CHAPTER 4. Irrigation System Evaluations

4.1 Introduction

The major function of the mobile irrigation lab is to evaluate irrigation systems and to provide recommendations to landowners for the purpose of water conservation. Evaluating an irrigation system consists of measuring its performance and identifying problems that prevent the system from operating at its optimum level. There are many types of irrigation systems, but the process by which they are rated is similar for all pressurized pipe irrigation system types. The performance can be measured as the uniformity with which the water is distributed to the crop by the irrigation system, and the percentage of the applied water that reaches the crop's root system.

Before any field evaluation is done on an irrigation system, the MIL should verify in advance with the irrigation system owner or operator if the irrigation system is operating under normal/typical conditions. If that is not the case, the MIL should not proceed with the evaluation and should schedule a future date to do the evaluation when the irrigation system is operating under normal/typical conditions.

4.2 Performance Terms

The following terms are used to describe irrigation system performance:

Christiansen's Coefficient of Uniformity (CU) – A measure of the uniformity of irrigation water application. The average depth of irrigation water infiltrated minus the average absolute deviation from this depth, all divided by the average depth infiltrated. CU is expressed as a percent. The CU value indicates on average how uniform the sprinkler application pattern is. CU gives no indication of how bad a particular localized area might be, or how big that critical area might be.

Distribution Uniformity (DU) - A term used for sprinkler systems, it is the uniformity with which the water is distributed over the field surface. Measured with catch cans, it is the ratio of the average amount of water caught in the lowest fourth of the catch cans, to the overall average. DU is expressed as a percent. A DU less than 70% would indicate poor performance. A DU between 70% and 90% would indicate good performance. A DU greater than 90% would indicate excellent performance.

Effective Portion of Water Applied (Re) - The effective portion of water applied that reaches the soil-plant surface. This is a measurement of the amount of water that evaporates before it reaches the catch cans. For systems with high application rates, the Re should be one, but for systems with low application rates, especially when tested during hot weather, the Re could be less then one.

Emission Uniformity (EU) - A term used for microirrrigation (drip or microjet) systems, this is the uniformity with which the water is applied to the individual trees or plants. It is a ratio of the average of the low fourth of the emitter discharge rates to the overall average, expressed as a percent. Emission uniformity is considered excellent above 90%, good 80% to 90%, fair 70% to 80% and poor below 70%.

Potential or Maximum DU or EU Efficiency - This is a measure of the best possible or maximum DU or EU, for each type of irrigation system. Such DU's or EU's have been obtained for several irrigation systems via field testing by the irrigation industry and/or research community over the years; they have also been verified via actual field evaluations the MILs have conducted over the years on different types of irrigation systems. The USDA NRCS has compiled a table of maximum

DU's or EU's, which can be found in the Florida Supplement to the USDA NRCS National Engineering Handbook (NEH), Part 652- Irrigation, Chapter 15, Table FL 15-1, System Potential Efficiencies. This document can be found at http://www.fl.nrcs.usda.gov/technical/irrigation.html

A revised version of that table is shown in Chapter 7 of this Handbook, which reflects any updates to any maximum DU's or EU's that the MILs and the ICC have reviewed and approved over the years, based on their own evaluation results and/or new industry or research tests and results.

Application Efficiency (Ea) - This is a measure of the efficiency based on the current operating time. It is calculated by dividing the average depth of water stored in the plant root zone by the amount of water applied, diverted or pumped. Application efficiency accounts for all losses between the pump and the plant, including system leaks, evaporation, spray drift, deep percolation, and runoff.

For subirrigation systems, the application efficiency is estimated by using the NRCS FIRM method which considers many system and management factors. Application efficiency above 70% is considered good for this type of system.

4.3 Evaluation of Microirrigation Systems

The recommended procedure for evaluating microirrigation (drip or microjet) systems is presented in the NRCS National Engineering Handbook (NEH), Part 652, Irrigation, Guide, Chapter 9 (Pages 9-163 to 9-173) and the FL NRCS approved *microirreval.xls* computer program. The microirrigation evaluation (Micro-Eval) program uses the procedure in the NEH, performs the calculations, compiles a report, and is available in Section IV, C. Tools, Florida Engineering Computer Programs of the electronic Field Office Technical Guide-eFOTG/Florida which is located on the FL NRCS website, (http://www.fl.nrcs.usda.gov/technical/program.html).

4.3.1 Equipment Needs

The equipment needed for the field evaluation:

1. 50 ft. tape measure
2. Pressure gauges (0-30psi, 0-60psi) with fittings
3. Stop watch
4. 100 or 1000ml graduated cylinder
5. 6 ft. soil auger
6. Blank worksheets

4.3.2 Field Procedure

The following is a description of the field procedure for evaluating microirrigation (drip or microjet) systems.

1. Start the system and let the pressure stabilize (5-10 minutes).
2. Record soil, crop, and irrigation system data on worksheet printed from Micro-Eval Excel workbook.
3. Measure and record the minimum lateral inlet pressure (MLIP) of all the operating manifolds. The MLIP is the lowest pressure in all laterals served by one manifold, measured at the lateral inlet. Record these readings on the field sheet or on a drawing for complex irrigation systems.

4. Measure the discharge (for 30 seconds for microjets-sprinklers or 60 seconds for drippers) of 16 emitters, on 4 laterals on a representative manifold.
5. Enter the ml collected on the worksheet. A and B readings may be made at two adjacent emitters if two or more emitters serve one plant. The worksheet is set up such that the manifold is horizontal across the top of the page, with the pump end on the left. The laterals are vertical, with the top reading being next to the manifold.
6. Measure the inlet and end pressure of the laterals.
7. Measure the wetted area per plant.

4.3.3 Calculations

$$Emitter\ Discharge\ Rate, q\ (gph) = \frac{Catch\ in\ ml\ \times 0.951}{Seconds}$$

This is calculated for the 16 emitters.

$$Average\ Emitter\ Discharge\ Rate, q\ (gph) = \frac{sum\ of\ all\ averages, gph}{number\ of\ averages}$$

$$Low\frac{1}{4}\ Emitter\ Discharge\ Rate, q\ (gph) = \frac{sum\ of\ low\frac{1}{4}\ averages, gph}{number\ of\ low\frac{1}{4} averages}$$

The low quarter is lowest four gph measurements, regardless of location.

A discharge correction factor (DCF) is needed since the overall system average pressure may be different than the pressure in the manifold where the flow measurements were made. The DCF is a factor to calculate the system average emitter discharge rate from the test manifold average emitter discharge rate.

$$DCF = \frac{2.5\ \times average\ MLIP}{average\ MLIP\ + (1.5\ \times test\ manifold\ MLIP)}$$

$$System\ average\ discharge\ rate, gph = DCF\ \times manifold\ average\ dischrage\ rate, gph$$

$$Test\ manifold\ emission\ uniformity, EU'm = \frac{low\frac{1}{4}\ emitter\ discharge\ rate\ (gph)}{average\ emitter\ discharge\ rate\ (gph)} \times 100\%$$

$$Efficiency\ Reduction\ Factor\ (ERF) = \frac{average\ MLIP + (1.5\ \times minimum\ MLIP)}{2.5\ \times average\ MLIP}$$

$$System\ Emission\ Uniformity, EU' = EU'm\ \times ERF$$

$$Potential\ Application\ Efficiency, PELq = \frac{EU'}{T_r\ \times 1 - LR_t}$$

Where T_r = Transpiration ratio, NEH Part 623, Table 7-3

This ratio estimates losses due to untimely rainfall and variations in the soil.

LR_t = Leaching requirement ratio, NEH Part 623, Formula 7-16 or 7-17

This is to be considered if harmful soluble salts need to be removed from the root zone.

4.3.4 Analysis of Evaluation Results

The level of performance of microirrigation systems is indicated by the potential and application efficiency. A low potential efficiency indicates physical problems with the system, while low application efficiency indicates inaccurate scheduling. It is an economic decision whether the level of performance of a system is acceptable or whether improvements should be made.

If the level of performance is not acceptable, then the cause of the low efficiency must be determined. Through the evaluation process and detailed note keeping, the problems with the system can be identified. Florida NRCS conservation practice standard for microirrigation (drip or microjet) systems (Irrigation System, Microirrigation, Code 441) and pipeline (Irrigation Water Conveyance, Pipeline, Code 430) establish a basis for comparison and help identify less than acceptable system components.

The main factor that determines system performance is emitter discharge rate variation throughout the system. NRCS specifications allow no more than a 20% discharge rate variation. Since discharge rates are dependent on pressure, pressure variation will affect performance. Pressure should not vary more than 30% throughout the system. The following table lists specific test results, possible problems and possible solutions.

4.3.5 Typical Problems and Recommendations for Microirrigation Systems

Table 4 – Test Results, Problems, and Solutions for Microirrigation Systems

Test	Problems	Solution
Pressure at pump	Low pressure	Check pump specs.
	< 30 psi	Change pump
	(small wetted area)	Use smaller jets
	(clogging)	Use smaller zones
	(elevation effects)	Use higher rpm
	High pressure	Use larger jets
	(low fuel efficiency)	Use larger zones
	(caused by clogging)	Use pressure regulators
Filter inlet/outlet pressure	> 5psi difference	Clean or replace filter
Pressure between pump and first manifold (deadhead)	> 5psi difference	Use larger pipeline
		Rezone
		Increase rpm
		Check valves
Pressure between manifolds	> 2-3 psi difference	Rezone
		Control with valves
		Use larger pipe
Pressure between laterals	> 2-3 psi difference	Use additional manifolds
		Use pressure regulators

Test	Problems	Solution
Pressure variation in lateral	> 2-3 psi difference	Use additional manifolds
		Use smaller emitters
		Use higher pressure if elevation change
		Use larger tubing
Emission Uniformity	< 90%	Use same brand and type of emitter
		Clean emitters

The following list describes typical microirrigation system problems and possible solutions.

1. Low System Pressure - The overall pressure found in the system is lower than normally used in this type of system. The pressure could be increased by irrigating smaller or fewer zones at one time or by increasing pump rpm.
2. Filter Clogged - The pressure loss was higher than normally seen for this type of filter. The filter should be flushed and the screen cleaned. If cleaning the filter does not reduce the pressure loss, then check the pressure gauges for accuracy and install a higher capacity filter if necessary. Screen filters usually have no more than 5 psi loss between the inlet and outlet.
3. Mainline Pressure Loss - Excessive pressure losses were found in the mainline. This reduces efficiency, since a higher pumping head is required to deliver adequate pressure to the emitters. Possible solutions are to divide the flow between mainlines by changing the zones that are operated at one time or to install additional mainlines.
4. Different Pressures between Manifolds - The average pressure varied between the submains. Valves should be installed or existing valves should be used to equalize pressure between submains to make pressure and flow more uniform throughout the system.
5. Poor Emission Uniformity - Poor emission uniformity reduces the system efficiency since some of the trees will receive insufficient water while some will be over-irrigated. Emission uniformity is especially important if fertigation is being used. Excellent uniformity would be 90% or above.
6. Clogged Emitters - Many emitters were clogged, especially at the ends of the lateral lines. Clogging can be reduced by flushing the laterals more often, using self-flushing end caps, or in severe cases, injecting chlorine, with the injection program based on sulphide and iron concentrations and pH.
7. Mixed Emitters - Emitters with differing discharge rates are being used. The system design should be reviewed to determine the correct discharge rate and number of emitters to use. It is important to use the correct emitter to allow good pressure and flow distribution for a particular pipe design. It is usually good to use one model of emitter throughout the system, since different models and makes could have different flow rates.
8. Poor Emitter Uniformity - A variation was found in the discharge rate between emitters operating at the same pressure. This is caused by variation in the emitters themselves. If this variation is unacceptable then the emitters should be replaced with new emitters of uniform operating characteristics.

9. Broken Pipes - Cuts and breaks were found in the lateral lines. Even small leaks can significantly reduce pressure in downstream sections. Repairing breaks will improve discharge uniformity and increase overall pressure.
10. Valves Not Opening - It appears that the control valves are not opening completely. A pressure differential was found upstream and downstream from the valves.
11. Pressure Regulators Not Functioning - The pressure regulators are not maintaining the downstream pressures within a satisfactory range. This is caused by some regulators malfunctioning or not having the required inlet pressure.
12. Submain Pressure Loss - Pressure was lost in the submains due to inadequate pipe size. The system design should be checked to determine the most practical way to reduce losses. Alternatives include using smaller emitters to reduce flow, installing more submains or using pressure regulators.
13. Lateral Pressure Loss - The tubing is improperly sized for the number and size of emitters that are being used, causing an excessive loss of pressure near the end of the tube. The system design should be checked to determine the best alternative for reducing losses. Possibilities include using larger tubing, lower discharge emitters or additional submains.
14. Elevation Effects - Pressures and discharge rates varied due to differences in elevation. The system design should be checked to determine the best way to compensate for elevation and to equalize pressure. Alternatives include using pressure regulators or gate valves to reduce pressure in higher pressure areas and installing additional submains to increase pressure in lower pressure areas.
15. Small Irrigated Area - A small percentage of the field area was covered by irrigation. When a small area of soil is available to hold irrigation water, frequent, short irrigations are required. With extremely small wetted areas, the soil in this area may not be able to hold sufficient water to meet the crops needs. By installing emitters with a larger area of coverage, longer operating times could be used, the times between irrigations could be increased and the water will be more readily available to the crop. We recommend that at least 33% of the field area be covered. If you want to convert a drip system to a spray jet system, a complete redesign is necessary.
16. Emitter Integrity – Worn or missing emitters can greatly reduce the efficiency of an irrigation system. With worn emitters, they may not be able to provide the required flow rate for plant survival or they do not work at all. Missing emitters on the other hand may provide too much water which can lead to plant damage or disease. By installing new emitters you can ensure adequate survival rates for the plants. When replacing emitters we recommend you do not mix and match emitter types as well this too could lead to a less efficient irrigation system.

4.4 Evaluation of Sprinkler Irrigation Systems

The evaluation of sprinkler systems is based on a test of the pressure throughout the system and a measurement of the uniformity with which the water is distributed over the field surface.

The recommended procedure for evaluating sprinkler irrigation (center pivot, lateral move, traveling gun, periodic move or solid set) systems is presented in the NRCS National Engineering Handbook (NEH), Part 652, Irrigation Guide, Chapter 9 (Pages 9-119 to 9-162).

4.4.1 Evaluation of Fixed and Portable Lateral Sprinkler Systems (Solid Set and Linear Move)

The FL NRCS solid set evaluation (SPR-SS-Eval) program (*spr-ss-eval_ver_1.1.xls)* uses the procedure in the NEH, performs the calculations, compiles a report, and is available in Section IV, C. Tools, Florida Engineering Computer Programs of the electronic Field Office Technical Guide-eFOTG/Florida which is located on the FL NRCS website, (**http://www.fl.nrcs.usda.gov/technical/program.html**).

4.4.1.1 Equipment Needs

The equipment needed for the field evaluation:

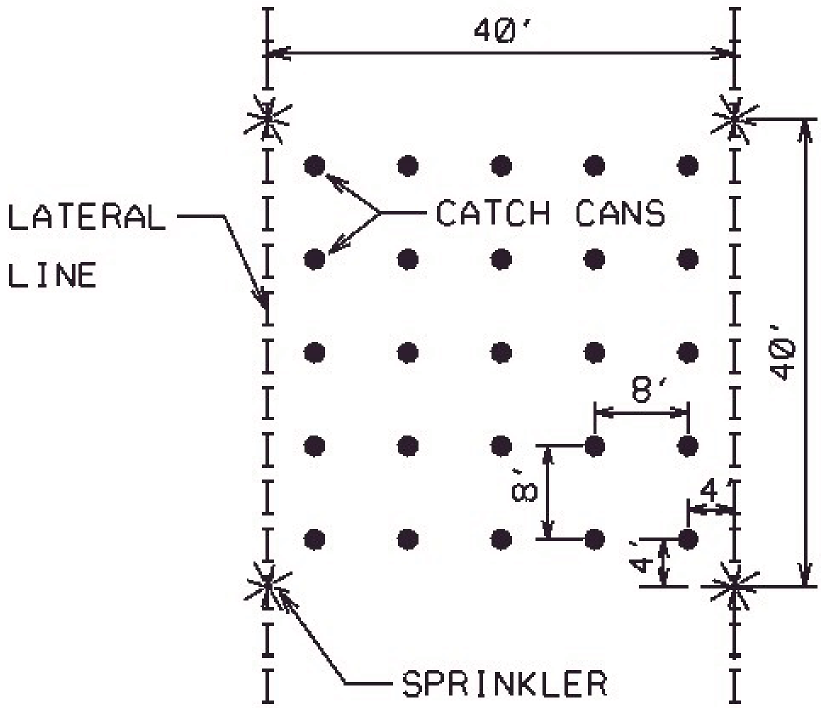
1. Pressure gauge (0-100 psi) with pitot tube attached
2. Stopwatch
3. A large container of known volume clearly marked (1 gallon or larger)
4. A 4-ft hose having a diameter appreciably larger than the outside diameter of nozzles
5. Catch containers
6. 500 ml graduated cylinder to measure volume of water caught in containers
7. Soil probe
8. Shovel
9. 100-ft tape measure
10. Wind velocity gauge
11. Rain coat, rubber boots
12. Manufacturer's sprinkler performance charts
13. Set of drill bits

4.4.1.2 Field Procedure

The following is a description of the field procedure for evaluating fixed solid set and portable lateral sprinkler systems.

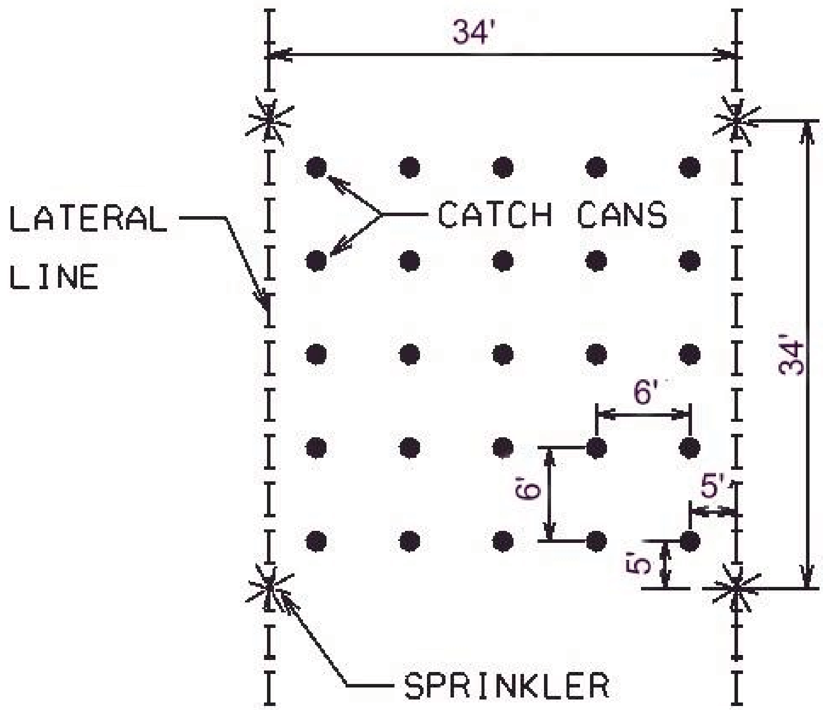
1. Select the field location for the evaluation. Field location should be a location at which the pipe pressure is representative of the entire system. If the pipe diameter is the same throughout the entire lateral, about half the pressure loss resulting from pipeline friction loss in that lateral occurs in the first 20 percent of the length. Over 80 percent of pressure loss occurs in the first half of the lateral length. On a flat field, the most representative pressure occurs about 30 to 40 percent of the distance from the lateral inlet to the terminal end.
2. Measure and record sprinkler spacing.
3. Obtain and record duration and frequency of irrigation from operator.
4. Record Management Allowable Depletion (MAD) as described in the NEH, Part 652, Irrigation Guide, Florida Supplement, Chapter 4, Water Requirements, if available.
5. Locate catch containers. The containers should be evenly spaced between two adjacent laterals for solid set systems. Any surrounding vegetation that would interfere with a container should be removed.

Example Catch Can Layout:

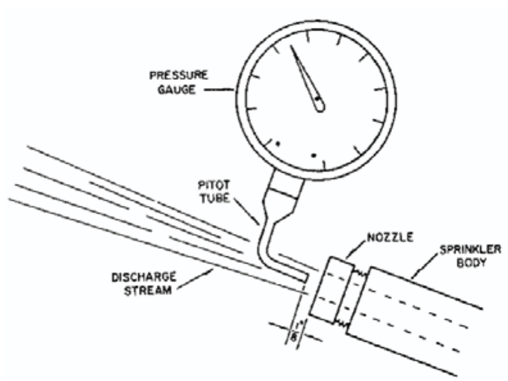


Spacing catch cans: Divide sprinkler spacing by number of cans (row or column). If answer is a whole number, this will be the spacing between cans. One-half of this number will be the spacing between the sprinkler and the first can.

If the answer is not a whole number, round down for can spacing and divide the remaining length in half, for spacing between the sprinkler and first can. For example, if spacing is 34 ft. and there will be 5 rows of cans, 34/5=6.8. Spacing between cans will be 6 ft. 34 ft. minus the sum of the spacings between cans (24 ft in this case) = 10 ft. Divide the 10 ft by 2 to get the spacing between the sprinkler and the first can (5 ft).



6. Check and record make and model of sprinklers and diameter of nozzles.
7. Record rated sprinkler discharge, pressure and design application rate from manufacturer's charts.
8. Check and record the size and slope of lateral lines and the height of risers.
9. Temporarily turn sprinklers that will irrigate the catchment area, away from catchment area. To do so, block sprinklers by wedging a short piece of wire or stick behind the swinging arm.
10. Set a known amount of water (in the same type of container as the catch containers) outside the catchment area to measure the approximate volume of water lost to evaporation.
11. Turn on water to fill lateral lines.
12. Measure pressure and discharge rates at sprinklers that are going to irrigate the catchment area.



13. Remove wire or stick from sprinklers that are going to irrigate the catchment area, and start test time.
14. While test is in progress, measure pressure and discharge rates at random sprinklers within the system.

15. Note wind speed and direction.
16. Operate the system long enough to catch a measurable amount of water. End test and record time.
17. Measure and record catch volumes.
18. Measure and record evaporation.

The Sprinkler Irrigation System Evaluation Form can be found in the NRCS Irrigation Guide, Chapter 15, pages 15-73 to 15-78. The form is set up for transposing catch data. Adjustments in computations are needed if data are not transposed when adjacent laterals are operating.

4.4.1.3 Calculations

1. Convert volumes of water caught to rates (in/hr).

$$Catch\ Can\ Conversion\ Factor = ml/in = Area\ of\ top\ of\ can, in^2 \times 16.39\, ml/in^3$$

$$Catch\ volume, in/hr = \frac{Catch, ml}{Catch\ can\ factor, ml/in \times Duration, hr}$$

After performing the catch can test, the average catch is calculated by adding the amount caught in all containers and dividing by the number of containers. The amount of evaporation is added to this average and the result is divided by the catch can conversion factor to give the average catch rate.

2. Compute and evaluate Distribution Uniformity (DU) and Christiansen's Uniformity (CU) coefficient.

$$DU = \frac{Average\ catch\ low\frac{1}{4}\ composite\ containers}{Average\ total\ catch} \times 100$$

$$CU = 100 - 0.63 \times (100 - DU)$$

3. Determine system DU and CU.

$$System\ DU = DU \times 1 - \left(\frac{(P_x - P_n)}{5P_a}\right)$$

$$System\ CU = CU \times 1 - \left(\frac{(P_x - P_n)}{8P_a}\right)$$

Where:
P_x = the maximum sprinkler pressure (psi)
P_n = the minimum sprinkler pressure (psi)
P_a = the average sprinkler pressure (psi)

4. Calculate gross application rate per test.

$$Average\ Application\ Rate, in/hr = \frac{Sprinkler\ discharge\ rate, gpm \times 96.3}{Lateral\ Length, ft \times Lateral\ Spacing, ft}$$

If a flow meter is present in the system, the average sprinkler discharge rate can also be determined by dividing the total system flow rate by the number of sprinklers.

Re = Effective application of water applied

$$R_e = \frac{Average\ catch\ rate}{Average\ Application\ rate}$$

Application Efficiency of Low Quarter, Eq (%)

$$Eq = DU,\% \times R_e$$

4.4.2 Evaluation of Traveling Gun Sprinkler System

4.4.2.1 Equipment Needs

1. Catch containers and stakes
2. 50 ft. measuring tape
3. 500 ml graduated cylinder
4. Pressure gauge (0-160 psi)
5. Inside diameter measurement calipers
6. Soil auger, push tube sampler, probe, shovel
7. Stopwatch
8. Wind velocity gauge
9. Thermometer to measure air temperature
10. Manufacturer's sprinkler head performance charts

4.4.2.2 Field Procedure

The following is a description of the field procedure for evaluating traveling gun sprinkler systems.

1. Obtain sprinkler gun specifications from the manufacturer, including operating pressures, nozzle type, inside diameter of nozzle, and system speed.
2. Record system information including the condition of the unit, operating pressure at pump and nozzle, the size of the nozzle, and the crop(s) being irrigated.
3. Record size and length of hose.
4. Record the make and model of the sprinkler.
5. Record the make and model of the traveler.
6. Document any wet/dry areas in the field.
7. Document any erosion or runoff.
8. Record the size of risers and pipe.
9. Estimate soil water deficit in field, both ahead of and behind traveler.
10. Note depth to water table, apparent root development, and any root and water movement restriction.
11. Select evaluation site that is representative of field and ahead of traveler.
12. Measure system flow rate at the beginning and end of the evaluation.
13. Observe system operating pressure from the ground. Do not climb up unit while operating.

The Sprinkler Irrigation System Evaluation Form can be found in the NRCS Irrigation Guide, Chapter 15, pages 15-89 to 15-93.

4.4.3 Evaluation of Center Pivot Sprinkler System

4.4.3.1 Equipment Needs

1. Catch containers and stakes

$$No.Needed = \frac{Lateral\ length\ + 10}{Catch\ Container\ Spacing}$$

2. 300 ft. measuring tape
3. 500 ml graduated cylinder
4. Pocket tape (inches)
5. Diameter tape
6. Pressure gauge with pitot tube (0-100 psi)
7. Flow measuring device
8. Ohmmeter or electrical ground check meter to measure salinity
9. Soil auger, push tube sampler, probe, shovel
10. Equipment for determining soil moisture
11. Stopwatch
12. Thermometer to measure air temperature
13. Wind velocity gauge
14. Ladder
15. Raincoat, rubber boots
16. Printout of manufacturer's pivot design (for use in field and office)

4.4.3.2 Field Procedure

The following is a description of the field procedure for evaluating center pivot sprinkler systems.

1. Select an evaluation site that is representative of the field.
2. Obtain sprinkler gun specifications from the manufacturer, including operating pressures, nozzle type, inside diameter of nozzle, and system speed.
3. Obtain end gun specifications from the manufacturer, including model and capacity.
4. Record system information including the condition of the unit and the crop(s) being irrigated.
5. Determine flow into system.
6. Determine operating pressure at the beginning of the system.
7. Record wind speed and direction, and air temperature.
8. Set catch containers along radius from pivot at a spacing of ≤30 feet. Omit placing them under the first one or two spans. Level the containers. Extend the containers beyond the wetted area. Avoid the tower wheels.
9. Set a known amount of water (in the same type of container as the catch containers) outside the catchment area, to measure the approximate volume of water lost to evaporation.
10. Allow the wetted area to completely pass over the catch containers.
11. Measure water caught in the catch containers.
12. Reference the evaporation lost in the evaporation container.
13. Weight the catches.

$$Weighted\ Low\frac{1}{4}\ Average\ Application\ Depth = \frac{Sum\ Low\frac{1}{4}\ weighted\ catches}{Sum\ Low\frac{1}{4}\ position\ numbers}$$

The Sprinkler Irrigation System Evaluation Form can be found in the NRCS Irrigation Guide, Chapter 15, pages 15-81 to 15-88. The form is set up for transposing catch data. Adjustments in computations are needed if data are not transposed when adjacent laterals are operating. A fillable version of the Sprinkler Irrigation System Evaluation Form can be downloaded from the Florida NRCS eFOTG website, http://efotg.nrcs.usda.gov/references/public/FL/FLENG442F_HH.xls.

4.4.4 Analysis of Sprinkler System Evaluations (Solid Set, Linear Move, Traveling Gun, and Center Pivot)

The level of performance of sprinkler systems is indicated by the potential efficiency and application efficiency. A low potential efficiency indicates physical problems with the system, while low application efficiency indicates inaccurate scheduling. Ultimately, it is an economic decision whether the level of performance of a system is acceptable or whether improvements should be made.

If the level of performance is not acceptable, then the cause of the low efficiency must be determined. Through the evaluation process and detailed note keeping, the problems with the system can be identified. Florida NRCS conservation practice standards for sprinkler systems (Irrigation System, Sprinkler, Code 442) and pipelines (Irrigation Water Conveyance, Pipeline, Code 430) establish a basis for comparison and help identify less than acceptable system components.

The two main factors that determine system performance are pressure variation and sprinkler spacing. NRCS specifications allow no more than a 20% variation in pressure among sprinklers, and a sprinkler spacing no more than 50% to 65% of the wetted diameter of the sprinkler.

The average system pressure should be high enough to break up the water discharge stream, normally 40 psi or higher. For low pressure systems the average system pressure should be 40 psi or lower, unless specified by manufacturer. Nozzle sizes should be uniform throughout the system. In small fields, partial circle nozzle heads may be used to adequately cover the edge of the field. In this case, application rates should be matched for the sprinklers. For example, 180 degree sprinklers should have one half the discharge rate of the 360 degree sprinklers.

4.4.5 Typical Problems and Recommendations for Sprinkler Irrigation Systems

Table 5 – Test Results, Problems and Solutions for Sprinkler Systems

Test	Problems	Solution
Pressure at pump	Low pressure	Check pump specs.
	< 40 psi (poor coverage)	Change pump
		Use smaller nozzles
		Use smaller zones
		Use higher rpm
	High pressure	Use larger nozzles
	60 psi	Use larger zones
Filter inlet/outlet pressure	> 5 psi difference	Clean or replace filter
Pressure between pump and first manifold (deadhead)	> 10 psi difference	Use larger pipeline
		Rezone
		Increase RPM
		Check valves
Pressure between submains	> 4-6 psi difference	Rezone
		Control with valves
		Use larger pipe
Pressure between laterals	> 4-6 psi difference	Use additional submains
		Use pressure regulators
Pressure variation in lateral	> 4-6 psi	Use additional submains
		Use smaller nozzles
		Use pressure regulators
Sprinkler spacing	> 65% of wetted diameter	Increase pump rpm
		Redesign system
Sprinkler discharge	> 20% variation	Use same brand and type of sprinkler
		Clean or replace nozzles
		Clean screens
End gun	Out of adjustment or not operating	Adjust the end gun position or repair end gun
	Boot Leak	Repair boot leak
	No booster pump	Install booster pump
Distribution uniformity	< 60%	Adjust sprinklers
		Increase pressure
		Change sprinkler type
		Redesign system
Control box	Malfunctioning	Replace control box

The following list describes typical sprinkler system problems and possible solutions.

1. Low System Pressure - The overall pressure found in the system is lower than normally used in this type of system. To produce uniform coverage, sprinklers require high pressure to break up the discharged stream of water. The sprinkler manufacturer usually will provide a recommended pressure range for each sprinkler. Usually the minimum pressure is 40 psi. Increasing pressure could improve the spray pattern and the uniformity of coverage. The pressure could be increased by irrigating smaller or fewer zones at one time or by increasing pump rpm.
2. Filter Clogged - The pressure loss was higher than normally seen for this type of filter. The filter should be flushed and the screen cleaned. If cleaning the filter does not reduce the pressure loss, then check the pressure gauges for accuracy and install a higher capacity filter if necessary. Screen filters usually have no more than 5 psi loss between the inlet and outlet.
3. Mainline Pressure Loss - Excessive pressure losses were found in the mainline. This reduces efficiency, since a higher pumping head is required to deliver adequate pressure to the sprinklers. Possible solutions are to divide the flow between mainlines by changing the zones that are operated at one time or to install additional mainlines.
4. Different Pressures Between Manifolds - The average pressure varied between the manifolds/submains. Valves should be installed or existing valves should be used to equalize pressure between manifolds/submains to make pressure and flow more uniform throughout the system.
5. Wide Spacing - The sprinkler spacing is wide for the diameter of coverage of these sprinklers. Sprinklers should have close to head to head coverage when pressure is correct. The system design should be reviewed to determine nozzle, pressure and spacing alternatives that would produce better spray pattern overlap.
6. Poor Distribution Uniformity - The distribution uniformity is a measurement of how uniformly the water is applied over the field surface. Poor distribution uniformity reduces the system efficiency since some of the plants will receive insufficient water while some will be over-irrigated. The uniformity should increase if the pressure is increased. Occasionally sprinklers will have poor uniformity even with adequate pressure and spacing. Check the sprinkler for adjustments.
7. Broken Sprinklers - Many sprinklers had broken arms or nozzles.
8. Mixed Nozzle Sizes - Nozzles with differing discharge rates are being used. The system design should be reviewed to determine the correct nozzle to use. It is important to use the correct nozzle to allow good pressure and flow distribution for a particular pipe design and to provide adequate spray pattern overlap. The nozzles should also be matched. All 360 degree sprinklers in a system should have the same nozzle size. 180 degree sprinklers should have a nozzle size to produce 1/2 of the 360 degree discharge rate. Check the original design and replace nozzles.
9. Poor Sprinkler Uniformity - A variation was found in the discharge rate between sprinklers operating at the same pressure. This is caused by variation in the sprinklers or nozzles themselves, possibly due to wear. If this variation is unacceptable then the sprinklers should be replaced with new sprinklers of uniform operating characteristics.

10. Broken Pipes - Breaks were found in the pipelines. Even small leaks can significantly reduce pressure in downstream sections. Repairing breaks will improve discharge uniformity and increase overall pressure.
11. Valves Not Opening - It appears that the control valves are not opening completely. A pressure differential was found upstream and downstream from the valves.
12. Pressure Regulators Not Functioning - The pressure regulators are not maintaining the downstream pressures within a satisfactory range. This is caused by some regulators malfunctioning or not having the required inlet pressure.
13. Submain Pressure Loss - Pressure was lost in the submains due to inadequate pipe size. Pressure variation is sometimes caused by partially closed valves or clogging of the sprinkler screens. The system design should be checked to determine the most practical way to reduce losses. Alternatives include using smaller nozzles to reduce flow, installing more submains or using pressure regulators.
14. Lateral Pressure Loss - The lateral pipes are improperly sized for the number and size of sprinklers that are being used, causing an excessive loss of pressure near the end of the lateral. The system design should be checked to determine the best alternative for reducing losses. Possibilities include using lower discharge nozzles or additional submains.
15. Elevation Effects - Pressures and discharge rates varied due to differences in elevation. The system design should be checked to determine the best way to compensate for elevation and to equalize pressure. Alternatives include using pressure regulators or gate valves to reduce pressure in higher pressure areas and installing additional submains to increase pressure in lower pressure areas.
16. Blocked Sprinklers - Sprinkler performance will be affected if the sprinkler stream is blocked. The sprinkler should be above the crop vegetation or should be a low-trajectory type if under-tree or in a greenhouse.
17. Clogged Sprinklers - The nozzles or screens in the sprinklers were clogged. Remove and clean the nozzle or screens. Check the water supply and install a filter if the water contains particles larger than the sprinkler nozzle.
18. Boot Leak – A Boot is approximately an 18 inch piece of flexible material connecting each tower to allow the pivot to flex with the terrain. If the boot is leaking we recommend that they replace the boot.
19. Pipe Joint Leak - A section of the overhead pipe is connected and each connection has a rubber gasket. If the pipe joint is leaking the gasket has to be replaced.

4.5 Evaluation of Subirrigation Systems (Flow Through and Underground Conduit)

Successful operation of subirrigation systems requires that the water table be maintained at a uniform depth below the ground surface, so that moisture can be supplied to plants through capillary movement (upward flux). The water table is regulated by controlling drainage to manage the removal of subsurface and/or surface water and water is added to keep the water table high enough to provide adequate moisture to plants. A drainage system is essential to remove excess surface water and subsurface water, so that the water table does not remain in the root zone for long enough periods to cause crop damage.

Information gathered should include both management factors as well as irrigation system factors. Management factors include whether or not water measurement devices are used (Md), method used to determine when to irrigate (S) (scheduling procedure), the skill of the irrigator in operating the system (I), the condition of the system (M) (maintenance), the ability of the system to provide irrigation water when needed (W), and the surface condition of the soil (Sc). System factors include the type of conveyance system used (F), the uniformity of application (U), the capacity of the delivery system (D), the elevation variation of the field being irrigated (L), and tailwater recovery systems (T). These factors are discussed in detail in "Farm Irrigation Rating Method (FIRM)", Florida Supplement to the Irrigation Guide, Chapter 15, FL652.1501. The FIRM computer program can be downloaded from the electronic version of the Field Office Technical Guide in Section IV, C. Tools, Florida Engineering Computer Programs which is located on the Florida NRCS website. The necessary data can be obtained by interviewing the irrigator and by making observations and measurements.

This section describes how to perform and evaluate both *general* and *detailed* evaluations of subirrigation systems. It is recommended that detailed evaluations be performed in order to gain knowledge and experience of how subirrigation systems perform under different management techniques, soil types, crops, etc., and when time and equipment are available.

General field evaluations will normally be performed when information is available on the system and/or when time and equipment are not available. These evaluations are qualitative and often provide the necessary information for identifying and correcting problems of the system layout and of its operation. *Detailed* field evaluations are quantitative and provide more detailed data needed for recommending changes, for making economic comparisons, and for furnishing background data for design of systems operating under similar conditions.

4.5.1 Equipment Needs

The equipment needed for the *general* field evaluation:

1. Soils auger for verifying soil type and installing water table wells (cased or uncased).
2. Stopwatch or watch with easily visible second hand for timing irrigation inflows and outflows.
3. Measuring tape to measure water table depth and furrow spacing.
4. Flow measurement equipment.
5. Soil Moisture Sensor.
6. Survey equipment for checking irrigation slope.

Equipment needed for the *detailed* field evaluation includes the same equipment needed for *general* evaluation plus:

1. Flow measuring devices such as small Parshall flumes, orifice plates, flow meters, large Parshall flumes, and/or calibrated containers. Devices must be capable of measuring head or recording velocity of flow.
2. Equipment for determining soil moisture may be desirable.
3. Stage recorders may be necessary.
4. Soil Moisture Sensor.
5. Cased observation wells.

4.5.2 Field Procedure

The following describes information to be gathered for the field procedure for a *general* field evaluation.

1. Estimate water loss in the delivery system (if open ditches).
2. Determine or verify soil type. Include areas where irrigator has observed abnormal conditions.
3. Determine from irrigator and by observation, wet and dry locations in the field. (Points that wilt early and areas where plant's response indicates wet areas).
4. Choose typical locations (furrows) in fields to be evaluated. A minimum of three furrows shall be evaluated in a management zone. Locations shall include wet and dry points that contain a significant area (greater than 10 percent of the management zone).
5. During the irrigation cycle, record furrow inflow (gpm), length, slope, spacing, and depth.
6. Observe the runoff (tailwater) in furrows or mains and record observations. Estimate the rate, length of time, and amount of tailwater loss.
7. During the irrigation cycle, two water table depths shall be measured at each location evaluated. The water table depth shall be recorded at points ¼ and ¾ along the furrow length, midway between the furrows. The measurements should be taken when the irrigation stream is at least midway along the furrow. Measure the elevation difference between the water table and the bottom of the furrow.
8. Observe drainage characteristics of the system. If inadequate, discuss with the irrigator.
9. Check erosion throughout the system (furrows, drainage mains and laterals).
10. Estimate total water available for irrigation.

Information to be gathered for the field procedure of a *detailed* field evaluation includes the same as for *general* field evaluation but may also include:

1. Actual measurement of water loss in delivery system or portions of the system.
2. During the irrigation cycle, record hourly water table response, i.e., depth and time to rise in observation wells.
3. Measure lateral (furrow) inflow and hourly outflow for 24 hours or one irrigation cycle, when water is fluctuating.
4. Measure tailwater losses from the management zone when possible, or selected furrows, for 24 hours or longer.
5. In addition to survey data for general evaluations, survey to determine:
    a. Elevations of water control structures.
    b. Capacity of water control structures.
    c. Capacity and adequacy of surface drainage system.
6. Determine water flow into the system. Where possible measure pump discharges or water flow in open channels, or use other data such as pump curves, meter readings, etc.
7. Using the "Farm Irrigation Rating Method" (FIRM) computer program, rate the irrigation system. The program can be downloaded from the electronic version of the Field Office Technical Guide in Section IV, C. Tools, Florida Engineering Computer Programs.

4.5.3 Analysis of Subirrigation System

1. Analyze to determine if total water available is sufficient to meet the crop's peak consumptive use.
2. Check variation in water table depth and water table response. When stabilized, the water table depth from the top of the bed should not vary more than 0.5 ft within a management zone. When the irrigation stream is pulsed and water table is allowed to fluctuate, the system should have the capacity to build the water table to the desired depth within twelve hours over the entire field. Briefer periods are desirable.
3. If erosion is a problem, recommend methods or practices to control erosion.
4. Estimate amount of water loss in the delivery system.
5. Estimate tailwater loss and consider methods to reduce loss if it exceeds 10 percent of the total water pumped to the field or if it occurs for more than two hours.
6. Analyze drainage problems. It is desirable to remove excess surface water in 24 hours or less on a two to five year frequency rainfall. The water table should drop to a 12-inch depth from the top of the bed within 24 to 48 hours after surface water removal. Consider the type of crop being grown and any applicable regulatory requirements, when proposing drainage solutions.
7. Run the DrainMod computer model when the furrow spacing exceeds the Florida Drainage Guide recommendations and the water table variation in the field at the beginning of the irrigation cycle exceeds 0.5 feet. DrainMod can be downloaded from North Carolina State University at the following web address: http://www.bae.ncsu.edu/soil_water/drainmod/index.html. Check the model's output of predicted water table response. Compare this data with how well the system responded to irrigation and observed drainage.
8. Using the FIRM computer program, rate the irrigation system. (See FIRM worksheet below.)

    FIRM = E x FUDLT x Md SIMWSc

The analysis of the field data for a *detailed* field evaluation is essentially the same as for the *general* field evaluation; however, the use of more accurate data and possibly more data should result in a more precise analysis.

4.5.4 Typical Problems and Recommendations for Subirrigation Systems

The analysis should indicate recommendations for improved management and/or system modifications. A review of the various management and system factors should be a starting point in making recommendations to the landowner. Additional items to review and address for a *general* field evaluation are as follows:

1. Furrows should be spaced to allow no more than 0.5 ft variation in water table depth from furrow to mid-point, during periods of peak consumptive use, after the water table has stabilized. Variations in water table suggest need for irrigation land leveling, closer spacing on irrigation furrows, and/or closer spacing of water table control structures. Larger irrigation streams are needed when excessive time is required to raise the water table in the entire system to the desired depth.
2. Normally the water table should be raised to the predetermined desirable level during each 24-hour period. Irrigation during the night is more efficient.
3. Increased depths to the water table decreases the amount of water lost from evaporation from the soil surface. Though this increases irrigation efficiency, it is essential that the

water table is within the zone that will supply adequate moisture to the root zone (through upward flux).

4. Water erosion can be controlled by structures at the ends of laterals, reducing the irrigation stream, structures in open ditches, and/or changing system layout to reduce slope in the direction of irrigation.
5. Wind erosion may be reduced by maintaining a water table depth during fallow periods at a level that will provide moisture to the ground surface.
6. Prevent delivery system losses by using underground pipelines or an underground conduit system.
7. Reduce tailwater losses by:
    a. Installing water table control structures in outlet drainage ditches at 0.5 foot (or less) elevation intervals to maintain desired water table depths.
    b. Allowing the water table to fluctuate within an allowable range. Stop irrigation when water is raised to a desired depth. Start irrigation when water table drops to a predetermined depth. This may be automated with electric motors and switches on water control structures or on floats in observation wells.
    c. Installing a tailwater recovery system.
    d. Regulating irrigation streams to a continuous flow which minimizes tailwater losses. Water will normally recede up to the furrows during peak use period of the day (from noon to early afternoon, normally).
8. Poor drainage suggests the enlargement of drainage ditches, increased capacity of structures, increased depth of irrigation laterals, and/or installation of subsurface drains. An underground conduit sub- irrigation system should normally be recommended when subsurface drains are needed.
9. Cased observation wells that are properly located should always be recommended to allow the irrigator to observe the position of the water table at any time.

The recommendations for a *detailed* field evaluation should be the same as those suggested by the *general* field evaluation. However, the use of more information and background data is available to make economic comparisons and to allow for more accurate design and/or system modifications.

FARM IRRIGATION RATING METHOD - FLORIDA (FIRM-FL) Ver. 1.0		
Cooperator:		
Farm Name/Field No.:		
Identification No.:		
Location:		
County:		
Soil and Water Conservation District:		
Water Management District:		
Field Office:		
Prepared by:		
Date:		
Checked by :		
Date:		
	Present	**Improved**
Type of Irrigation System		
POTENTIAL EFFICIENCY (E)		
Measuring Devices (Md)		
Soil Moisture Monitoring and Scheduling (S)		
Irrigation Skill (I)		
Maintenance (M)		
Water Delivery (W)		
Soil Condition (Sc)		
MANAGEMENT ELEMENT(Md)(Sx)(I)(M)(W)(Sc)		
Sprinkler: Use Only (F)(U)(D)(C) Subirrigation: Use Only(F)(U)(D)(L)(T) Microirrigation: Use Only (F)(A)(D) Surface: Use Only (F)(U)(L)(T)		
Farm Conveyance (F) ----->		
Uniformity (U)		
% Root Zone Wetted (A)		
Delivery (D)		
Land Surface (L)		
Tailwater Loss - % of Water Applied		
% of Tailwater Reused		
Tailwater (T)		
Climate Effect (C)		
SYSTEM ELEMENT		
Sprinkler-(F)(U)(D)(C)		
Subirrigation-(F)(U)(D)(L)(T)		
Microirrigation-(F)(A)(D)		

FARM IRRIGATION RATING METHOD - FLORIDA (FIRM-FL) Ver. 1.0		
Surface-(F)(U)(L)(T)		
FIRM-(E)x(ManagementElement)x (System Element)		
Normal Net Irrigation Requirement (in.)		
Gross Irrigation Requirement (inches) NNIR/FIRM		
Water Conserved (Present - Improved) (in.)		
Area Irrigated (acres)		
Total Water Conserved (ac-in)		