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).

Part G: Contents

Date of Issue: February 2015

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.

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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 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**

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)

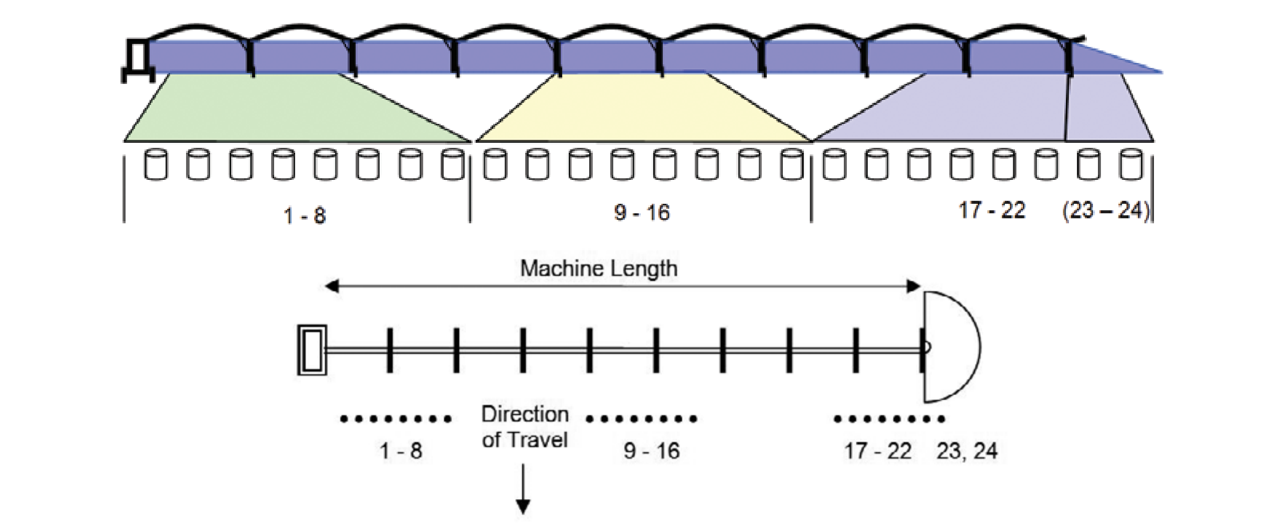

Figure 2.1. Layout of collectors along length of linear move irrigator

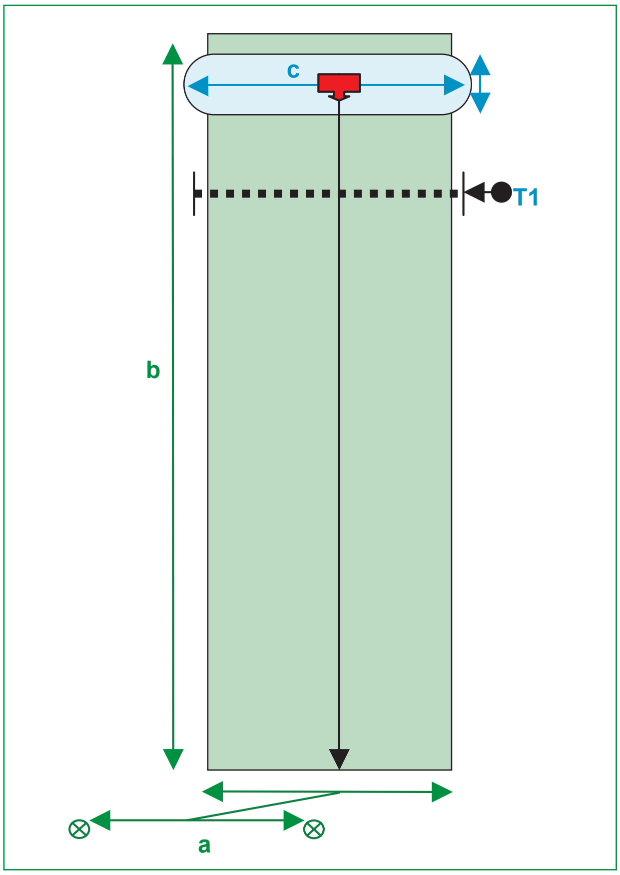

Figure 2.2. Layout of calibration test of linear move irrigators

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

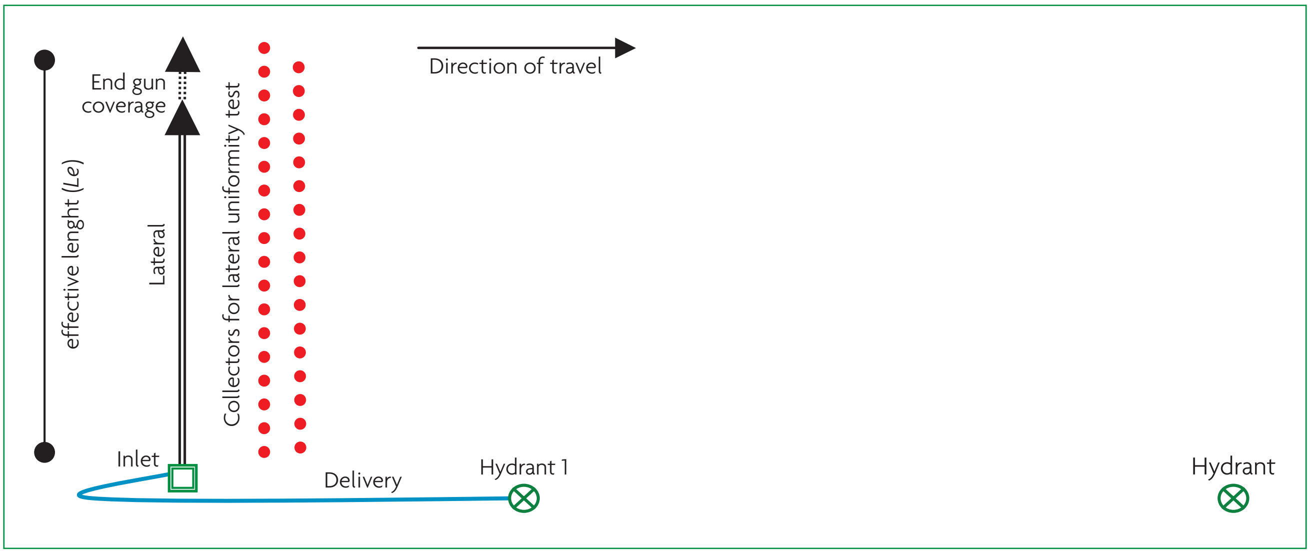

Figure 3.1. Layout of test site for linear move application testing

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.

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

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, either side of a radial line starting about 20% of the way along the lateral (Figure 3.1)
   - 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

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. 2Calculate 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.

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.