

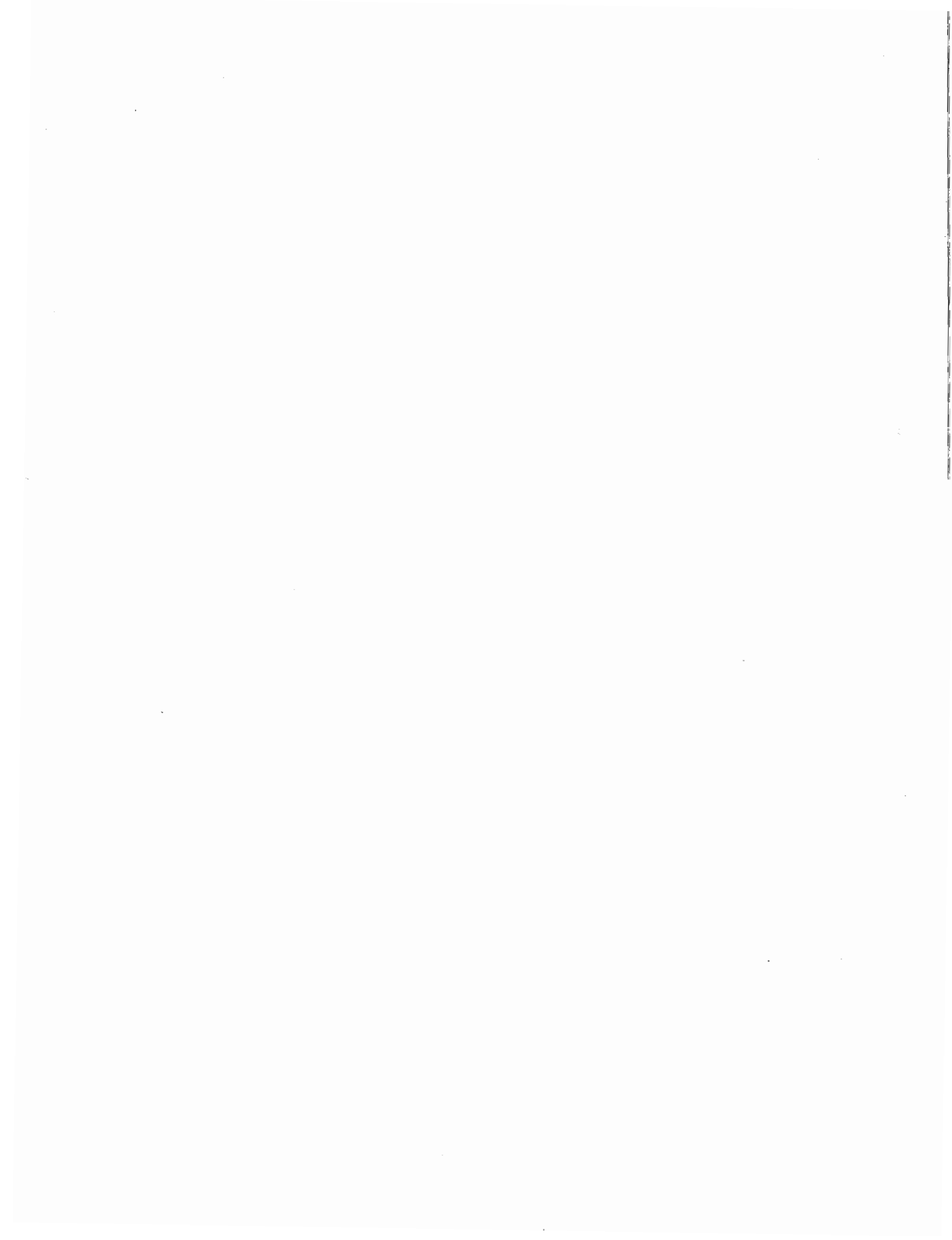
United States
Department of
Agriculture

Natural
Resources
Conservation
Service

IRRIGATION WATER MANAGEMENT

Trickle Irrigation System Evaluation

Field Guide



TRICKLE IRRIGATION SYSTEM EVALUATION

INTRODUCTION

Trickle irrigation (drip) is the frequent, slow application of water to soils through mechanical devices called emitters. The objective of drip irrigation is to maintain a high soil moisture content in the plant root zone at all times during the irrigation season. This can be accomplished by starting the season with a high soil moisture content and replacing the amount depleted by the plant and evaporation every other day to every 4th day basis. This is done by delivering the amount of water needed to the root zone of each plant through a metered delivery system.

To accomplish this objective the system must be adequately designed and constructed and; a method of management developed to determine the amount of water needed on a daily basis; and a method of monitoring developed to verify the validity of both the delivery system performance and the amount of water delivered as being adequate.

Components:

The various components of drip or trickle irrigation system are shown in Figure 8-29 and a typical layout in Figure 8-30. An adequate filter system is needed to insure performance of the metered delivery (emitters) at each plant without clogging. Clogging sometimes causes poor distribution along the laterals.

Trickle irrigation wets only a portion of the soil volume allocated to each plant, especially in orchards and vineyards. If the volume of soil irrigated is small it can restrict crop yield and quality. The percentage of the wetted area compared to the total area for each plant depends on the emitter discharge area, discharge rate, spacing of emitters and the soil type. The percentage of area wetted is a poor measure of emitter performance. A much preferred measure is based on the volume of soil irrigated compared to the total volume available to each plant. Where more than one emitter is used per plant, the wetted volume created by each emitter should overlap in the upper half of the root zone of the plant as shown in Figure 8-31.

One of the objectives in evaluating a trickle system is to determine the average volume of soil wetted per plant. A minimum volume appears to be about one-third for vines and orchards and should be higher for close-spaced crops.

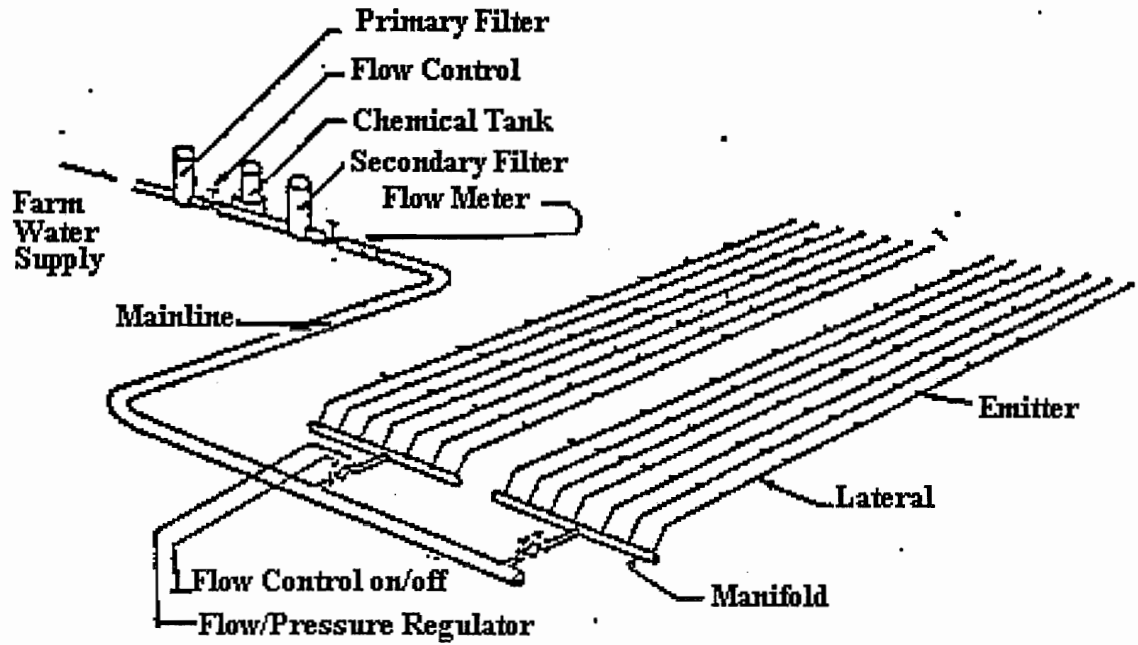


Figure 8-29. Basic components of a trickle-irrigation system.

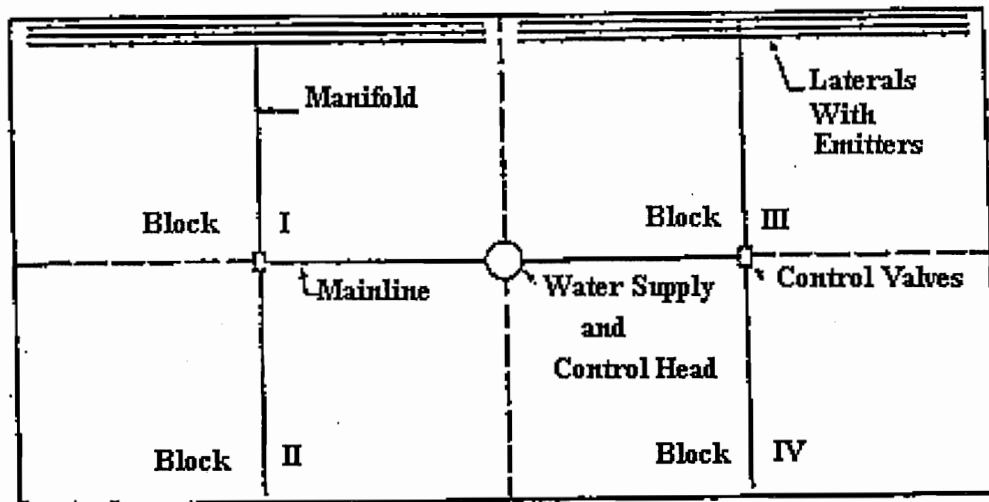


Figure 8-30. Typical two station split flow layout for trickle irrigation system with Block I and III, or II and IV operating simultaneously.

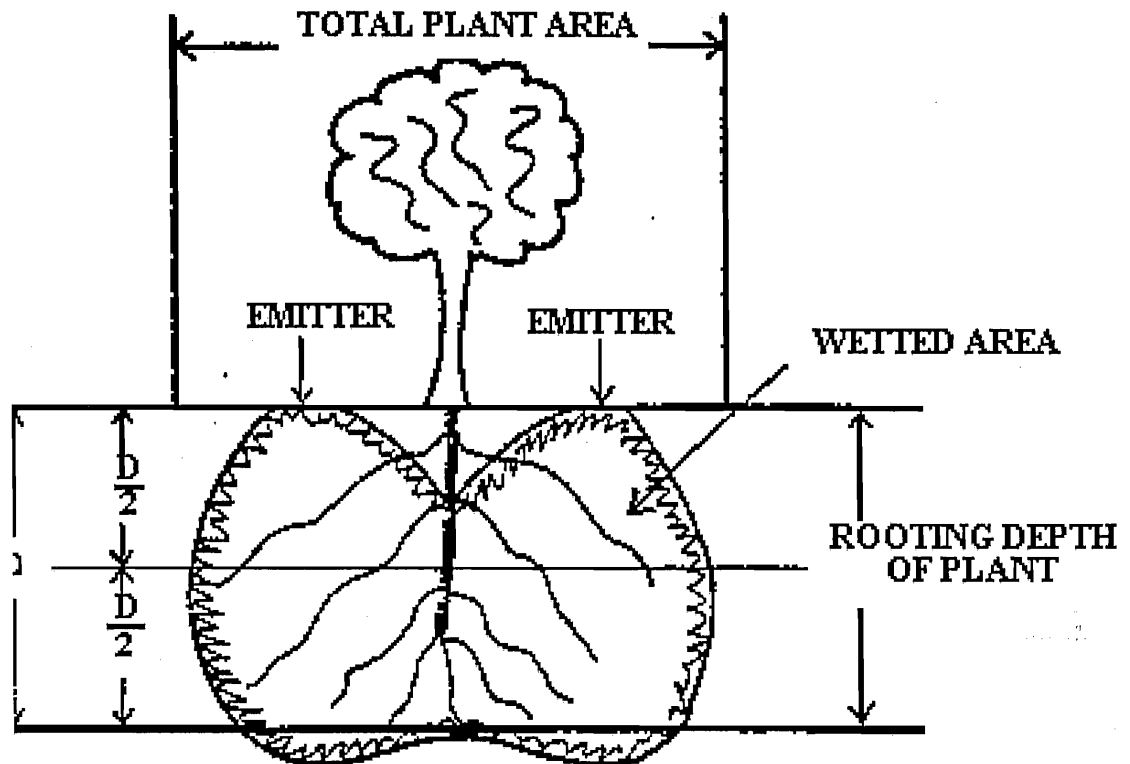


Figure 8-31. typical wetted area under a plant with two emitters.

Irrigating the total plant area is not necessary but overlapping should occur in the upper half of the plant root zone and should be continuous along the plant row.

The successful operation of a trickle system requires that the frequency of irrigation and volume of water applied be carefully scheduled to meet the plant's need. Under irrigation is easier to detect than over irrigation. Over irrigation is lost to deep percolation and may not be apparent unless the water applied is compared to the plant evapotranspiration (ET).

Checking the soil salinity level at various locations from the plant and for various depths is important to determine if salt build-up is becoming a problem. The four contact salinity probe can be used for this purpose and the change in salinity over time noted.

The field emission uniformity, EU, must be known in order to properly manage the amount of water applied. Since EU can change throughout the season, periodic evaluations are needed to determine maintenance needs and irrigation scheduling changes.

Evaluation

Use of much of the information is similar to the field data and analysis for orchard sprinklers. The data needed for evaluating a trickle irrigation system can be obtained by determining:

1. Duration, frequency, and sequence of operation of normal irrigation cycle.
2. The SMD and MAD in the wetted volume.
3. Rate of discharge at the emission points and the pressure near several emitters spaced throughout the system.
4. Changes in rate of discharge from emitters after cleaning or other repair.
5. The percent of soil volume wetted.
6. Spacing and size of trees or other plants being irrigated.
7. Location of emission points relative to trees, vines, or other plants and uniformity of spacing of emission points.
8. Losses of pressure at the filters.
9. General topography.
10. Additional data indicated in Figure 8-32.

Equipment

The equipment needed for collecting the necessary field data is:

1. Pressure gauge (0-50 psi range) with "T" adapters for temporary installation at either end of the lateral hoses.
2. A stopwatch or watch with an easily visible second hand.
3. Graduated cylinder with 250 ml capacity.
4. Measuring tape 10 to 20 feet long.
5. Funnel with 3- to 6-inch diameter.

6. Shovel and soil auger or probe.
7. Manufacturer's emitter performance charts showing the relationships between discharge and pressure plus recommended operating pressures and filter requirements.
8. Sheet metal or plastic trough 3 feet long for measuring the discharge from several outlets in a perforated hose simultaneously or the discharge from a 3-foot length of porous tubing. (A piece of 1-or 2-inch PVC pipe cut in half lengthwise makes a good trough.)
9. Copies of form for recording data.

Field Procedure

The following field procedure is suitable for evaluating both systems with individually manufactured emitters and systems that use perforated or porous lateral hose. Fill in the data blanks of the evaluation form (Figure 8-32) while conducting field procedure.

1. Fill in parts 1,2, and 3 of Figure 8-32 concerning the general soil and crop characteristics throughout the field.
2. Determine from the operator the duration and frequency of irrigation and his concept of the MAD to complete part 4.
3. Check and note in part 5 the pressures at the inlet and outlet of the filter and, if practical, inspect the screens for breaks and any other possibility for contaminants to bypass the screens.
4. Fill in parts 6, 7 and 8 which deal with the emitter and lateral hose characteristics. (When testing perforated or porous tubing the discharge may be rated by the manufacturer in flow per unit length.)
5. Locate four emitter laterals along an operating manifold (see Figure 8-29); one should be near the inlet and two near the "third" points, and the fourth near the outer end. Sketch the system layout and note in part 9 the general topography, manifold in operation, and manifold where the discharge test will be conducted.
6. Record the system discharge rate (if the system is provided with a water meter) and the numbers of manifolds and block (or stations). The number of blocks is the total number of manifolds divided by the number of manifolds in operation at any one time.
7. For laterals having individual emitters, measure the discharge at two adjacent emission points (denoted as A and B in part 14) at each of four different tree or plant locations on each of the four selected test laterals. (See Figure 8-33). Collect the flow for a number of full minutes (1, 2, 3, etc.) to obtain a volume between 100 and 240 ml for each emission point tested. Convert each reading to ml per minute before entering the data in part 14 on Figure 8-32. To convert ml per minute to gallons per hour (gph), divided by 63.

These steps will produce eight pressure readings and 32 discharge volumes at 16 different plant locations for individual emission points used in wide-spaced crops with two or more emission points per plant.

For perforated hose or porous tubing, use the 3-foot trough and collect a discharge reading at each of the 16 locations described above. Since these are already averages from 2 or more outlets, only one reading is needed at each location.

For relatively wide-spaced crops such as grapes where one single outlet emitter may serve one or more plants, collect a discharge reading at each of the 16 locations described above. Since the plants are only served by a single emission point, only one reading should be made at each location.

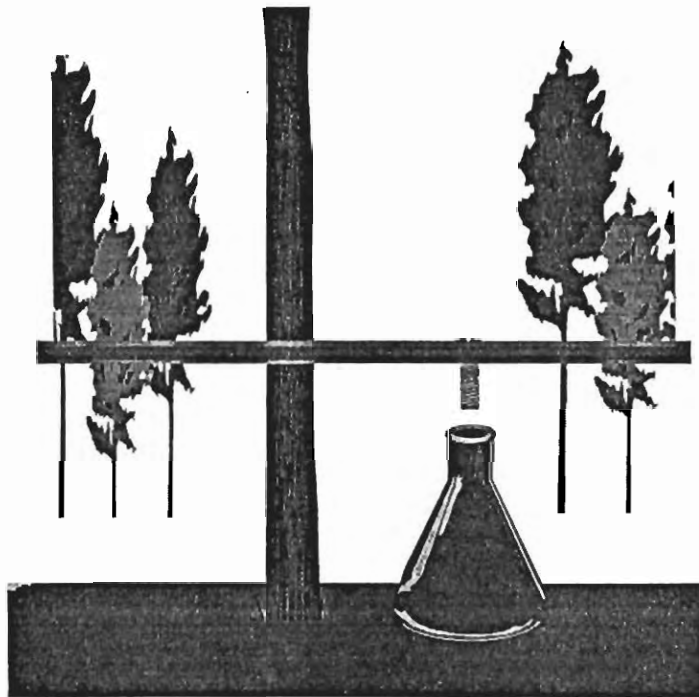


Figure 8-33 Field measurement of emitter discharge.

8. Measure and record in part 15 the water pressures at the inlet and downstream ends of each lateral tested in part 14 under normal operation. On the inlet end, this requires disconnecting the lateral hose, installing the pressure gauge, and reconnecting the hose before reading the pressure. On the downstream end, the pressure can be read after connecting the pressure gauge the simplest way possible.
9. Check the percentage of the soil that is wetted at one of the tree locations on each test lateral and record in part 16. It is best to select a tree at a different relative location on each lateral. Use the probe, soil auger, or shovel--whichever seems to work best--for estimating the real extent of the wetted zone below the surface around each tree. Determine the percentage wetted by dividing the wetted area by the total surface area between four trees.

10. If an interval of several days between irrigations is being used, check the SMD in the wetted volume near a few representative trees in the next block to be irrigated and record it in part 17. This is difficult and requires averaging samples taken from several positions around each tree.
11. Determine the minimum lateral inlet pressure, MLIP, along each of the operating manifolds and record in part 18. For level or uphill manifolds the MLIP will be at the far end of the manifold. For downhill manifolds it is often about two-thirds down the manifold. The manifolds on undulating terrain it is usually on a knoll or high point.
12. Determine the discharge correction factor, DCF, to adjust the average emission point discharges for the tested manifold. This adjustment is needed if the test manifold happened to be operating with a higher or lower MLIP than the system average MLIP. If the emitter discharge exponent, x , is known, use the second formula presented in part 19.
13. Determine the average and adjusted average emission point discharges according to the equations in parts 11 and 12 of Figure 8-32.

Utilization Of Field Data

In trickle irrigation all the system flow is delivered to individual trees, vines, shrubs, or other plants. Essentially there is no opportunity for loss of water except at the tree or plant locations. Therefore, uniformity of emission is of primary concern, assuming the crop is uniform. Locations of individual emission points, or the tree locations when several emitters are closely spaced, can be thought of in much the same manner as the container positions in tests of sprinkler performance.

There are four single emission point emitters per tree in the citrus grove where this test was conducted to obtain the data listed in Figure 8-32. Therefore, the discharges from the two (A and B) emitters at each tree can be averaged. The minimum rate of discharge (or low 1/4) is then the adjusted average discharge of the lowest four of these (average) discharges per tree of 2.30 gph for the sample evaluation. The adjusted average rate of discharge per tree for the entire system was 2.65 gph. (See Figure 8-32, part 12.)

Average Application Depth:

The average depth applied per irrigation to the wetted area, D_{aw} , is useful for estimating MAD. The D_{aw} in inches is computed from the average gph at each

emission point, the number, of emission points per tree, N, the number of hours of operation per irrigation, and the area wetted per tree in square feet:

$$D_{aw} = \frac{1.605 \times N \times \text{gph} \times \text{hours}}{\text{feet}^2}$$

which for the sample evaluation (Figure 8-32, parts 2, 4, 7, 12, and 14) is:

$$D_{aw} = \frac{1.605 \times 4 \times 2.65 \times 6}{140} = 0.73 \text{ inch}$$

The overall average depth applied, D_a , in inches can be found by substituting the tree spacing for the wetted area in the formula immediately preceding. Therefore:

$$D_a = \frac{1.605 \times 4 \times 2.65 \times 6}{22 \times 22} = 0.21 \text{ inch}$$

Volume Per Day Per Tree:

The average number of gallons per day per tree or plant is computed from the average gph at each emission point, the number N of emission points per tree, the number of hours of operation per irrigation, and the irrigation interval in days:

$$\text{Average daily gallons per tree} = \frac{N \times \text{gph} \times \text{hours}}{\text{days}}$$

which for the sample evaluation (Figure 8-32, parts 4, 7, and 12) is:

$$\text{Average daily gallons per tree} = \frac{4 \times 2.65 \times 6}{1} = 63.6 \text{ gallons/day}$$

Emission Uniformity

In order to determine whether the system is operating at acceptable efficiency, evaluate the uniformity of emission by calculating EU by this formula:

$$EU = \frac{\text{minimum rate of discharge per plant}}{\text{average rate of discharge per plant}} \times 100$$

in which the average of the lowest quarter (Figure 8-32, part 12) is used as the minimum for each of the four emitters per plant:

$$EU = \frac{4 \times 2.30}{4 \times 2.65} \times 100 = 87\%$$

General criteria for EU values for systems which have been in operation for one or more seasons are: greater than 90%, excellent; between 80% and 90%, good; 70% to 80%, fair; and less than 70%, poor.

Potential Application Efficiency Low Quarter (PELQ)

The concept of PELQ used in other evaluation procedures must be modified when evaluating trickle irrigation systems, which wet only part of the area because the minimum depth would be zero. Since trickle irrigation wets only a portion of the soil volume, the SMD must be replaced frequently. It is always difficult to estimate SMD because parts of the wetted portion of the root zone often remains near field capacity even when the interval between irrigation is several days.

For the sample evaluation where irrigations are applied every day, it is practically impossible to estimate SMD. For this reason, SMD must be estimated from weather data or information derived from evaporation devices. Such estimates are subject to error and since there is no practical way to check for slight under irrigation, some margin for safety should be allowed. As general rule, about 10% more water than the estimated SMD or evapotranspiration should be applied to the least watered areas. Thus the PELQ under full trickle irrigation can be estimated by:

$$PELQ = 0.9 \times EU$$

which for the sample test data shown in Figure 8-32 is

$$PELQ = 0.9 \times 87\% = 78\%$$

In a trickle irrigation system, there are no field boundary effects or pressure variations along the manifold tested which are not taken into account in the field estimate of EU. Therefore, the estimated PELQ is an overall value for the manifold in the sub-unit tested except for possible minor water losses due to leaks, draining of lines, and flushing (unless leaks are excessive).

Some trickle irrigation systems are fitted with pressure compensating emitters or have pressure (or flow) regulation at the inlet to each lateral. However, most systems are only provided with a means for pressure control or regulation at the inlets to the manifolds as was the case with the system evaluated. If the manifold inlet pressures are not properly set, the overall system PELQ will be lower than

the PELQ of the tested manifold. An estimate of this efficiency reduction factor, ERF, can be computed from the minimum lateral inlet pressure, MLIP, along each manifold by:

$$\text{ERF} = \frac{\text{average MLIP} + 1.5 \text{ X minimum MLIP}}{2.5 \text{ X average MLIP}}$$

The ratio between the average emission point discharges in the manifold with the minimum pressure and the system is approximately equal to ERF. Therefore, the system PELQ can be approximated by:

$$\text{System PELQ} = \text{ERF X Test PELQ}$$

Using the data in Figure 8-32, part 18, and the test PELQ of 78%,

$$\text{ERF} = \frac{46.1 + (1.5 \text{ X } 42)}{2.5 \text{ X } 46.1} = 0.95$$

and,

$$\text{System PELQ} = 0.95 \text{ X } 78\% = 74\%$$

A more precise method for estimating the ERF can be made if the emitter discharge exponent, x, is known by

$$\text{ERF} = \frac{(\text{minimum MLIP})^x}{(\text{average MLIP})^x}$$

For the tested system with orifice type emitters, which have an x of 0.5, this alternative calculation of ERF gives:

$$\text{ERF} = \frac{42^{0.5}}{46.1^{0.5}} = \frac{\sqrt{42}}{\sqrt{46.1}} = .95$$

In this case the two methods for computing ERF give essentially equal results; however, for larger pressure variations or x values higher or lower than 0.5, the differences could be significant.

Application Efficiency, Low Quarter (AELQ)

Like PELQ, the concept of AELQ must also be modified for trickle irrigation. Effectiveness of a trickle system can be estimated by how much of the applied

water is stored in the root zone and is available for consumptive use by the plants. Since there are essentially no opportunities for losses due to evaporation and drift, for inadequate irrigation in which the least watered areas are under irrigated:

$$\text{System AELQ} = \text{ERF} \times \text{Test EU}$$

However, if excess water is applied in the least watered areas:

$$\text{System AELQ} = \frac{\text{SMD in wetted area}}{\text{average depth applied to wetted area}} \times 100$$

for an ideal irrigation in which the SMD plus 10% extra water is applied to the least watered areas, AELQ = PELQ.

For the evaluation shown in Figure 8-32 where daily irrigations were being applied, it was impossible to estimate SMD in the wetted areas around each tree. Furthermore, the average depth applied to the total area, D_a was only 0.21 inch per day which is hardly sufficient to meet the expected consumptive use requirements for mature citrus trees at the study location. Therefore, it is highly probable that the trees were being under irrigated, in which case for the test EU of 87%:

$$\text{System AELQ} = 0.95 \times 87 = 83\%$$

Overall Minimum Depth Applied:

The overall average depth applied to the total area, D_a multiplied by System PELQ (or AELQ) is useful for managing the irrigation schedule because water requirements are expressed in similar units. (Multiply by the System PELQ except when there is under irrigation and AELQ is greater than PELQ.) For the sample evaluation the overall minimum depth applied to the total area, D_n is:

$$D_n = D_a \times \text{System PELQ (or AELQ)}/100$$

which for the sample evaluation which is under irrigated and has System PELQ and AELQ values of 74% and 83%, respectively, is:

$$D_n = 0.21 \times 83/100 = 0.17 \text{ inch}$$

Analysis and Recommendations:

Several observations and some recommendations can be based on the additional data in Figure 8-32 and the computations of EU, PELQ, and AELQ.

The pressure differences throughout the operating manifold studied were very small. (See Figure 8-32, part 15.) Pressure variations of 20% for orifice-type emitters and 10% for the long tube type result in flow differences of about 10%. Obviously it is important that each control valve be adjusted accurately to insure uniform pressures throughout the orchard. However, this was not the case as noted by the minimum lateral inlet pressure variations between manifolds as indicated in part 18 or Figure 8-32.

Uniformity of application throughout the operating manifold, expressed by the EU of 87%, was good. Since the pressures were very nearly constant, it appears that most of the lack of uniformity of application resulted from variations in operation of the individual emitters. This can be verified by studying the table in Figure 8-32, part 14. The discharges of emitters A and B at the same location, which would have almost identical pressures, often differed considerably.

Differences in elevation throughout the system were not extreme so the other manifolds should have produced similar uniformities. (See Figure 8-32, part 9.)

The percentage of wetted area ranged between 26% and 31% (Figure 8-32, part 12); this was less than the recommended minimum discussed in the introduction for arid areas.

For the fertilizer application program, urea was being injected into the irrigation water. Other fertilizers were being applied directly to the soil surface and incorporated by cultivation in the fall prior to the winter rainy season. This fertilizer program should prove satisfactory and the cause no problem with the irrigation equipment.

Emitters:

The emitters used in the recorded test were the automatic flushing type. The variations in discharge reported above probably were due to differences in manufacturing tolerance. These emitters, operating at pressures near 45 psi, averaged a discharge of 2.62 gph (Figure 8-32, parts 6, 11, and 15), which is considerably less than the rated 3.0 gph at 30 psi and indicates that the orifices may have been closing slowly or clogging after about one season's operation.

Variable clogging can cause large differences in flow from non-flushing emitters even though manufacturing tolerances may be very close. Some emitters can be

flushed manually. Systems having manually flushed emitters should be checked monthly to determine the amount of change in flow before and after flushing.

Some multiple outlet emitters have a separate pressure dissipating channel for each outlet and thus the discharges at each emission point are independent. Other multiple outlet emitters have a single pressure dissipating channel discharging into the several outlets. With such emitters, the discharges through each outlet tube are usually erratic due to small elevation differences and blockage in the spaghetti tubes.

Filters:

The filter system near the pumping plant seemed to be performing reasonably well. Apparently, it was not seriously clogged at the time of the check since the loss of pressure across it was only 5 psi (Figure 8-32, part 5). Small safety screen filters were installed at the inlet to each lateral hose. This precaution is recommended. Several of these screens were checked at random and all were reasonably clean; however, several screens had intercepted a considerable amount of coarse material that would have clogged some emitters if it had passed through the laterals. The operator said he routinely cleans each safety screen after every 1000 hours of operation.

Improvements:

A major improvement would be to increase the percent of wetted volume or area allocated to each plant. This could be achieved by increasing the interval between irrigations to 2 days or by adding one or two emitters at each tree and decreasing the operating pressure accordingly.

Changing to a 12-hour irrigation on alternate days instead of continuing the present 6 hours per day could improve the percent of wetted area because longer applications wet more soil volume. No problems of infiltration were apparent, and the average depth applied to the wet area, D_{aw} of 0.73 inch, could easily be doubled without exceeding the SMD at a MAD of 30%. For example, for the 4-foot root depth and 2 inches per foot of available moisture, a total of 8 inches of moisture would be available. The depletion of $2 \times 0.73 = 1.46$ inch gives a MAD of less than 20% in the wetted area.

The manifold inlet valves should be adjusted to give the same minimum lateral inlet pressure on each manifold. This would increase the System PELQ and AELQ to the PELQ and AELQ of the tested manifold which is a 5% improvement.

It appears that emission from the lateral hoses had been gradually decreasing and that the system was designed to yield greater flow than was observed.

Thus, adding emitters could restore the system's capacity to the original 12 gph per tree at an average pressure of 30 psi and increase the percentage wetted area to almost 40%.

The only sure way to improve EU would be to replace the emitters; this would be very expensive and is not now warranted. Chemical treatment may clean some of the mineral deposits and partially restore the discharge rate and uniformity.

The overall minimum depth applied to the total are, D_n , (only 0.17 inch per daily cycle) seems to be marginal for a mature orchard during the peak period of water demand. Although emitters were rated at 3.0 gph when operated at 30 psi, the test results in the field indicated that average rate of flow as only 2.62 gph at 45 psi; to meet the peak demands of water, the flow rate per tree would have to be restored to the original design of 12 gph (four emitters at 3 gph) by cleaning or otherwise repairing the emitters, by increasing the operating pressure, or by adding another emitter to the system at each tree.

Summary

The EU of 87% and estimated PELQ of 78% of the tested manifold are good. The main system problems are associated with a marginal amount of soil wetted (only about 30%), poor manifold control valve adjustment, and low rates of flow in the system. The operator was advised to try scheduling the irrigation to apply water for 12-hour periods on alternative days instead of continuing the current 6 hours per day cycling. He was also urged to (a) adjust the manifold control valves to obtain equal minimum lateral inlet pressures on all manifolds; and (b) to clean or repair the emitters or to add an extra emitter at each tree to restore flow rates to the designed volume and to increase the percent of wetted area.

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TRICKLE IRRIGATION

SYSTEM EVALUATION

LEGEND:

FS	=	Field shot (slides or video)
BLANK	=	Blank, or dark slide
TITLE SLIDE	=	Graphic of subject title
GRAPHIC	=	Chart, graph or illustration
INST	=	Video of instructor, or narrator, performing examples or drawing illustration

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MUSIC

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SLIDE

TRICKLE IRRIGATION SYSTEM EVALUATION

FS
View of trickle
irrigation systems

INTRODUCTION

Trickle irrigation (drip) is described as the frequent, slow application of water to soils through mechanical devices called emitter.

The objective of drip irrigation is to maintain a high soil moisture content in the plant root zone at all times during the irrigation season. This can be accomplished by starting the season with a high soil moisture content and replacing the amount depleted by the plant and evaporation on a 1 to 4 day basis. This is done by delivering the amount of water needed directly to the root zone of each plant through a metered delivery system.

FS
Designer and/or
trickle system design

In order to accomplish this objective the system must be adequately designed and constructed and; a method of management developed to determine the amount of water needed on a daily basis; and a method of monitoring developed to verify the validity of both the delivery system performance and the amount of water delivered as being adequate.

Graphic of
Figure 8-29

Components:

The various components of a drip or trickle irrigation system shown in Figure 8-29 and a typical layout in Figure 8-30.

FS
Close-up of a
filter system

An adequate filter system is needed to insure performance of the metered delivery (emitters) at each plant without clogging. Clogging sometimes causes poor distribution along the laterals.

FS
Close-up of
an emitter

Graphic of
Figure 8-31

Trickle irrigation wets only a portion of the soil volume allocated to each plant, especially in orchards and vineyards. If the volume of soil irrigated is small it can restrict crop yield and quality. The percentage of the wetted area compared to the total area for each plant depends on the emitter discharge area, discharge rate, spacing of emitters and the soil type. The percentage of area wetted is a poor measure of emitter performance. A much preferred measure is based on the volume of soil irrigated compared to the total volume available to each plant. Where more than one emitter is used per plant, the wetted volume created by each emitter should overlap in the upper half of the root zone of the plant as shown in Figure 8-312.

FS
Technician determining
the wetted area of the
plant.

One of the objectives in evaluating a trickle system is to determine the average volume of soil wetted per plant. A minimum volume appears to be about one-third for vines and orchards and should be higher for close spaced crops.

Graphic
Showing overlap
of wetted area
on the surface.

It is not necessary to irrigate the total plant area but overlap should occur in the upper half of the plant root zone and should be continuous along the plant row.

The successful operation of a trickle system requires that the frequency of irrigation and volume of water applied be carefully scheduled to meet the plant need. Under irrigation is easier to detect than over irrigation. Over irrigation is lost to deep percolation and may not be apparent unless the water applied is compared to the plant ET.

FS
Technician showing
the soil salinity
probe

It is also important to check the soil salinity level at various locations from the plant and for various depths to determine if salt build-up is becoming a problem. The four contact salinity probe can be used for this purpose and the change in salinity over time noted.

Graphic
Minimum Rate of
EU= $\frac{\text{Discharge per plant}}{\text{Average Rate of Discharge per plant}} \times 100$

The field emission uniformity, EU, must be known in order to properly manage the amount of water applied. Since EU can change throughout the season, periodic evaluations are needed to determine maintenance needs and irrigation scheduling changes.

Graphic
List 1 thru 5

Evaluation

Use of much of the information is similar to the field data and analysis for orchard sprinklers. The data needed for evaluating a trickle irrigation system can be obtained by determining:

1. Duration, frequency, and sequence of operation of normal irrigation cycle.
2. The SMD and MAD in the wetted volume.
3. Rate of discharge at the emission points and the pressure near several emitters spaced throughout the system.
4. Changes in rate of discharge from emitters after cleaning or other repair.
5. The percent of soil volume wetted.
6. Spacing and size of trees or other plants being irrigated.
7. Location of emission points relative to trees, vines, or other plants and uniformity of spacing of emission points.
8. Losses of pressure at the filters.
9. General topography.
10. Additional data indicated in Figure 8-32.

Graphic
List 6 thru 10

FS
Photographs showing the list of equipment.
Graphic may be used for item #7

Graphic
Subtitle Slide
FIELD EVALUATION
PROCEDURE

Graphic
Figure 8-32 parts 1,2,3, being completed using soil survey & crop data.

FS
Technician interviewing the landowner.

FS
Technician measuring pressures at the filter

Equipment needed

The equipment needed for collecting the necessary field data is:

1. Pressure gauge (0-50 psi range) with "T" adapters for temporary installation at either end of the lateral hoses.
2. A stopwatch or watch with an easily visible second hand.
3. Graduated cylinder with 250 ml capacity.
4. Measuring tape 10 to 20 feet long.
5. Funnel with 3- to 6-inch diameter.
6. Shovel and soil auger or probe.
7. Manufacturer's emitter performance charts showing the relationships between discharge and pressure plus recommended operating pressures and filter requirements.
8. Sheet metal or plastic trough 3 feet long for measuring the discharge from several outlets in a perforated hose simultaneously or the discharge from a 3-foot length of porous tubing. (A piece of 1- or 2-inch PVC pipe cut in half lengthwise makes a good trough.)
9. Copies of form for recording data.

Field Procedure

The following field procedure is suitable for evaluating both systems with individually manufactured emitters and systems that use perforated or porous lateral hose. Fill in the data blanks of the evaluation form (Figure 8-32) while conducting field procedure.

1. Fill in parts 1, 2, and 3 of Figure 8-32 concerning the general soil and crop characteristics throughout the field.
2. Determine from the operator the duration and frequency of irrigation and his concept of the MAD to complete part 4.
3. Check and note in part 5 the pressures at the inlet and outlet of the filter and, if practical, inspect the screens for breaks and any other possibility for contaminants to bypass the screens.

FS
Technician checking
the manufacturer's
specifications

4. Fill in parts 6,7 and 8 which deal with the emitter and lateral hose characteristics. (When testing perforated or porous tubing the discharge may be rated by the manufacturer in flow per unit length.)

FS
Technician deciding
on which emitters he
will evaluate

5. Locate four emitter laterals along an operating manifold (see Figure 8-29); one should be near the inlet and two near the "third" points, and the fourth near the outer end. Sketch the system layout and note in part 9 the general topography, manifold in operation, and manifold where the discharge test will be conducted.

FS
Technician checking
system flow capacity

6. Record the system discharge rate (if the system is provided with a water meter) and the numbers of manifolds and blocks (or stations). The number of blocks is the total number of manifolds divided by the number of manifolds in operation at any one time.

FS
Technician measuring
discharge at an emitter

7. For laterals having individual emitters, measure the discharge at two adjacent emission points (denoted as A and B in part 14) at each of four different tree or plant locations on each of the four selected test laterals. (See Figure 8-33). Collect the flow for a number of full minutes (1,2,3, etc.) to obtain a volume between 100 and 240 ml for each emission point tested. Convert each reading to ml per minute before entering the data in part 14 on Figure 8-32. To convert ml per minute to gallons per hour (gph), divided by 63.

These steps will produce eight pressure readings and 32 discharge volumes at 16 different plant locations for individual emission points used in wide-spaced crops with two or more emission points per plant.

Graphic
REPEAT STEPS
5 and 7
on 4 other
LATERALS

For relatively wide-spaced crops such as grapes where one single outlet emitter may serve one or more plants, collect a discharge reading at each of the 16 locations described above. Since the plants are only served by a single emission point, only one reading should be made at each location.

FS

Technician measuring discharge from porous tubing using plastic trough.

For perforated hose or porous tubing, use the 3-foot trough and collect a discharge reading at each of the 16 locations described above. Since these are already averages from 2 or more outlets, only one reading is needed at each location.

FS

Technician measuring lateral pressures

8. Measure and record in part 15 the water pressures at the inlet and downstream ends of each lateral tested in part 14 under normal operation. On the inlet end, this requires disconnecting the lateral hose, installing the pressure gauge, and reconnecting the hose before reading the pressure. On the downstream end, the pressure can be read after connecting the pressure gauge the simplest way possible.
-

FS

Technician determining wetted area

9. Check the percentage of the soil that is wetted at one of the tree locations on each test lateral and record in part 16. It is best to select a tree at a different relative location on each lateral. Use the probe, soil auger, or shovel--whichever seems to work best--for estimating the real extent of the wetted zone below the surface around each tree. Determine the percentage wetted by dividing the wetted area by the total surface area between four trees.
-

FS

Technician determining SMD by the "Feel" method

10. If an interval of several days between irrigations is being used, check the SMD in the wetted volume near a few representative trees in the next block to be irrigated and record it in part 17. This is difficult and requires averaging samples taken from several position around each tree.
-

Graphic

Showing approximate location of MLIP for:

1. Level lateral
2. Downhill lateral
3. Uphill lateral

11. Determine the minimum lateral inlet pressure, MLIP, along each of the operating manifolds and record in part 18. For level or uphill manifolds the MLIP will be at the far end of the manifold. For downhill manifolds it is often about two-thirds down the manifold. The manifolds on undulating terrain it is usually on a knoll or high point.

Graphic
Illustrate Eq. 19
DCF = _____

12. Determine the discharge correction factor, DCF, to adjust the average emission point discharges for the tested manifold. This adjustment is needed if the test manifold happened to be operating with a higher or lower MLIP than the system average MLIP. If the emitter discharge exponent, x , is known, use the second formula presented in part 19.
-

Graphic
Illustrate Eq. 12
Adj. Average Emission
Point Discharge

13. Determine the average and adjusted average emission point discharges according to the equations in parts 11 and 12 of Figure 8-32.
-

FS
Select an emitter
showing wetted area,
without any ponding
or runoff.

Utilization Of Field Data

In trickle irrigation all the system flow is delivered to individual trees, vines, shrubs, or other plants. Essentially there is no opportunity for loss of water except at the tree or plant locations. Therefore, uniformity of emission is of primary concern, assuming the crop is uniform. Locations of individual emission points, or the tree locations when several emitters are closely spaced, can be thought of in much the same manner as the container positions in tests of sprinkler performance.

FS
Emitters operating
in a citrus grove

There are four single emission point emitters per tree in the citrus grove where this test was conducted to obtain the data listed in Figure 8-32. Therefore, the discharges from the two (A and B) emitters at each tree can be averaged. The minimum rate of discharge (or low 1/4) is then the adjusted average discharge of the lowest four of these (average) discharges per tree of 2.30 gph for the sample evaluation. The adjusted average rate of discharge per tree for the entire system was 2.65 gph. (See Figure 8-32, part 12.)

FADE
FOR
BREAK

BREAK

Facilitator to review the evaluation steps with the students.

TRICKLE IRRIGATION SYSTEM EVALUATION

PART II

APPLICABLE EQUATIONS

SUBTITLE
APPLICABLE
EQUATIONS

Graphic
Average application
depth = D_{aw}
 $D_{aw} = \frac{1.605 \times N \times \text{gph} \times \text{hours}}{\text{feet} \times \text{feet}}$

INST
Instructor illustrating
these two equations
with graphics.

INST & GRAPHICS

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Average Application Depth:

The average depth applied per irrigation to the wetted area, D_{aw} is useful for estimating MAD. The D_{aw} in inches is computed from the average gph at each emission point, the number, of emission points per tree, N, the number of hours of operation per irrigation, and the area wetted per tree in square feet:

$$D_{aw} = \frac{1.605 \times N \times \text{gph} \times \text{hours}}{\text{feet}^2}$$

which for the sample evaluation (Figure 8-32, parts 2, 4, 7, 12, and 14) is:

$$D_{aw} = \frac{1.605 \times 4 \times 2.65 \times 6}{140} = 0.73 \text{ inch}$$

The overall average depth applied, D_a in inches can be found by substituting the tree spacing for the wetted area in the formula immediately preceding. Therefore:

$$D_a = \frac{1.605 \times 4 \times 2.65 \times 6}{22 \times 22} = 0.21 \text{ inch}$$

Volume Per Day Per Tree:

The average number of gallons per day per tree or plant is computed from the average gph at each emission point, the number N of emission points per tree, the number of hours of operation per irrigation, and the irrigation interval in days:

$$\text{Average daily gallons per tree} = \frac{N \times \text{gph} \times \text{hours}}{\text{days}}$$

which for the sample evaluation (Figure 8-32, parts 4, 7, and 12) is:

$$\text{Average daily gallons per tree} = \frac{4 \times 2.65 \times 6}{1} = 63.6 \text{ gallons/day}$$

Emission Uniformity

In order to determine whether the system is operating at acceptable efficiency, evaluate the uniformity of emission by calculating ER by this formula:

$$EU = \frac{\text{minimum rate of discharge per plant}}{\text{average rate of discharge per plant}} \times 100$$

in which the average of the lowest quarter (Figure 8-32, part 12) is used as the minimum for each of the four emitters per plant:

$$EU = \frac{4 \times 2.30}{4 \times 2.65} \times 100 = 87\%$$

Graphic

EU Values
 90% Excellent
 80-90% Good
 70-89% Fair
 70% Poor

General criteria for EU values for systems which have been in operation for one or more seasons are: greater than 90%, excellent; between 80% and 90%, good; 70% to 80%, fair; and less than 70%, poor.

Graphic

PELQ =
 Potential Application
 Efficiency Low Quarter

Potential Application Efficiency Low Quarter (PELQ)

The concept of PELQ used in other evaluation procedures must be modified when evaluating trickle irrigation systems, which wet only part of the area because the minimum depth would be zero. Since trickle irrigation wets only a portion of the soil volume, the SMD must be replaced frequently. It is always difficult to estimate SMD because parts of the wetted portion of the root zone often remains near field capacity even when the interval between irrigation is several days.

Graphic

Estimated by
 PELQ = 0.9 X EU

For the sample evaluation where irrigations are applied every day, it is practically impossible to estimate SMD. For this reason, SMD must be estimated from weather data or information derived from evaporation devices. Such estimates are subject to error and since there is no practical way to check for slight under irrigation, some margin for safety should be allowed. As general rule, about 10% more water than the estimated SMD or evapotranspiration should be applied to the least watered areas. Thus the PELQ under full trickle irrigation can be estimated by:

$$PELQ = 0.9 \times EU$$

which for the sample test data shown in Figure 8-32 is

$$PELQ = 0.9 \times 87\% = 78\%$$

Graphic

In a trickle irrigation system, there are no field boundary effects or pressure variations along the manifold tested which are not taken into account in the field estimate of EU. Therefore, the estimated PELQ is an overall value for the manifold in the sub-unit tested except for possible minor water losses due to leaks, draining of lines, and flushing (unless leaks are excessive).

Graphic

ERF = Efficiency Reduction Factor

$$= \frac{\text{Avg. MLIP} + 1.5 \times \text{Min. MLIP}}{2.5 \times \text{Avg. MLIP}}$$

Some trickle irrigation systems are fitted with pressure compensating emitters or have pressure (or flow) regulation at the inlet to each lateral. However, most systems are only provided with a means for pressure control or regulation at the inlets to the manifolds as was the case with the system evaluated. If the manifold inlet pressures are not properly set, the overall system PELQ will be lower than the PELQ of the tested manifold. An estimate of this efficiency reduction factor, ERF, can be computed from the minimum lateral inlet pressure, MLIP, along each manifold by:

$$ERF = \frac{\text{average MLIP} + 1.5 \times \text{minimum MLIP}}{2.5 \times \text{average MLIP}}$$

Graphic
System PELQ =
ERF x Test PELQ

The ratio between the average emission point discharges in the manifold with the minimum pressure and the system is approximately equal to ERF. Therefore, the system PELQ can be approximated by:

$$\text{System PELQ} = \text{ERF} \times \text{Test PELQ}$$

Graphic
ERF =

Using the data in Figure 8-32, part 18, and the test PELQ of 78%,

$$\text{ERF} = \frac{46.1 + (1.5 \times 42)}{2.5 \times 46.2} = 0.95$$

and,

$$\text{System PELQ} = 0.95 \times 78\% = 74\%$$

Graphic

A more precise method for estimating the ERF can be made if the emitter discharge exponent, x , is known by

$$\text{ERF} = \frac{(\text{minimum MLIP})^x}{(\text{average MLIP})^x}$$

For the tested system with orifice type emitters, which have an x of 0.5, this alternative calculation of ERF gives:

$$\text{ERF} = \frac{42^{0.5}}{46.1^{0.5}} = \frac{\sqrt{42}}{\sqrt{46.1}} = .95$$

Graphic

In this case the two methods for computing ERF give essentially equal results; however, for larger pressure variations or x values higher or lower than 0.5, the differences could be significant.

Application Efficiency, Low Quarter (AELQ)

Like PELQ, the concept of AELQ must also be modified for trickle irrigation. Effectiveness of a trickle system can be estimated by how much of the applied water is stored in the root zone and is available for consumptive use by the plants. Since there are essentially no opportunities for losses due to evaporation and drift, for inadequate irrigation in which the least watered areas are under irrigated:

$$\text{System AELQ} = \text{ERF} \times \text{Test EU}$$

However, if excess water is applied in the least watered areas:

$$\text{System AELQ} = \frac{\text{SMD in wetted area}}{\text{average depth applied to wetted area}} = 100$$

Graphic

Graphic

For the evaluation shown in Figure 8-32 where daily irrigations were being applied, it was impossible to estimate SMD in the wetted areas around each tree. Furthermore, the average depth applied to the total area, D_a , was only 0.21 inch per day which is hardly sufficient to meet the expected consumptive use requirements for mature citrus trees at the study location. Therefore, it is highly probable that the trees were being under irrigated, in which case for the test EU of 87%:

$$\text{System AELQ} = 0.95 \times 87 = 83\%$$

Overall Minimum Depth Applied:

The overall average depth applied to the total area, D_a , multiplied by System PELQ (or AELQ) is useful for managing the irrigation schedule because water requirements are expressed in similar units. (Multiply by the System PELQ except when there is under irrigation and AELQ is greater than PELQ.) For the sample evaluation the overall minimum depth applied to the total area, D_n is:

$$D_n = D_a \times \text{System PELQ (or AELQ)} / 100$$

which for the sample evaluation which is under irrigated and has System PELQ and AELQ values of 74% and 83%, respectively, is:

$$D_n = 0.21 \times 83 / 100 = 0.17 \text{ inch}$$

Analysis and Recommendations:

Several observations and some recommendations can be based on the additional data in Figure 8-32 and the computations of EU, PELQ, and AELQ.

The pressure differences throughout the operating manifold studied were very small. (See Figure 8-32, part 15.) Pressure variations of 20% for orifice-type emitters and 10% for the long tube type result in flow differences of about 10%. Obviously it is important that each control valve be adjusted accurately to insure uniform pressures throughout the orchard. However, this was not the case as noted by the minimum lateral inlet pressure variations between manifolds as indicated in part 18 or Figure 8-32.

Uniformity of application throughout the operating manifold, expressed by the EU of 87%, was good. Since the pressures were very nearly constant, it appears that most of the lack of uniformity of application resulted from variations in operation of the individual emitters. This can be verified by studying the table in Figure 8-32, part 14. The discharges of emitters A and B at the same location, which would have almost identical pressures, often differed considerably.

Differences in elevation throughout the system were not extreme so the other manifolds should have produced similar uniformities. (See Figure 8-32, part 9.)

Graphic

Graphic

Graphic

Graphic

Graphic

The percentage of wetted area ranged between 26% and 31% (Figure 8-32, part 12); this was less than the recommended minimum discussed in the introduction for arid areas.

For the fertilizer application program, urea was being injected into the irrigation water. Other fertilizers were being applied directly to the soil surface and incorporated by cultivation in the fall prior to the winter rainy season. This fertilizer program should prove satisfactory and the cause no problem with the irrigation equipment.

FS
Showing several types and styles of emitters

Emitters:

The emitters used in the recorded test were the automatic flushing type. The variations in discharge reported above probably were due to differences in manufacturing tolerance. These emitters, operating at pressures near 45 psi, averaged a discharge of 2.62 gph (Figure 8-32, parts 6, 11, and 15), which is considerably less than the rated 3.0 gph at 30 psi and indicates that the orifices may have been closing slowly or clogging after about one season's operation.

FS
Showing clogged emitters
FS
Showing multiple outlets

Variable clogging can cause large differences in flow from non-flushing emitters even though manufacturing tolerances may be very close. Some emitters can be flushed manually. Systems having manually flushed emitters should be checked monthly to determine the amount of change in flow before and after flushing.

Some multiple outlet emitters have a separate pressure dissipating channel for each outlet and thus the discharges at each emission point are independent. Other multiple outlet emitters have a single pressure dissipating channel discharging into the several outlets. With such emitters, the discharges through each outlet tube are usually erratic due to small elevation differences and blockage in the spaghetti tubes.

FS
Showing various types and styles of filters

Filters:

The filter system near the pumping plant seemed to be performing reasonably well. Apparently, it was not seriously clogged at the time of the check since the loss of pressure across it was only 5 psi (Figure 8-32, part 5). Small safety screen filters were installed at the inlet to each lateral hose. This precaution is recommended. Several of these screens were checked at random and all were reasonably clean; however, several screens had intercepted a considerable amount of coarse material that would have clogged some emitters if it had passed through the laterals. The operator said he routinely cleans each safety screen after every 1000 hours of operation.

Graphic
Showing change in wetted area by increasing irrigation interval

Improvements:

A major improvement would be to increase the percent of wetted volume or area allocated to each plant. This could be achieved by increasing the interval between irrigations to 2 days or by adding one or two emitters at each tree and decreasing the operating pressure accordingly.

Changing to a 12-hour irrigation on alternate days instead of continuing the present 6 hours per day could improve the percent of wetted area because longer applications wet more soil volume. No problems of infiltration were apparent, and the average depth applied to the wet area, D_{aw} of 0.73 inch, could easily be doubled without exceeding the SMD at a MAD of 30%. For example, a total of 8 inches of moisture would be available. The depletion of $2 \times 0.73 = 1.46$ inch gives a MAD of less than 20% in the wetted area.

FS
Landowner adjusting valves while technician checks pressures.

The manifold inlet valves should be adjusted to give the same minimum lateral inlet pressure on each manifold. This would increase the System PELQ and AELQ to the PELQ and AELQ of the tested manifold which is a 5% improvement.

It appears that emission from the lateral hoses had been gradually decreasing and that the system was designed to yield greater flow than was observed.

FS
Showing the addition of an emitter.

Thus, adding emitters could restore the system's capacity to the original 12 gph per tree at an average pressure of 30 psi and increase the percentage wetted area to almost 40%.

The only sure way to improve EU would be to replace the emitters; this would be very expensive and is not now warranted. Chemical treatment may clean some of the mineral deposits and partially restore the discharge rate and uniformity.

FS
Showing flow variations between emitters.

The overall minimum depth applied to the total are, D_n (only 0.17 inch per daily cycle) seems to be marginal for a mature orchard during the peak period of water demand. Although emitters were rated at 3.0 gph when operated at 30 psi, the test results in the field indicated that average rate of flow as only 2.62 gph at 45 psi; to meet the peak demands of water, the flow rate per tree would have to be restored to the original design of 12 gph (four emitters at 3 gph) by cleaning or otherwise repairing the emitters, by increasing the operating pressure, or by adding another emitter to the system at each tree.

Graphic

Summary

The EU of 87% and estimated PELQ of 78% of the tested manifold are good. The main system problems are associated with a marginal amount of soil wetted (only about 30%), poor manifold control valve adjustment, and low rates of flow in the system. The operator was advised to try scheduling the irrigation to apply water for 12-hour periods on alternative days instead of continuing the current 6 hours per day cycling. He was also urged to (a) adjust the manifold control valves to obtain equal minimum lateral inlet pressures on all manifolds; and (b) to clean or repair the emitters or to add an extra emitter at each tree to restore flow rates to the designed volume and to increase the percent of wetted area.

Graphic

CREDITS

END

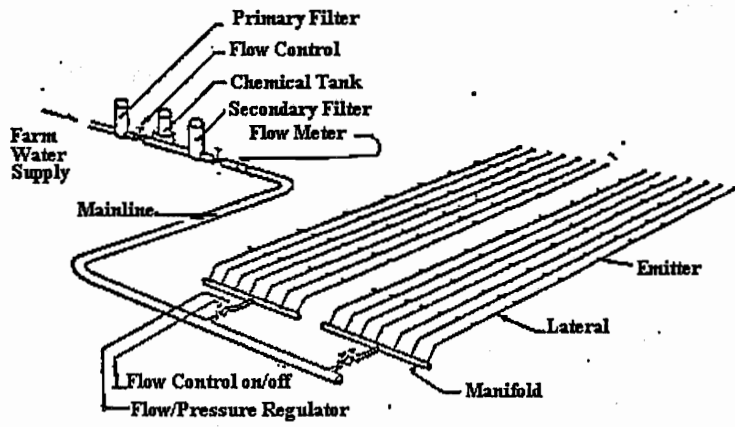


Figure 8-29 - Basic components of a trickle-irrigation system.

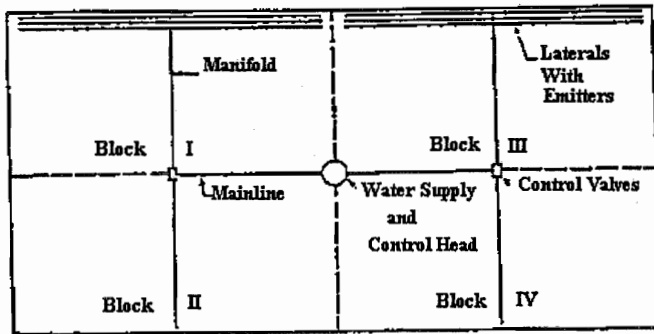


Figure 8-30 - Typical two station split flow layout for trickle irrigation system with Block I and III, or II and IV operating simultaneously.

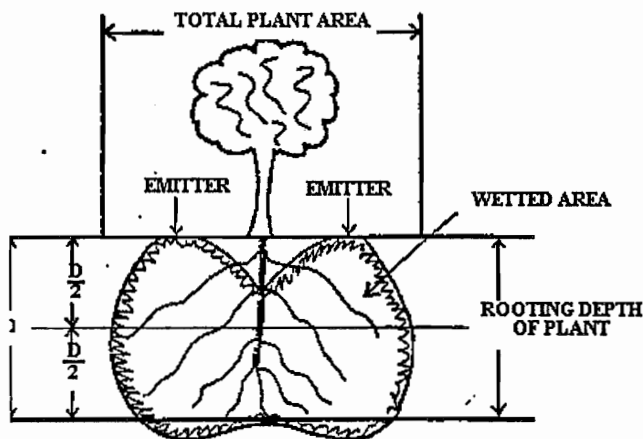
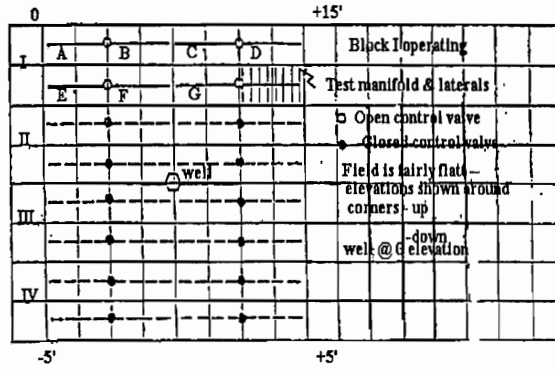


Figure 8-31 - Typical wetted area under a plant with two emitters.

Figure 8-32. TRICKLE IRRIGATION EVALUATION

1. Location Ranch , Observer JK , Date 8-1-1971
2. Crop: type Citrus , age 7 years , spacing 22-by 22-feet
root depth 4 ft., percent area covered or shaded 70 %
3. Soil: texture silt loam available moisture 2.0 in/ft
4. Irrig: duration 6 hrs. frequency 1 days , MAD 10 % , .8 in
5. Filter pressure: inlet 60 psi , outlet 55 psi , loss 5 psi
6. Emitter: make SP , type flushing , point spacing 5 ft
7. Rated discharge per emission point 3.0 gph at 30 psi
Emission points per plant 4 giving 72 gallon per plant per day
8. Hose: diameter 0.58 in. material PVC , length 150ft., spacing 22 ft
9. System layout, general topography, and test locations:



10. System discharge -- gpm, No. of manifolds 32 and blocks 4
11. Average test manifold emission point discharges at 45 psi

$$\text{Manifold} = \frac{(\text{sum of all averages } 41.94 \text{ gph})}{(\text{number of averages } 16)} = 2.62 \text{ gph}$$

$$\text{Low 1/4} = \frac{(\text{sum of low 1/4 averages } 9.07 \text{ gph})}{(\text{number of low 1/4 averages } 4)} = 2.27 \text{ gph}$$

12. Adjusted average emission point discharges at 46.1 psi

$$\text{System} = (\text{DCF } 1.012) \times (\text{manifold average } 2.62 \text{ gph}) = 2.65 \text{ gph}$$

$$\text{Low 1/4} = (\text{DCF } 1.012) \times (\text{manifold low 1/4 } 2.27 \text{ gph}) = 2.30 \text{ gph}$$

13. Comments: Trees looked as if they were not receiving enough water! Urea was being injected. Filter system seemed okay.

14. Discharge test volume collected in 1.0 min (1.0 gph = 63 ml/min)

Outlet Location on Lateral		Lateral Location on the Manifold							
		Inlet end		1/3 down		2/3 down		far end	
		ml	gph	ml	gph	ml	gph	ml	gph
inlet end	A	132	2.10	160	2.54	192	3.04	195	3.10
	B	160	2.54	188	2.99	140	2.23	205	3.26
	Ave		2.32		2.77		2.64		3.18
1/3 down	A	160	2.54	295	3.10	175	2.78	169	2.69
	B	168	2.66	158	2.50	170	2.70	180	2.86
	Ave		2.60		2.80		2.74		2.78
2/3 down	A	187	2.97	146	2.31	125	1.99	144	2.29
	B	175	2.78	155	2.46	155	2.46	175	2.78
	Ave		2.88		2.38		2.23		2.54
far end	A	170	2.70	190	3.02	210	3.34	151	2.39
	B	125	1.99	135	2.15	166	2.62	130	2.07
	Ave		2.34		2.58		2.98		2.18

15. Lateral inlet closed end 47.5 psi 45.0 psi 45.5 psi 45.0 psi
46.0 psi 43.5 psi 45.0 psi 44.0 psi
16. Wetted area 150 ft² 125 ft² 140 ft² 145 ft²
per plant 31 % 26 % 29 % 30 %
17. Estimated average SMD in wetted soil volume _____ in _____
18. Minimum lateral inlet pressures, MLIP, on all operating manifolds:
Manifold: Test A B C D E F G Ave.
Pressure-psi 45 49 47 43 42 50 48 45 46.1

19. Discharge correction factor, DCF, for the system is:
 $DCF = \frac{2.5 \times (\text{average MLIP } 46.1 \text{ psi})}{(\text{average MLIP } 46.1 \text{ psi}) + 1.5 \times (\text{test MLIP } 45 \text{ psi})} = 1.015$
or if the emitter discharge exponent _____ = 0.5 is known
 $DCF = \left[\frac{(\text{average MLIP } 46.1 \text{ psi})}{(\text{test MLIP } 45 \text{ psi})} \right]^{0.5} = 1.012$

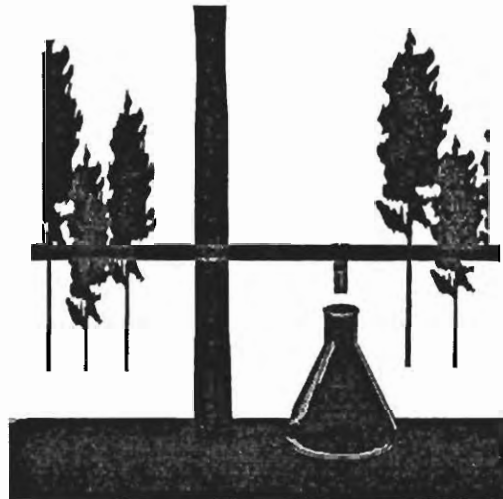


Figure 18-33 Field measurement of emitter discharge.