. Key information is pressure, elevation and flow rate so you need some way of accurately determining these at critical system points.

Combining flow, pressure and elevation allows calculation of the energy losses from friction as water flows through the system, operating under the conditions when tested.

Significant changes to flow rate will change the outcomes. If you use different irrigators, combinations of irrigators or have permanent irrigation systems with blocks of significantly different sizes, the process should be repeated for each different combination.

What needs to be done?

1. Gather information about the system
2. Record the data on the worksheet
3. Work out answers using the worksheet calculations
4. Compare your results with target values.

When should testing be done?

Complete the efficiency test when commissioning a new system and after any major changes to the pumping or irrigation systems. It should also be repeated as part of annual maintenance.

Make sure the system operation is 'typical' when you test, so your results are meaningful.

What will the testing show?

The test will show water velocities in and energy losses from the irrigation system. These are described using 'performance indicators' which apply regardless of system type:

- **Headworks efficiency**
  How much of the energy consumed (and paid for) is lost at the headworks.
- **Hydraulic (mainline) velocity and efficiency**
  How fast water is moving along the pipeline and the amount of friction loss.
- **Suction line lift and velocity**
  The maximum suction and speed in the intake pipeline; important for safe pump operation.
- **Annual energy cost and savings**
  How much energy and money would be saved if the delivery system was operating at typical performance levels.

What are the test's limitations?

The delivery system efficiency test will only provide information for the conditions measured. The energy use and efficiency will change if system flow changes.

The more accurate your input values, the more accurate your results. Take care reading pressure and determining elevation changes. Use good equipment in good order.

If you don't already have pressure and suction gauges in place, it may take a little setting up the first time you do this testing. Next time, your equipment will already be in place.

The efficiency value determined is based on guidelines in the *Irrigation New Zealand Code of Practice for Irrigation Design*.

Get professional help if testing shows unexpected results.

What is it and what's acceptable?

HEADWORKS EFFICIENCY

Headworks efficiency is a measure of the hydraulic performance of the intake structure, pump and headworks (excluding pump pressure and elevation differences). It considers pressure loss in the system between the water take point and the mainline entry.

Headworks efficiency can be determined from pressure readings and knowledge of elevation changes. We need consistent measurement units; in this guideline pressures are measured in kPa. Elevations are converted from metres to kPa.

Guideline – For a basic headworks including water meter, clean filters and gate valves, but excluding pressure control valves

- Maximum friction head loss < 30kPa

Unclean filters may cause extra 10–50+ kPa head loss.

Query the use of headworks pressure regulators. They are designed to burn off excess pressure. Unless you have changing conditions and need to protect your system, regulators are probably wasteful.

INTAKE SIDE / SUCTION LINE

A suction pressure gauge fitted at the pump inlet is needed to accurately determine intake side losses.

The maximum lift, including elevation gain and friction losses, must not exceed the practical limits for pumps. High water velocities or high pressure losses through suction lines can create major problems including cavitation and complete failure of centrifugal pumps.

Guideline

- Maximum intake suction < 60kPa
- Maximum suction velocity < 1.5m/s (where pipe sizes are not determined by pressure variation or velocity requirements)

NO SUCTION GAUGE ON PUMP INLET?

With no inlet suction gauge, you can only calculate the headworks efficiency from the pump outlet. (When you complete the pump efficiency test, the intake efficiency will be included as part of the overall pumping plant efficiency calculated.)

ELEVATION CHANGE

Increasing elevation unavoidably requires energy. In determining system efficiency, elevation effects are discounted so the pipe work and other system components can be assessed fairly. The intake elevation is the surface level of the water supply, not the position of the actual intake itself which must be under water.

In this Guideline, elevations in metres are converted to kilopascals (kPa) using specific gravity (SG). The standard factor is SG = 9.8, but if your measurements are less than 95% accurate, you could just multiply metres by 10 to get kilopascals.

HYDRAULIC (MAINLINE) EFFICIENCY

Hydraulic efficiency refers to the proportion of energy lost carrying water from the headworks to the entry to the 'irrigator' itself. The 'irrigator' might be a traveller, a pivot or a block of micro-irrigation. Hydraulic efficiency is an assessment of mainline performance. It can be determined from pressure readings and knowledge of elevation changes.

Guideline

- Mainline friction loss < 100kPa (unless there is need to burn off pressure, such as in gravity supplied systems).
- Mainline friction loss 4–12kPa/100m pipe

Higher speeds cause higher friction losses and increase the risk of damage through surges and water hammer. In high sediment conditions, minimum velocities may be needed to avoid blockages.

Large diameter pipes subject to uncontrolled starting and stopping are particularly sensitive. The INZ Code of Practice for Irrigation Design recommends maximum water velocities:

Guideline

Condition / location	Max Velocity
< 150mm diameter pipe	
• open end, controlled start & stop	< 3.0m/s
• uncontrolled start and stop	< 1.5m/s
>150mm diameter pipe	
• open ended, controlled start & stop	< 2.0m/s
• uncontrolled start and stop	< 1.0m/s

Why does efficiency change?

There are two basic reasons why a system is inefficient:

1. it has physically deteriorated, and/or
2. it is not suitable for the required operating conditions (i.e. required flow).

If the losses are higher than expected, assess the cost of efficiency improvement. In some cases, relatively minor changes can give considerable on-going energy savings.

What is excess energy loss costing?

The opportunity cost of inefficiency is calculated from energy cost, energy consumption and the relative efficiency of your system compared to guideline values.

This test does not account for extra capital investment that may be required to reduce losses by using larger pipelines and components.

Determining performance

The efficiency of your delivery system can be estimated from flow rates, pressures and elevation changes. The information should be easy to obtain, and calculations needed are set out below.

What equipment will you need?

- This guide and the worksheet
- Pressure gauge
- Vacuum (suction) gauge
- Tape measure
- Pen or pencil.

Field measurements

- Water meter readings
- Elevation (height) at water level, pump, mainline entry and mainline exit
- Pressure readings at pump inlet and outlet
- Pressure readings at mainline entry and exit.

Table A: Headworks efficiency

The basic question is, "How much of the pressure created is remaining after water passes through the headworks?"

Pressure in the system is the result of pump input and pipeline friction losses, and changes in elevation. Elevation effects are discounted to focus on the efficiency of pipes and components.

Follow the steps in Table A of the Worksheet to calculate the efficiency of your system.

NOTES:

- *Elevation accuracy is important!*
  Work to the nearest tenth of a metre.
  Remember: 0.1 m is about 1kPa.
  You can use actual elevations above sea level, or just call the water level 100.0m and determine all other elevations relative to that.
- *Intake elevation* is the surface level of the water supply, not the position of the actual intake itself which must be under water. The level may drop in a well when the system is running.
- *Pump inlet elevation* is determined relative to the water level at the intake. It will be positive from a bore, but may be negative from a higher dam.
- *Elevation change* will be usually positive from a bore or river but may be negative from a dam. Multiply metres head by specific gravity to get elevation and pressure both in kilopascals (kPa).
- *Intake pressure* is 0kPa unless there is a pre-pump or community pipe providing pressure.
- *Change in head* combines the effects of elevation and friction and is measured by the difference in pressure on the inlet vacuum gauge and the intake pressure.
- *Friction loss* is the difference between the change in head and the elevation change. It changes with intake screen size and type and pipe diameter.
- *Mainline entry* is the point where the headworks stop. It will be after control valves, filters, meters and injection points etc.
- *Total friction head loss* combines values from both the inlet and outlet sides of the pump.
- *Headworks efficiency* is a measure of the amount of energy consumed that is converted to useful work.

Table B: Hydraulic (mainline) efficiency

Hydraulic efficiency asks the same questions about the mainline. It considers friction losses and is calculated from the change in total head and elevation differences between the entry to, and exit from, the mainline.

Follow the steps in Table B of the Worksheet to calculate mainline efficiency.

NOTES:

- *Elevation accuracy is important!*
  As with the headworks measurements, work as accurately as you can, to the nearest 0.1m if possible.
- *Mainline entry pressure and elevation* are the same as those for the Headworks exit. Mainline length is recorded in metres. Friction losses are often considered in 100m lengths of mainline. The calculations have a factor built in to convert head loss per metre to head loss per 100m.
- *Excess mainline friction* is the difference between the maximum 100kPa for a mainline and the value you calculate for your system.
- *Excess friction loss/100m* compares the maximum reasonable loss of 12kPa/100m with the value you calculate for your system.

ENERGY COSTS

The excess friction loss (if any) from headworks and from the mainline is combined with the cost of pumping (creating the total energy) determined from the pump efficiency test.

Table C: Pipe velocities

Excess velocity in pipes causes excess friction, and increases the risk of pipe damage from water hammer and other shock loads.

The internal pipe diameter must be known, and is not the 'nominal diameter' of the pipe in most cases. Either measure a sample or check with your supplier to ensure you have the right value. Small diameter errors cause big velocity errors.

Pipe section area calculations convert diameters in mm to cross sectional areas in square metres.

Excess velocities are the difference between the recommended maximum values and your results.

Worksheet for Delivery System Efficiency Test

Enter elevations, pressures and other data and complete the Calculations as directed. Enter information using the measurement units (e.g. kilopascals or metres) specified to ensure calculated answers have the correct units. Compare your results with standard recommendations.

TABLE A: HEADWORKS INLET EFFICIENCY

Inlet-side efficiency

a	Water surface elevation when operating – include drawdown (m)	0.0
b	Pump inlet elevation (m)	4.0
c	Change in elevation head (kPa) [(b – a) x SG]	39
d	Water intake pressure (kPa)	0
e	Pump inlet pressure (kPa)	-55
f	Change in pressure head (kPa) [d – e]	55
g	Friction head loss (kPa) [f – c]	16

Outlet-side efficiency

h	Pump outlet elevation (m)	4.0
j	Mainline entry elevation (m)	4.0
k	Change head (kPa) [(h – g) x SG]	0
m	Pump outlet pressure (kPa)	450
n	Pressure at mainline entry (kPa)	425
p	Change in pressure head (kPa) [m – n]	25
q	Friction head loss (kPa) [p – k]	25

Total headworks efficiency

r	Total friction head loss (kPa) [g + q]	41
s	Total pressure head (kPa) [f + p]	80
t	Headworks Efficiency [(s – r) / s] x 100	49

Excess energy cost

u	Excess headworks friction loss (kPa) [r – 30]	11
v	Excess system friction ratio [u / s]	0.1345
y	Annual Energy Cost ($ pa) From Pump Efficiency Test	9,846
z	Annual energy loss cost ($ pa) [w x y]	1324.3

TABLE B: MAINLINE EFFICIENCY

a	Mainline entry elevation (m)	4.0
b	Mainline exit elevation (m)	7.0
c	Change in elevation head (kPa) [(b – a) x SG]	29
d	Mainline entry pressure (kPa)	425
e	Mainline exit pressure (kPa)	300
f	Change in head (kPa) [d – e]	125
g	Friction head loss (kPa) [f – c]	96
h	Excess mainline friction (kPa) [100 - g]	4
j	Mainline length (m)	860
k	Friction loss (kPa/100m) [g / j x 100]	11
m	Excess mainline friction (kPa/100m) [12 - k]	1

Excess energy cost

n	Excess mainline friction loss (kPa) [greater of h or m]	4
p	Excess system friction ratio [n / f]	0.032
q	Annual Energy Cost ($ pa) From Pump Efficiency Test	9,846
r	Annual energy loss cost ($ pa) [p x q]	315.07

TABLE C: PIPE VELOCITIES

a	System flow rate (m^3/hr)	192
b	Intake pipe internal diameter (mm)	200
c	Intake pipe section area (m^2) [3.14 x (b / 2000) 2]	0.0314
d	Intake pipe velocity (m/s) [(a / 3600) / c]	1.7
e	Excess intake velocity (m/s) [d – 1.5]	2.0
f	Mainline internal diameter (mm)	200
g	Mainline section area (m^2) [3.14 x (f / 2000) 2]	0.0314
h	Mainline velocity (m/s) [(a / 3600) / g]	1.7
j	Standard velocity max for conditions (m/s) [from Guidelines p2]	860
k	Relative velocity (m/s) [h - j]	-0.3

Delivery system efficiency worksheet

What is the irrigation test about?

The purpose of this irrigation test is to determine the energy efficiency of the headworks and pipelines feeding the irrigation system. See also the guidelines for fuller explanation of the steps.

If findings are unexpected, or suggest low performance, consider getting professional advice.

When should testing be done?

Complete the efficiency test when commissioning a new system and after any major changes to the pumping or irrigation systems. It should also be repeated as part of annual maintenance.

Make sure the system operation is 'typical' when you test, so your results are meaningful.

What needs to be done?

1. Gather information about the system
2. Record the data on the worksheet
3. Work out answers using the worksheet calculations
4. Compare your results with target values.

What equipment will you need?

- This worksheet and the guide
- Pressure gauge
- Vacuum (suction) gauge
- Tape measure
- Pen or pencil.

Field measurements

- Water meter readings
- Elevation at water level, pump, mainline entry and mainline exit
- Pressure readings at pump inlet and outlet
- Pressure readings at mainline entry and exit.

The more accurate your input values, the more accurate your results. Take care reading pressure and determining elevation changes. Use good equipment in good order.

If you don't already have pressure and suction gauges in place, it may take a little setting up the first time you do this testing. Next time, your equipment will already be in place.

What is acceptable?

NOTE:
In this Guideline, elevations in metres are converted to kilopascals (kPa) using specific gravity (SG). The standard factor is SG = 9.8, but if your measurements are less than 95% accurate, you could just multiply metres by 10 to get kilopascals.

HEADWORKS EFFICIENCY

Basic headworks including water meter, clean filters and gate valves, but excluding pressure control valves.

- Maximum friction head loss < 30kPa

INTAKE SIDE / SUCTION LINE

- Maximum intake suction < 60kPa
- Maximum suction velocity < 1.5m/s
  (where pipe sizes are not determined by pressure variation or velocity requirements)

HYDRAULIC (MAINLINE) EFFICIENCY

- Mainline friction loss < 100kPa
  (unless there is need to burn off pressure, such as in gravity supplied systems).
- Mainline friction loss 4–12kPa/100m pipe

Situation	Max Velocity
< 150mm diameter pipe	
• open end, controlled start & stop	< 3.0m/s
• uncontrolled start and stop	< 1.5m/s
>150mm diameter pipe	
• open end, controlled start & stop	<2.0m/s
• uncontrolled start and stop	< 1.0m/s

Worksheet for Delivery System Efficiency Test

Enter elevations, pressures and other data and complete the Calculations as directed. Enter information using the measurement units (e.g. kilopascals or metres) specified to ensure calculated answers have the correct units. Compare your results with standard recommendations.

TABLE A: HEADWORKS INLET EFFICIENCY

Inlet-side efficiency

a	Water surface elevation when operating – include drawdown (m)	
b	Pump inlet elevation (m)	
c	Change in elevation head (kPa) [(b – a) x SG]	
d	Water intake pressure (kPa)	
e	Pump inlet pressure (kPa)	
f	Change in pressure head (kPa) [d – e]	
g	Friction head loss (kPa) [f – c]	

Outlet-side efficiency

h	Pump outlet elevation (m)	
j	Mainline entry elevation (m)	
k	Change head (kPa) [(h – g) x SG]	
m	Pump outlet pressure (kPa)	
n	Pressure at mainline entry (kPa)	
p	Change in pressure head (kPa) [m – n]	
q	Friction head loss (kPa) [p – k]	

Total headworks efficiency

r	Total friction head loss (kPa) [g + q]	
s	Total pressure head (kPa) [f + p]	
t	Headworks Efficiency [(s – r) / s] x 100	

Excess energy cost

u	Excess headworks friction loss (kPa) [r – 30]	
v	Excess system friction ratio [u / s]	
y	Annual Energy Cost ($ pa) From Pump Efficiency Test	
z	Annual energy loss cost ($ pa) [w x y]	

TABLE B: MAINLINE EFFICIENCY

a	Mainline entry elevation (m)	
b	Mainline exit elevation (m)	
c	Change in elevation head (kPa) [(b – a) x SG]	
d	Mainline entry pressure (kPa)	
e	Mainline exit pressure (kPa)	
f	Change in head (kPa) [d – e]	
g	Friction head loss (kPa) [f – c]	
h	Excess mainline friction (kPa) [100 - g]	
j	Mainline length (m)	
k	Friction loss (kPa/100m) [g / j x 100]	
m	Excess mainline friction (kPa/100m) [12 - k]	

Excess energy cost

n	Excess mainline friction loss (kPa) [greater of h or m]	
p	Excess system friction ratio [n / f]	
q	Annual Energy Cost ($ pa) From Pump Efficiency Test	
r	Annual energy loss cost ($ pa) [p x q]	

TABLE C: PIPE VELOCITIES

a	System flow rate (m^3/hr)	
b	Intake pipe internal diameter (mm)	
c	Intake pipe section area (m^2) [3.14 x (b / 2000) 2]	
d	Intake pipe velocity (m/s) [(a / 3600) / c]	
e	Excess intake velocity (m/s) [d – 1.5]	
f	Mainline internal diameter (mm)	
g	Mainline section area (m^2) [3.14 x (f / 2000) 2]	
h	Mainline velocity (m/s) [(a / 3600) / g]	
j	Standard velocity max for conditions (m/s) [from Guidelines p2]	
k	Relative velocity (m/s) [h - j]	

Pump efficiency guidelines

What is the irrigation test about?

The purpose of this trrigation test is to determine the energy efficiency of the motor and pump combination feeding the irrigation system.

The test is designed so irrigation managers can do testing and calculations themselves. As well as this guideline, a worksheet is available to assist. If findings are unexpected, or suggest low performance, consider getting professional advice.

A full irrigation pump performance test must be performed by a trained service provider with appropriate testing equipment.

Why check pump performance?

Profitability – Incorrectly sized or physically deteriorated pumps will waste energy and money. A good pumping system saves money!

Sustainability – Efficient pumping minimises energy use and carbon emissions. A good pumping system saves the environment!

Pump and motor selection are important system design considerations. Incorrectly sized pumps and/or motors will not operate at their most efficient points. So they will waste energy.

Low pressure is a common cause of poor irrigation uniformity which reduces overall system effectiveness and efficiency. The pump must provide adequate pressure and flow to ensure the system operates as designed.

Excessive pressure affects performance and wastes energy. Pump selection will usually allow about 5% extra pressure capacity to allow for slippage with time. But excessively oversized pumps are major energy wasters.

What is involved?

Measured flow rates are combined with energy consumption information. This allows calculation of the energy efficiency of the motor and pump combination, operating as tested.

The process should be repeated if there are significantly different operating conditions, essentially varying flow and/or pressure.

NOTE:
Using this method, the intake pipe efficiency is included as part of the overall pump efficiency calculated. In multiple pump systems, it is possible to analyse each pump separately if pressures between pumps can be measured.

What will the testing show?

The main things the calibration test will show are:

- **Energy consumed**
  The kWh or diesel energy used to run the system; hourly and annually.
- **Pump efficiency**
  How much of the energy consumed (and paid for) is used to do useful 'work' driving the irrigation system.
- **Pump performance**
  How well the pump compares with typical values for that type and size of equipment.
- **Annual energy cost and savings**
  How much energy and money would be saved if the pump was operating at typical performance levels.

What needs to be done?

1. Gather information about the system
2. Record the data on the worksheet
3. Calculate answers using the worksheet and guide.

When should testing be done?

Complete the efficiency test when commissioning a new system and after any major changes to the pump or irrigation system. Testing should be repeated as part of system checks at the start of every season. Compare with past results to identify slippage or failures.

What are the test's limitations?

The irrigation pump efficiency test will only provide information for the conditions measured, running at a given flow and pressure with a given depth to water. The energy use and efficiency will change if system pressure or flow changes or if the water table moves up or down.

The efficiency value determined is for the motor and pump combination. It is not easy to separate the individual performance of the motor or the pump. By looking at typical values, some indication is possible.

Get professional help if your results show low efficiency.

What is acceptable?

Using an oversized pump will result in higher operating costs. The pressure at the nozzle (the end nozzle if there is more than one) gives best guidance to adequacy of system pressure.

New pumps may have spare capacity to allow for wear. However, if the system pressure is more than 5% over the sprinkler operating requirement, or if partially closed gate valves or pressure regulators are installed to 'burn-off' pressure, it is likely you are wasting energy and money.

It is usually more economical in the long term to select the most efficient pump, even if it requires higher initial outlay. Replacing incorrectly sized motors or pumps can often have a quick payback.

The efficiencies of both the pump itself and the motor are combined for overall efficiency. So, for example, a 90% efficient motor on a 70% efficient pump is only 63% efficient overall ($0.9 \times 0.7 = 0.63$).

Check manufacturer's data sheets to determine the expected efficiency of your pump-motor combination. They should be selected to operate at or near their maximum efficiency points as much as possible.

Table 1 gives guidelines for expected efficiencies, based on motor size and assuming the pump is matched appropriately to the motor.

Why does efficiency change?

There are two basic reasons for a pump being inefficient:

1. it has physically deteriorated, and/or
2. it is not suitable for the required operating conditions (i.e. required flow and pressure).

Most irrigation systems are powered by electric motors or internal combustion engines, sometimes both. In general, electric motors are more energy efficient than diesel engines, which are usually more efficient than petrol engines.

Differences in potential efficiencies between standard electric motors are generally small (1–5%), but as the motor is at the start of the drive train the savings achieved by an efficient motor and motor operating at its best efficiency point can be substantial.

Changing flow or pressure requirements will change the pump operating point, and can move from its optimum to a less efficient performance.

If pump loads fluctuate widely or if pumps are often run at partial loads, adding a variable speed drive may be cost effective since it closely matches output to actual demand. An alternative is to use multiple pumps turning on or off to optimise to different operating conditions.

Table 1. Typical electric motor and pumping plant efficiencies by motor size

Electric motor kW	Efficiency % of full load motor	Efficiency % of correctly matched pump	Overall efficiency % pump & motor
2 – 4	80 – 86	55 – 65	44 – 56
5 – 7.5	85 – 89	60 – 70	51 – 62
10 – 22	86 – 90	65 – 75	56 – 68
30 – 45	88 – 92	70 – 80	62 – 74
> 55	90 – 93	75 – 85	68 – 79

Source: North Carolina Cooperative Extension Service, Publication Number: AG 452-6

NOTES:

Pump type variations:

1. Values shown are typical for centrifugal pumps.
   - Under 55kW submersible pumps range 3–5% higher and turbine pumps range 5–10% higher.
   - Above 55kW, centrifugal pumps may approach efficiencies of 88%, whereas large submersible and turbine pump efficiencies peak at about 90%.
2. Overall Pump Efficiency ranges are obtained by multiplying the Full Load Motor Efficiency range by the Matched Pump Efficiency range e.g. 80% × 55% = 44% (on a calculator $0.80 \times 0.55 = 0.44$)

Converting values for typical fossil fuels to usable energy values:

1. NZ Diesel contains 10.4kWh per litre but only about 3.5–4.0kWh / L of useful energy are generated
2. NZ 91 Petrol contains 9.69kWh per litre but only about 2.5–2.8kWh / L of useful energy is generated.

The usable energy values for diesel and petrol above are already adjusted for engine efficiency.

If using them as 'Power Conversion' factors in Step 1B: Fossil Fuel, use values from the Matched Pump Efficiency column rather than the Overall Pump Efficiency column as the 'Typical' Pumping Plant Efficiency in Step 4.

Example worksheet for Pump Efficiency Test

Enter times, meter readings, elevation and pressure data. Complete the calculations as directed. Enter information using the measurement units (e.g. kWh or metres) specified to ensure calculated answers have the correct units.

Determining performance

The effective efficiency of your pump and motor combination can be estimated from power readings, flow rates and pressures. The information should be easy to obtain, and calculations needed are set out below.

What equipment will you need?

- This guide and the worksheet
- Stop watch
- Measuring jug (for fuel tank topping)
- Pressure gauge
- Tape measure
- Pen or pencil.

Field measurements

- Test duration
- Power meter readings
- Fuel used
- Water meter readings
- Pressure generated
- Height from water level to pump outlet.

Step 1: Energy use

The rate of energy use is measured in kilowatts (kW) and whether your pump runs on electricity or fuel or both, you need to calculate the kilowatt consumption.

If you have more than one pump, add the energy use rates to get a total. It doesn't matter if you have a combination of electric and diesel, because we calculate energy use rate in the same units (kW).

A Electricity meters show energy consumption in kilowatt hours (kWh) – the combination of energy use rate (kW) and time (hours). Watch though, many have a 'multiplier value' you must include.
Divide kilowatt hours consumed by hours taken to calculate the kilowatts. (kWh / h = kW).

B Diesel and petrol engine fuel use is most easily measured by measuring the amount required to refill the tank. Do this accurately after a set running time.
Convert fuel energy to kWh equivalent values.

Step 2: Water consumption

Hopefully there is a correctly calibrated water meter in the system to show flow rate.

If so; follow **Step 2** to record and calculate water use.

If not; determine flow rate from field measurements by doing an irrigation calibration.

Step 1 A: Electricity

		Pump 1	Pump 2
a	Test Duration (hours)	1.0	
b	Meter kWh Start	34,657.6	
c	Meter kWh End	34,712.5	
d	Meter kWh Used [c – b]	54.7	
e	Meter Multiplier	1.0	
f	Energy Used / Hour (kW) [d x e / a]	54.7	
g	Energy Cost ($ / kWh)	0.12	
h	Annual Run Time (h)	1,500	
i	Annual Energy Use (kWh) [f x h]	82,050	
k	Annual Energy Cost ($ pa) [g x j]	9,846	

Step 1 B: Fossil Fuel

		Pump 1	Pump 2
a	Test Duration (hours)	1.0	
b	Fuel Used (L)	20.0	
c	Energy Conversion (kWh/L) [from Table 1]	4.0	
e	Fuel Cost ($/L)	1.1	
f	Energy Used / Hour (kW) [b x c / a]	80.0	
g	Energy Cost ($ / kWh) [e / f]	0.275	
h	h Annual Run Time (h)	1,500	
j	Annual Energy Use (kWh pa) [f x h]	33,000	
k	Annual Energy Cost ($ pa) [g x j]	9,075	

Step 2: Water Use

a	Test Duration (hours)	1.0
b	Meter m³ Start	4,126,585
c	Meter m³ End	4,126,712
d	Meter m³ Used [c – b]	192
e	Meter Multiplier	1.0
f	Water Used (m)³ [d x e]	192
g	Water Flow Rate (m³/h) [f / a]	192
h	Annual Run Time (h)	1,500
j	Annual Water Use (m³ pa) [g x h]	288,000

Step 3: Rate of work done

The rate of work done by a pump is calculated from the water flow rate, lift (change in elevation × specific gravity) and increase in Pressure Head.

ELEVATION HEAD (LIFT)

Elevation head refers to the lift from the source water level to the pump discharge. It is the lift from the actual water level when the pump is running (drawn down) to the centre of the pump outlet.

Elevation head is usually positive, but if the water level is higher than the pump (e.g. a dam), the elevation change is recorded as a negative value.

Specific Gravity (SG) accounts for the force of gravity. SG = 9.8, but you could just multiply metres elevation change by 10 to get approximate kilopascals Head.

In these calculations, a further adjustment of 3600 is required to convert flow per hour to flow per second.

PRESSURE HEAD INCREASE

The system intake is usually not pressured. (Water depth above intakes or submerged pumps is taken into account already, as we measure from the water surface level to the pump for Elevation Head.)

However, if there is positive head on the intake from a primary pump, this pressure needs to be subtracted to get the increase in pressure generated by the pump you are testing.

The pump is working to overcome friction in the intake side of the headworks. To account for this, add the friction determined using the delivery system efficiency guidelines.

OUTLET PRESSURE

The outlet pressure is read directly from a pressure gauge mounted at the pump outlet. Most systems have this facility, but make sure the gauge is in good condition.

Replace it if necessary.

Step 4: Pump efficiency

Pump efficiency shows how much of the energy consumed does useful work. It is usually given as a percentage.

In the examples here, energy use rate (kW) is easily compared to calculated work done. (The example calculation values in Fossil Fuel Use are ignored.)

RELATIVE PERFORMANCE

Select a reasonable value for your situation from Table 1 and compare it with the calculated efficiency for your actual pumping plant. The relative performance is usually given as a percentage.

Efficiency cost

The potential savings are calculated from the annual cost and the relative performance value determined.

In the worked example, the cost of energy for a pumping plant with 48.6% efficiency is 44% more than a typical plant running at 70% efficiency.

Step 3: Work Done

a	Elevation Change (m)	7
b	Elevation Head (kPa) [a x SG]	69
c	System Intake Pressure (kPa)	0
d	Pump Outlet Pressure (kPa)	414
e	Pressure Head (kPa) [d – c]	414
f	Inlet-side Friction (kPa) [from Delivery Efficiency Worksheet]	16
g	Total Dynamic Head (kPa) [b + e + f]	499
h	Water Flow Rate (m³/h) [g from Step 2]	192
j	Work Done (kW) [g x h / 3600]	26.6
k	Design Outlet Pressure (kPa) [from Design Details]	430
m	Outlet Pressure Deviation (kPa) [d – k]	-16
n	Outlet Pressure Deviation % [m / k x 100]	-3.7

Step 4: Pump Efficiency

a	Electric Power(kW) [from Step 1 A: f]	54.7
b	Fossil Fuel Power (kW) [from Step 1 B: d]	OPTION
c	Total Power (kW) [a + b] 54.7	54.7
d	Work Done (kW) [from Step 3: j]	26.6
e	Overall Pump Efficiency % [d / c) x 100]	48.6
f	Typical Efficiency [from Table 1]	70.0
g	Relative Performance % [e / f x 100]	69.4

Efficiency Cost

h	Electricity Cost ($ pa) [from Step 1 A: j]	9,846
j	Fossil Fuel Cost ($ pa) [from Step 1 B: h]	OPTION
k	Total Energy Cost ($ pa) [h + j]	9,846
m	Typical Efficiency Cost ($ pa) [k x g / 100]	6,833
n	Annual Cost Saving ($ pa) [k – m]	3,013
p	Annual Water Use (m^3 pa) [from Step 2: j]	288.000
q	Pumping Energy Cost ($/$m^3$) [k / p]	0.034
r	Power Demand (kW/m^3) [Step 1: f / Step 2: g]	0.284

Pump efficiency worksheet

What is the irrigation test about?

The purpose of this irrigation test is to determine the energy efficiency of the motor and pump combination feeding the irrigation system.

The test is designed so irrigation managers can do testing and calculations themselves. As well as this worksheet, a guideline is available to assist.

Determining performance

The effective efficiency of your pump and motor combination can be estimated from power readings, flow rates and pressures. The information should be easy to obtain, and calculations needed are included in the tables and explained in the Guidelines.

What needs to be done?

1. Gather information about the system
2. Record the data on the worksheet
3. Calculate answers using the worksheet & guide

When should testing be done?

Complete the efficiency test when commissioning a new system and after any major changes to the pump or irrigation system.

Testing should be repeated as part of system checks at the start of every season. Compare with past results to identify slippage or failures.

Equipment you will need

- This worksheet and the guidelines
- Stop watch
- Measuring jug (for fuel tank topping)
- Pressure gauge
- Tape measure
- Pen or pencil.

Field measurements

- Test duration
- Power meter readings
- Fuel used
- Water meter readings
- Pressure generated
- Height from water level to pump outlet.

Step 1: Energy use

For each pump, calculate energy use rate in kW. Add energy use rates of multiple pumps to get the total.

A Electricity meters show energy consumption in kilowatt hours (kWh). Include any 'multiplier value'.
Divide kilowatt hours consumed by hours taken to calculate the kilowatts. (kWh / h = kW).

B Diesel and petrol engine fuel use must be converted to kWh equivalent values.

Step 2: Water consumption

Follow Step 2 to record and calculate water use.

If no meter: Determine flow rate by doing an irrigation calibration.

Step 3: Rate of work done

The rate of work done by a pump is calculated from the water flow rate, lift (change in elevation × specific gravity) and increase in Pressure Head.

ELEVATION HEAD (LIFT)

Elevation head is the lift from drawn down water level to centre of pump outlet. Usually positive, but negative if water level is higher than the pump.

Specific Gravity (SG) accounts for the force of gravity. Divide by 3600 to convert flow/hour to flow/second.

PRESSURE HEAD INCREASE

If there is positive head on the intake from a primary pump, subtract it to get pressure generated by pump.

If possible, add the intake pipe friction determined using the delivery system efficiency test.

OUTLET PRESSURE

Read directly from a pressure gauge at pump outlet. Ensure gauge is in good condition. Replace it if not.

Step 4: Pump efficiency

Shows how much of the energy consumed does useful work. It is usually given as a percentage.

RELATIVE PERFORMANCE

Select a reasonable value for your situation from Guidelines Table 1 and compare it with the calculated efficiency for your actual pumping plant. The relative performance is usually given as a percentage.

EFFICIENCY COST

The potential savings are calculated from the annual cost and the relative performance value determined.

Worksheet for Pump Efficiency Test

Enter times, meter readings, elevation and pressure data. Complete the calculations as directed. Enter information using the measurement units (e.g. kWh or metres) specified to ensure calculated answers have the correct units.

Step 1 A: Electricity

		Pump 1	Pump 2
a	Test Duration (hours)		
b	Meter kWh Start		
c	Meter kWh End		
d	Meter kWh Used [c – b]		
e	Meter Multiplier		
f	Energy Used / Hour (kW) [d x e / a]		
g	Energy Cost ($ / kWh)		
h	Annual Run Time (h)		
i	Annual Energy Use (kWh) [f x h]		
k	Annual Energy Cost ($ pa) [g x j]		

Step 1 B: Fossil Fuel

		Pump 1	Pump 2
a	Test Duration (hours)		
b	Fuel Used (L)		
c	Energy Conversion (kWh/L) [from Table 1]		
e	Fuel Cost ($/L)		
f	Energy Used / Hour (kW) [b x c / a]		
g	Energy Cost ($ / kWh) [e / f]		
h	h Annual Run Time (h)		
j	Annual Energy Use (kWh pa) [f x h]		
k	Annual Energy Cost ($ pa) [g x j]		

Step 2: Water Use

a	Test Duration (hours)	
b	Meter m^3 Start	
c	Meter m^3 End	
d	Meter m^3 Used [c – b]	
e	Meter Multiplier	
f	Water Used $(m)^3$ [d x e]	
g	Water Flow Rate (m^3/h) [f / a]	
h	Annual Run Time (h)	
j	Annual Water Use (m^3 pa) [g x h]	

Step 3: Work Done

a	Elevation Change (m)	
b	Elevation Head (kPa) [a x SG]	
c	System Intake Pressure (kPa)	
d	Pump Outlet Pressure (kPa)	
e	Pressure Head (kPa) [d – c]	
f	Inlet-side Friction (kPa) [from Delivery Efficiency Worksheet]	
g	Total Dynamic Head (kPa) [b + e + f]	
h	Water Flow Rate (m^3/h) [g from Step 2]	
j	Work Done (kW) [g x h / 3600]	
k	Design Outlet Pressure (kPa) [from Design Details]	
m	Outlet Pressure Deviation (kPa) [d – k]	
n	Outlet Pressure Deviation % [m / k × 100]	

Step 4: Pump Efficiency

a	Electric Power(kW) [from Step 1 A: f]	
b	Fossil Fuel Power (kW) [from Step 1 B: d]	
c	Total Power (kW) [a + b] 54.7	
d	Work Done (kW) [from Step 3: j]	
e	Overall Pump Efficiency % [d / c) × 100]	
f	Typical Efficiency [from Table 1]	
g	Relative Performance % [e / f × 100]	

Efficiency Cost

h	Electricity Cost ($ pa) [from Step 1 A: j]	
j	Fossil Fuel Cost ($ pa) [from Step 1 B: h]	
k	Total Energy Cost ($ pa) [h + j]	
m	Typical Efficiency Cost ($ pa) [k x g / 100]	
n	Annual Cost Saving ($ pa) [k – m]	
p	Annual Water Use (m^3 pa) [from Step 2: j]	
q	Pumping Energy Cost ($/$m^3$) [k / p]	
r	Power Demand (kW/m^3) [Step 1: f / Step 2: g]	

NOTES

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