New Zealand Piped Irrigation System Performance Assessment Code of Practice

PART C: Micro-irrigation

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

Part C: Contents

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 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
Manatū Ahu Matua

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 C is specific to micro-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.

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**

System description

A micro-irrigation system consists of a network of lateral pipelines fitted with low discharge emitters or sprinklers. It is characterised by watering only part of the total soil area. Water is discharged under low pressure from emitters mounted on or built into the laterals which may lie on or above the soil surface or, in the case of drip, be buried below the ground in the crop root zone.
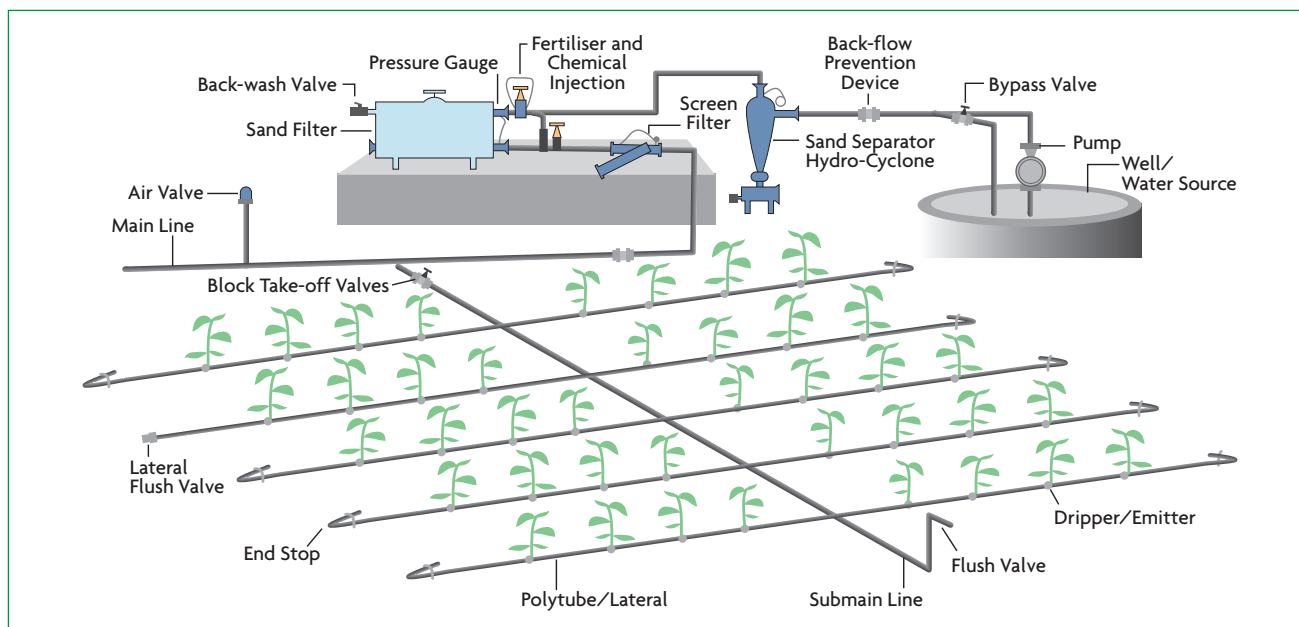

Figure 3.1. Components and layout of a drip irrigation system. Based on a diagram from Jain Irrigation.

Special features for analysis

SOIL MOISTURE

The behaviour of water in the drip wetted zone is influenced by conditions existing in the soil at the time, and by previous irrigation practices.

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.

PRESSURE COMPENSATING EMITTERS

Pressure compensating emitters are designed to give even discharge across a range of working pressures. Their performance is imperfect and the pressure:flow relationship of these emitters can vary across the range.

DISTRIBUTION 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 characteristics and variation in manufacture.

In older systems, these influences are compounded by damage to and deterioration of components, and by physical blockages of very small orifices. The nature of the system, with low pressures and very small orifices, requires that water quality be high.

PERMANENT SET SYSTEM

Because drip irrigation systems are typically set, each plant receives water from the same emitter(s) each time it is irrigated. Non-uniformity is repeated so there is an increased demand for high uniformity. There is no 'smoothing' effect as with moving systems, where non-uniformities vary between events and tend to cancel.

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 water.

SMALL ROOT FRACTION WETTED

Most 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 micro-irrigation system, a given volume of water soaks further into the soil. Care must be taken to avoid deep drainage losses.

FIELD VARIABILITY

The performance of drip 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.

FIELD ELEVATION

If the field is level, the hydraulically closest and furthest points for the headworks will normally have the highest and lowest inlet pressures respectively. These will be sampled as part of the basic testing procedure.

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.

1. Operational checklist

This is a minimum list of checks of drip or micro 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

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

Emitters
9. Check emitter fitted are as specified in nozzle chart
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 correctly
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. 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 Emission Uniformity.

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 water evenly across the irrigation station.

By repeating the process in each irrigation station, a plan to apply target depths in each station across the whole property can be determined.

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 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.

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 measurements are truly representative of system performance.

Application intensity
The rainfall equivalent depth of water being applied per hour.

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 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.

Micro irrigation system performance is largely unaffected by weather conditions. But performance can be influenced if alternative water takes significantly alter 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:

- 3–12 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 (30–50m)
- 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.

Follow placement instructions carefully and read volumes as accurately as possible to be sure of best results.
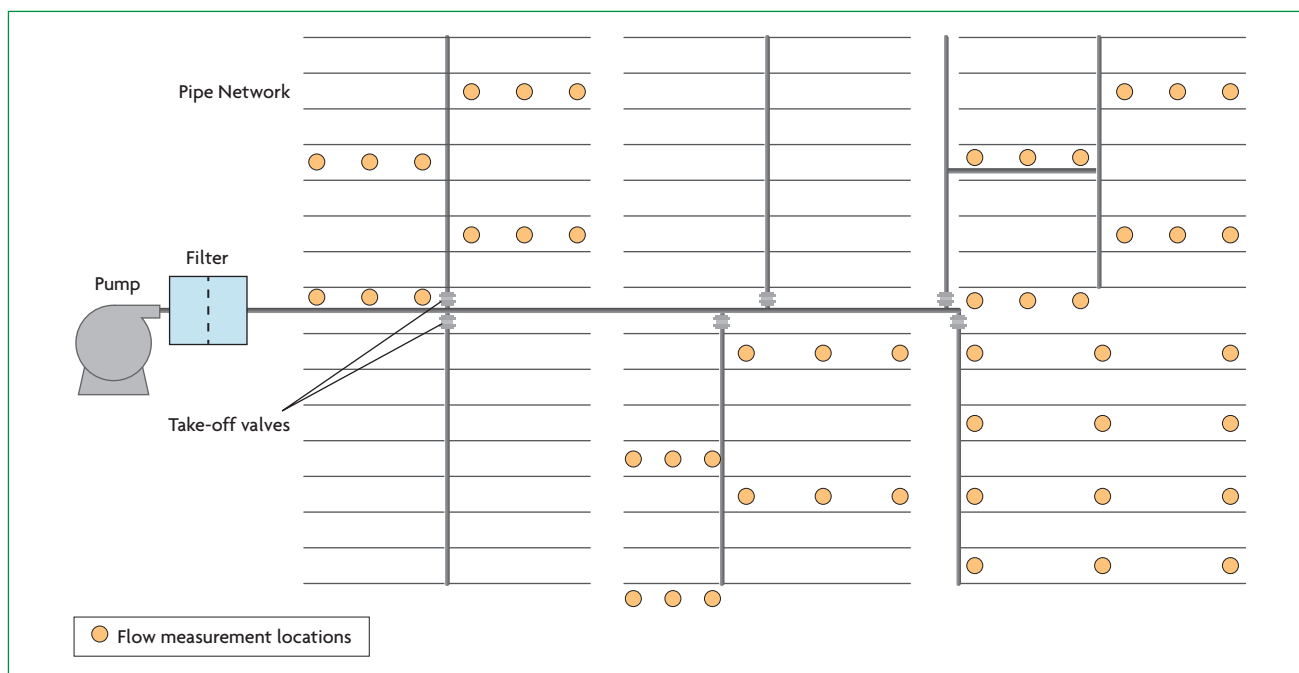
Figure 2.1. Recommended locations for emitter or sprinkler flow measurements for micro-irrigation calibration.

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

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.

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 ÷ collection time 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* (m³/h)
[Application Intensity x Station Area x 10]

Applied depth

5. Calculate *Mean Station Applied Depth* (mm)
[Application Intensity x Run Time]

6. Calculate *Soil Applied Depth* (mm)
[Applied Depth x Fraction Wetted]

7. Fraction Wetted = Wetted Strip Width ÷ Lateral Spacing

Emission uniformity

8. Calculate the *Emission Uniformity*
[Low quarter average volume ÷ average volume]

9. Calculate *Low Quarter Average Volume* (mL)
[Average of lowest 3 emitter volumes].

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

3. Compare calculated Station Flow Rate with Water Meter Flow Rate

Applied depth

4. 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)

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

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. Performance assessment of micro-irrigation systems

This schedule presents procedures for conducting efficient and reliable irrigation evaluations of micro-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.

Procedures are presented for assessing distribution uniformity of irrigation systems applying water through 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 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 farmer 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 made in three areas representing the cleanest, average and dirtiest parts of the system assess emitter performance and variability
- Station by station emitter discharge tests determine station specific application intensities
- Pressure sampling determines if the system is within the working pressure range specified by the emitter manufacturer and enables calculation of the pressure:flow relationship.

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 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 profile along a typical lateral.

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 by client and tester
   - Ensure the pressure is maintained during the test.
   - Ensure pressure measurements include lowest and highest areas.

Injection devices

2. If the system is designed with an injection device that is normally operative, perform the test with the injection device operating. 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

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. Note any soil features that indicate wetness, poor drainage or related properties and identify causes

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 drip 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).
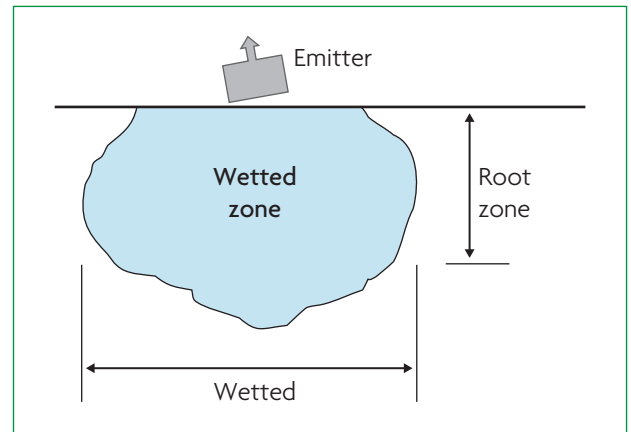

Figure 3.1. Wetting pattern under micro-irrigation outlet.

Emitters/sprinklers

11. Record details of the type of emitters or 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 system failure, in particular sprinkler or emitter blockage.

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.

Filtration

13. Identify the type(s) of filter fitted

14. Check filters and note nature and degree of contamination or blockage

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 lowest most distant ends through a nylon filter (sock)

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. 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 may require destruction, so ensure spares are available.

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

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

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 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 off-take

NOTE:
The pressure at the start of the first lateral (see Figure 3.2 below) may be a substitute measurement for off-take pressure.

Distribution network pressures

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

NOTE:
Measure a minimum of three 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.

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)
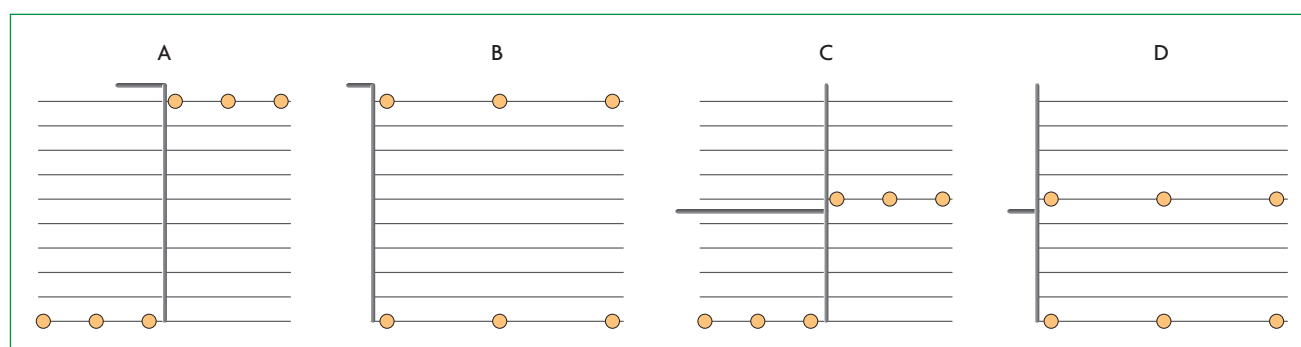

Figure 3.2. Location of positions for pressure testing

Lateral filter pressure loss

8. If there are in-line filters or strainers fitted at the beginning of laterals, randomly sample five filters from the 'dirtiest' station

   ▪ Record the pressure in each lateral with the filter in-place, then remove the filter element and record pressure with it out

   ▪ 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 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 placed either side of the emitter help avoid 'dribbles' along the lateral tubing.

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 convenient.

Measure the Emitter Discharges at three different locations, representing the 'cleanest', 'average' and 'dirtiest' areas within the system (Figure 3.2 A–C).

NOTE:
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 9–10L container.

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.

2. Measure the discharge of sixteen (16) adjacent emitters (or dripline sections) near the middle of the lateral closest to the off-take.

NOTE:
This test can be repeated at different pressure to determine the pressure:flow relationship (see below)

Average area uniformity test
NOTE:
This test should be conducted in an area typical of average conditions for the system. It is likely to be somewhere in the middle of the station, neither close to nor very far from the headworks and filters (Figure 3.2 B).

3. Measure the discharge of sixteen (16) adjacent emitters (or dripline sections) near the middle of a lateral near the middle of the manifold

NOTE:
For this and the 'clean area' tests, a sample size of 16 is sufficient assuming the system is clean and emitter variability is low.

Dirtiest area uniformity test
NOTE:
Usually the dirtiest location (that 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.

4. Measure the discharge of twenty eight (28) adjacent emitters (or dripline sections) at the end of the lateral at the end of the manifold

NOTE:
A larger sample set is used for this test to account for the greater variability that can be anticipated.

Adjusted pressure test – cleanest area
NOTE:
NOT USED when evaluating pressure compensated systems as the pressure flow relationship is NOT CONSTANT across the pressure range.

5. Adjust the pressure in the Cleanest Area station by at least 20%

6. Measure the discharge of the same sixteen (16) adjacent emitters (or dripline sections) used in the Clean Area Uniformity Test (Figure 3.2 A).
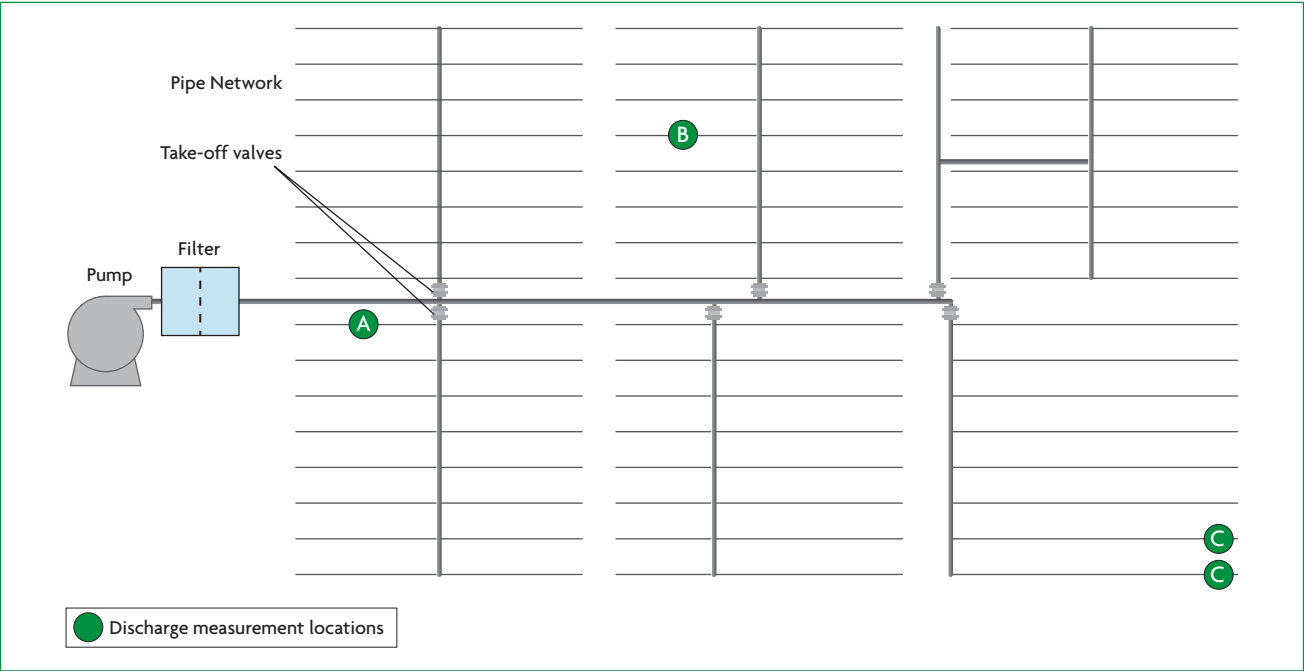
Figure 3.2. Multiple emitter flow measurement locations.

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 3.3)

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

SYSTEM ENERGY USE

1. Obtain energy consumption data for the period covered by flow measurement

NOTE: This information is related to system pressures and volume pumped to determine energy efficiency and cost.

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. This can be determined in the field and compared with manufacturer's quoted values.

Pressure compensating emitters

Pressure compensating emitters attempt to ensure even discharge across a range of working pressures. The pressure:flow relationships of these emitters is not constant across the working range.

NOTE:

Because of the unpredictable nature of pressure:flow in compensating emitters or sprinklers, the PRESSURE:FLOW RELATIONSHIP IS NOT USED in assessment of causes of flow variation in these systems.

PERFORMANCE INDICATORS

Application intensity

1. Calculate *Application Intensity*

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

   NOTE: Unlike other systems, application intensity is not generally considered as a limit based on soil infiltration rates. Some ponding may increase the area wetted under point or line source emitters.

Applied depth

2. Adjust the *Volume Applied* by the area served to ensure that the depth of irrigation water applied is comparable with PET and water consumption

   NOTE: Under micro-irrigation, not all the area available for plants is wetted.

Infiltration depth

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

   NOTE: The volume applied per irrigation is delivered to a fraction of the area available. The infiltration depth estimates the depth to which the wetting front will progress under the emitter.

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

System uniformity

Distribution uniformity (DU_{LQ})

Field DU_{lq} is determined from a base value of distribution uniformity adjusted to account for other contributing factors. The relative contribution made by each variable is estimated. This identifies those factors where system alterations may have most effect. Importantly, independent assessment of individual Stations allows management interventions if Mean Station Application Intensities vary.

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.

NOTE:

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

Emission 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.

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 will be imperfect but 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.

EU strictly 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 strictly 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 0Figure 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.

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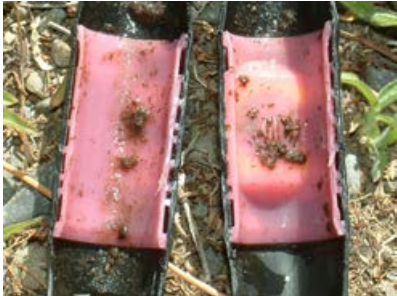
Figure 2. Dripper cut open to inspect for contaminants or other damage.

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 (m²)	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 (m³/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.
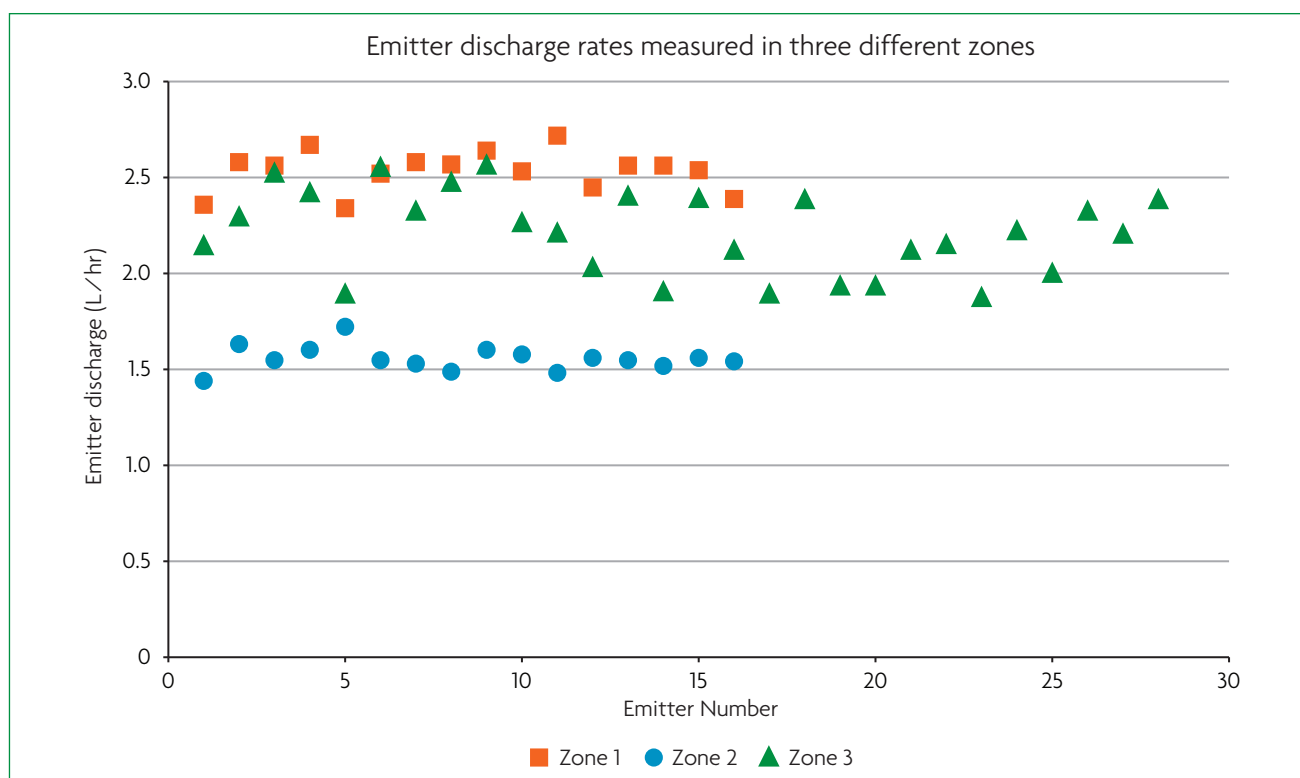

Figure 3. Emitter discharge rates measured in three different zones

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 microirrigation 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.
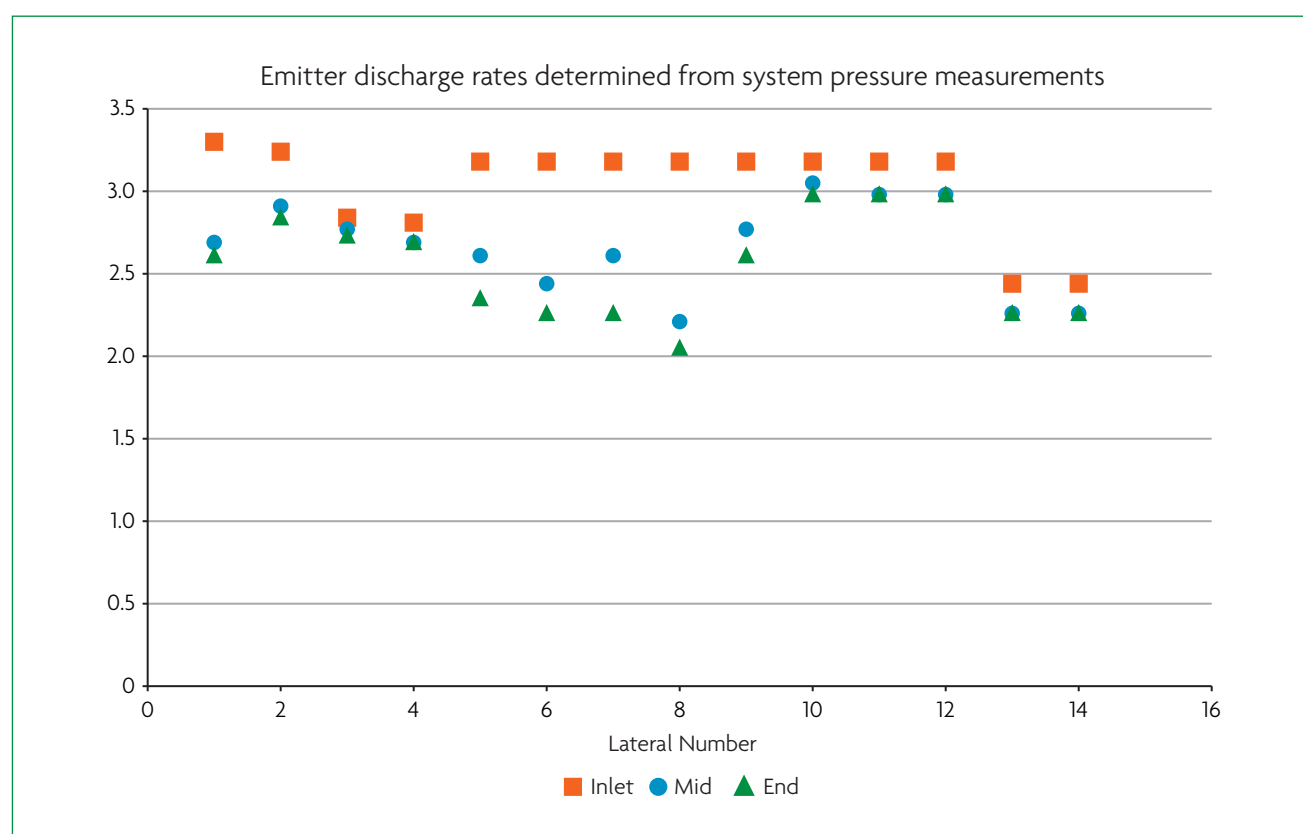

Figure 4. Emitter Discharge Rates determined from pressure measurements in driplines

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.