SOUTH CAROLINA IRRIGATION GUIDE

# CHAPTER 5. IRRIGATION METHOD SELECTION

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# CHAPTER 5. IRRIGATION METHOD SELECTION

## GENERAL

Selecting the irrigation system for a site is not always straighforward but is dependent upon many factors. Often times the case is that some sites are adaptable to several methods of irrigation with the final selection being based on factors such as initial cost, operating costs, adaptability to farming operation, adaptability for other uses and personal preference. Methods of irrigation used in South Carolina have advantages and disadvantages that are discussed in this chapter. This chapter will also discuss the various factors to consider in determining method suitability and provide general guidance in irrigation method selection.

## METHODS OF APPLYING WATER

There are four basic methods of applying water: (1) sprinkler, (2) trickle, (3) subirrigation, and (4) surface.

### SPRINKLER IRRIGATION

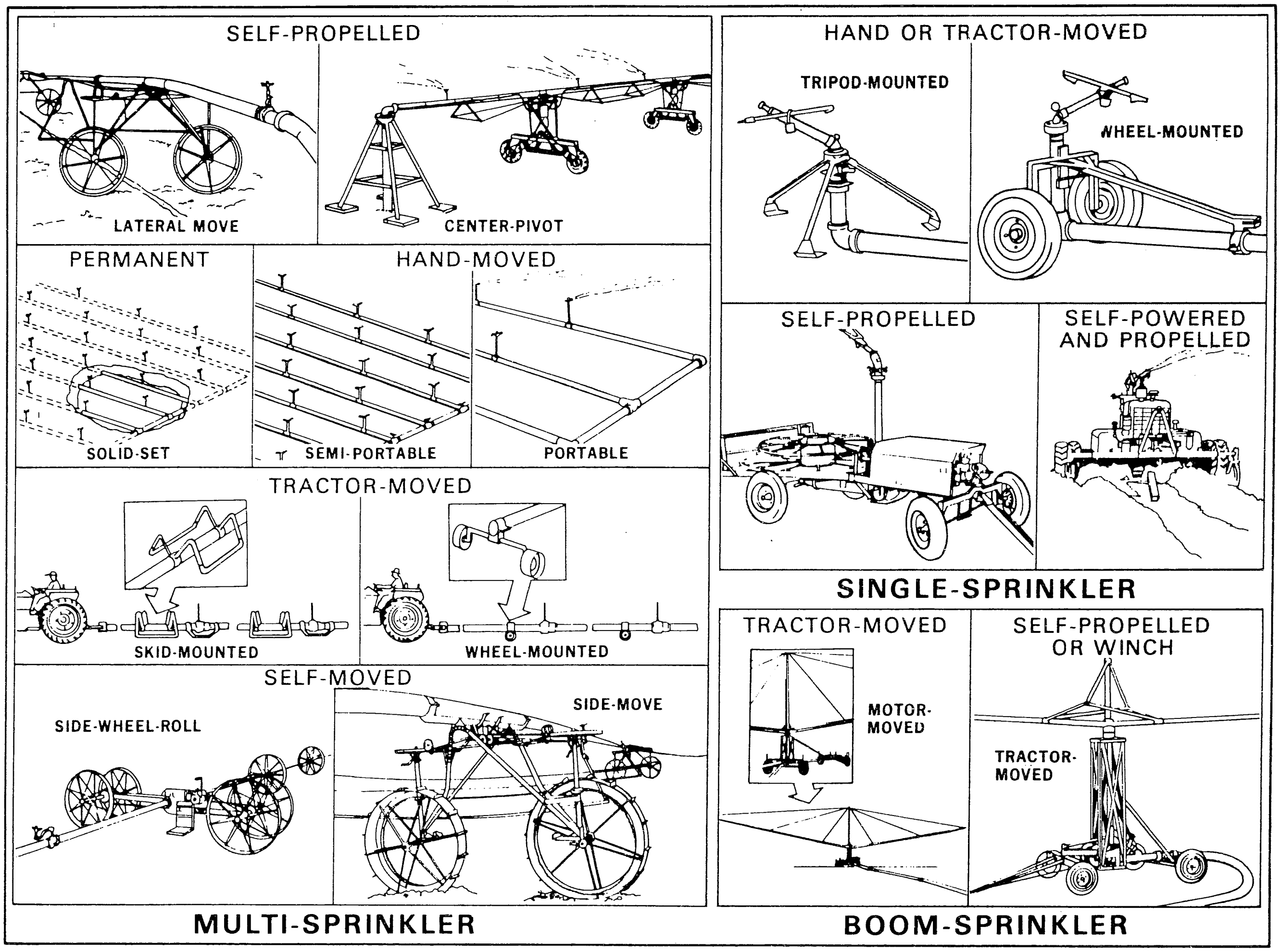
Sprinkler irrigation is a system in which the irrigation water is distributed to the field through pipelines and applied to the soil by spraying with sprinkler nozzles or perforations operated under pressure. Types of sprinkler systems include: permanent solid-set, hand move, tractor move, wheel or skid mounted, side move or side wheel-roll power move, hand or power moved single sprinkler (volume gun), power moved boom sprinkler and self propelled lateral move or center-pivot. The majority of sprinkler systems used in South Carolina are power moved volume gun (traveling gun) and center pivot. See Figure 5-1 showing the types of sprinkler irrigation systems.

### TRICKLE IRRIGATION

Trickle irrigation is a system for efficient, slow application of water for irrigation directly to the crop root zone area. The water is applied on or below the soil surface through emitters or applicators placed along small diameter laterals operated under pressure. Common types of emitters include orifices, micro tubes, sprayers, porous or perforated tubing and bubblers. See Figure 5-2 showing typical emitters.

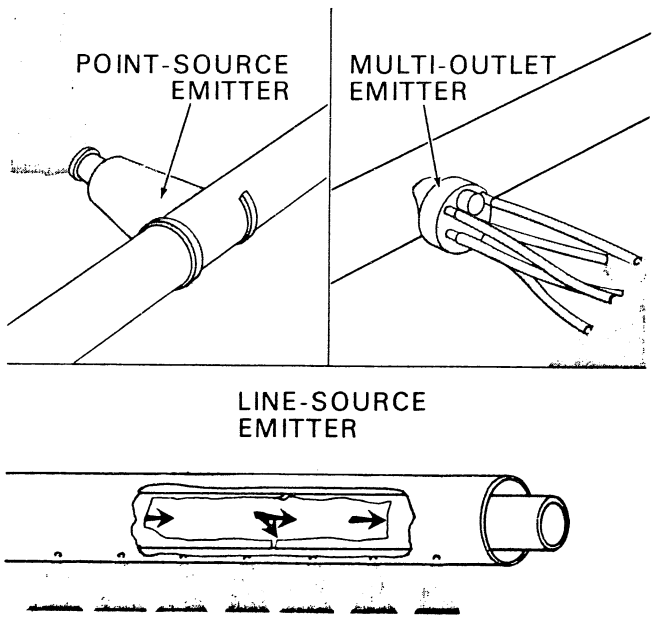
### SUBIRRIGATION

Subirrigation is a system where the water is supplied to the root zone of the crop by controlling the water table (natural or artificial). The basic types of subirrigation are open ditch and under-ground conduit.



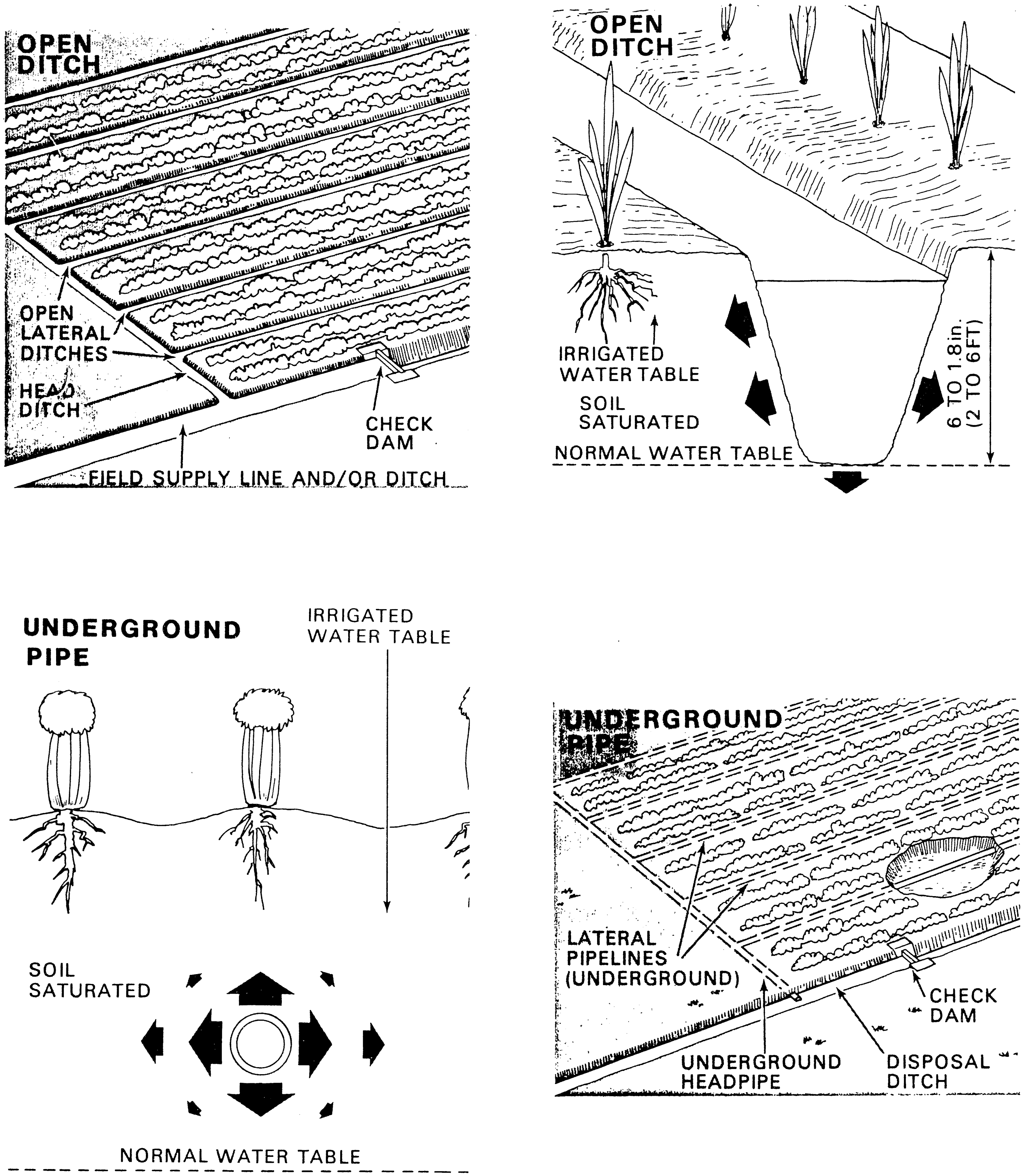

**TYPICAL SPRINKLER IRRIGATION SYSTEMS**

**FIGURE 5-1**




**TYPICAL TRICKLE EMITTERS**

**FIGURE 5-2**




**TYPICAL SUBIRRIGATION SYSTEMS**

**FIGURE 5-3**

The water table is usually controlled by the use of check dams. See Figure 5-3 showing typical subirrigation systems.

## SURFACE IRRIGATION

Surface irrigation is a system where the irrigation water is distributed and applied by gravity flood flow over the area to be irrigated. Surface flood methods include furrow, level and graded border, contour levee and contour ditch. There are few if any true surface irrigation systems in South Carolina.

# FACTORS AFFECTING THE IRRIGATION METHOD SELECTION

## TOPOGRAPHY

If the topography of the land is level or can be made level without too much expense, then it will have little affect on the irrigation method. If the land is sloping, it may be limited to only the sprinkler or trickle irrigation system. With the sprinkler method, water can be applied slowly enough to prevent runoff and possible erosion. With the trickle irrigation systems, the emitter discharge rates can be matched to soil intake rates and uniform pressure distribution can be obtained through pressure regulation and lateral arrangement. Surface irrigation methods are applicable to level or nearly level land; however, very little, if any, surface irrigation is used in South Carolina.

## WATER INTAKE RATE

The water intake rate of the soil affects the method of irrigation selected. The sprinkler and trickle irrigation systems can be used on low intake rates (0.5 inches per hour or less), or high intake rates (3.0 inches per hour or greater). The actual soil intake rate will dictate the type of sprinkler system used since some sprinkler systems have application rates higher than the soil intake rate. The intake rate for trickle irrigation systems will dictate the maximum application rate and number of emitters for a particular system. For subirrigation systems, the soil intake rate should be moderate to high to assure good distribution in the soil profile and there must be an impervious layer below the root zone or a high, controllable water table. For surface systems, the intake rate determines the time of flooding needed to supply the water.

## WATER HOLDING CAPACITY

The water holding capacity does not directly affect the method of irrigation. It does, however, determine the frequency of irrigation and the amount of water applied per irrigation. The method of irrigation must be able to irrigate the entire unit before the soil-water content depletes below the desired level. Otherwise, the crop may not reach its maximum production potential.

## WIND ACTION

Wind action can affect the water application efficiency of the sprinkler method. Strong winds will increase the direct evaporation losses to the atmosphere. These losses are greater as temperature and wind velocities increase and as humidity, drop size, and application rates decrease.

Table 5-1 summarizes the factors affecting the irrigation method selection.

Table 5-1. Factors Affecting the Selection of a Water-Application Method

| Water Application Method | Factors Affecting Selection | | |
|---|---|---|---|
| | Topography | Water Intake Rate of the Soil | Wind Action |
| Sprinkler | Adaptable to both level and sloping ground surfaces. | Some sprinkler systems limited by intake rate. However, any intake rate can be sprinkler irrigated. | Wind may affect application efficiency. |
| Trickle | Adaptable to all land slopes. | Adaptable to all intake rates. | No effect. |
| Subirrigation | Land should be level or contoured. | Adaptable to intake rates of 0.5"/hour or greater. Adaptable only to those soils which have an impervious layer below the root zone or a high controllable water table. Permeability should be 2 in/hr or greater for best results. | No effect. |
| Surface Irrigation | Adaptable to nearly level land where land leveling can be provided at a reasonable price and soil depth is sufficeint to not expose unproductive soil. | Soils with high intake rates are not suitable for surface irrigation. | Very little effect. |

Once the method of water application has been selected (sprinkler, trickle, or subirrigation), it is desirable to select the specific type of system that is best suited to the farming operation, soil and crop requirements, and desires of the farmer.

## PERMANENT/SOLID-SET

### Description

A solid-set system is an aluminum pipe system that is placed in the field or fields to be irrigated prior to the start of the growing season and left in place throughout the growing season. A permanent solid-set system is defined as a pipe system placed underground with only a portion of the risers and sprinklers above ground. Almost all the permanent systems being installed today use pressure rated polyvinyl chloride (PVC) plastic pipe.

Permanent and solid-set systems are normally designed for spacings of 40 ft x 40 ft, 40 ft x 60 ft, and 60 ft x 60 ft. When these systems are used in orchards, the spacings may be somewhat different to conform to tree spacing. The actual spacings are based on a percent of the sprinkler wetted diameter that is compatible with the farming operation.

The sprinklers are either single or dual nozzle design with operating pressures usually in the range of 30 to 60 pounds per square inch and a wetted diameter up to about 125 feet.

Risers are located out of the way of equipment and constructed to a height compatible with the height of the crop to be irrigated. The risers, when permanent, are supported in concrete anchor blocks.

The field application efficiency used in design ranges from 70 percent for daytime operation to 80 percent for nightime operation.

### Advantages and Disadvantages

The advantages of solid-set and permanent systems are that they can be adapted to irregularly shaped fields, low labor requirement, adaptable for frost and freeze protection, and chemigation. The disadvantages are high initial cost and moderate energy use.

## TRAVELING GUN

### Description

Traveling guns are of two general types and are referred to as cable-tow travelers and hose-pull travelers. The cable-tow traveler can be described as a gun sprinkler mounted on a wheeled chassis to which a hose is connected and the machine winds up a steel cable anchored at the far end of the field. Power to propel the cable winch is supplied by an auxiliary engine, water motor, water piston, or water turbine. In some cases, the auxiliary engine may drive the unit directly or power a hydraulic pump which drives a hydraulic motor to propel the unit.

The hose for the cable-tow is a woven synthetic fabric tube covered inside and out by either rubber or polyvinyl chloride. Hoses are available in sizes from 2½-inch to 5-inch and in lengths from 330 feet to 1320 feet.

The hose-pull traveler is a system composed of a large hose reel mounted on a four wheel cart to which is attached a polyethylene hose that pulls a single gun sprinkler through the field and also supplies water to the sprinkler. The trailer mounted hose reel is stationary at the end of the field while irrigation is being applied. The hose reel is driven by a turbine, bellows, water piston, or auxiliary engine and as the reel turns the hose is wound around the reel.

Hoses for the hose-pull are available in sizes from 2-inch to 4½-inch inside diameter. Hose length will vary from 620 feet to 1250 feet. The hose is made of polyethylene with a wall thickness of 3/16 to 9/16-inch depending upon the diameter.

The sprinkler is a high capacity nozzle ranging from 50 to 1000 gpm. Normally, the sprinkler pressure will be 70 to 100 psi. To satisfactorily operate, a large capacity cable-tow traveler will require a minimum pump discharge pressure of 125 psi on reasonably flat terrian to as much as 180 psi on steep terrain. In comparison a similar hose-pull system will require a minimum pump discharge pressure of 145 psi on reasonably flat terrain to as much as 200 psi on steep terrain.

The field application efficiency used in design is 70 percent. Under certain conditions higher efficiencies can be obtained.

## Operation of Cable-Tow and Hose-Pull Systems

### Cable-Tow Systems

To obtain maximum performance from the traveler, the system should be laid out to irrigate in the most economical manner. With a 660-foot hose a field up to 1400 feet long can be irrigated with the supply line across the middle of the field. The machine is moved into position in the first alley 60 to 120 feet from the edge of the field depending upon the size sprinkler. This will adequately water the outside edge and some water will be thrown out of the field. The cable will be uncoiled with a tractor and attached to an anchor which may be an earth anchor, tractor, truck or tree. The operator should be sure the anchor will withstand the pull exerted by the machine. The pull will depend upon the size of the machine. For a 4½-inch, 660 foot hose this could be more than 6000 pounds. The hose is unrolled and connected to a hydrant. There should be about 30 feet of hose behind the machine.

The machine will be positioned some 60 to 120 feet from the end of the field. The pump should be started and the sprinkler operated for about 30-45 minutes before the machine is placed in gear. Speed should be set to give the correct application of water. The anchor on the far end should be some 60 to 120 feet from the end of the field. When the machine reaches the end it will stop traveling, but the sprinkler will continue to operate until the pump is shut down. A run time of 30 to 45 minutes on the end should adequately water the end. Figure 5-4 shows a typical layout for the cable-tow traveler.

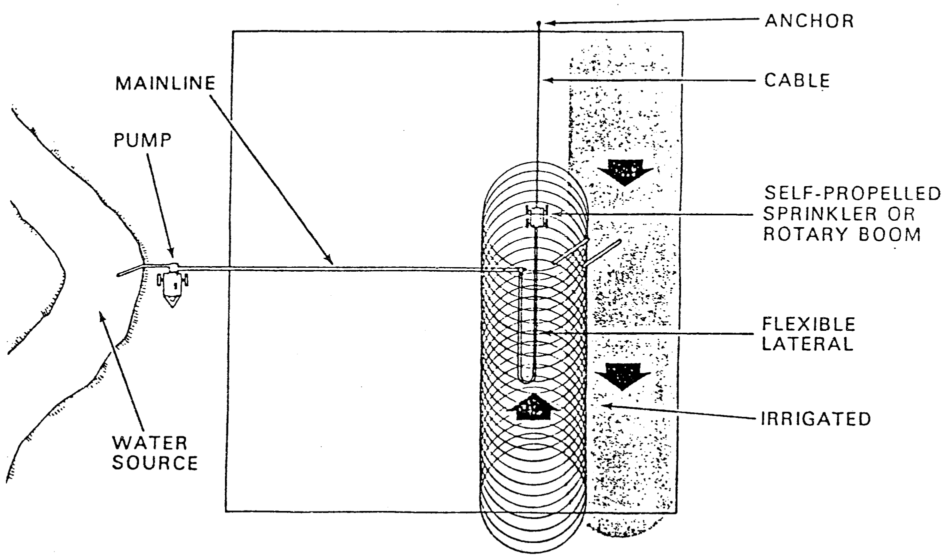



Figure 5-4. Layout for a traveling sprinkling system.

The normal spacing between alleys is approximately 70 percent of the sprinkler wetted diameter. Spacing will need to be reduced as wind speed increases.

When irrigation from an alley is completed, disconnect the hose from the hydrant, purge the hose of water, reel the hose onto the reel, and move the traveler to the next alley. Repeat the process of laying the cable and anchoring it and laying out the hose and connecting to the supply line. Once the pump is shut down, it will require from 45 to 60 minutes of time to move and set up the equipment for the next irrigation. A tractor will be needed to move the machine.

There are several items that should be considered in the maintenance of cable-tow systems. All of the pull of the traveler is against the cable. Check occasionally for frayed or worn cable and replace or repair before a break occurs. Check the hose for small cuts or nicks and repair before major damage occurs. The hoses can be repaired either with a metal hose mender or with a repair kit by a commercial company. When storing the hose, roll several coils of the hose loosely on the reel. This prevents stretching the end of the hose. Store hose away from grease, rodents, and sunlight. Do not try to reel the hose with water in it. Keep obstacles away from the hose. A hose that is handled carefully should last 10 years or more. Check the mechanical components of the machine. This includes the drive mechanism, sprinkler and hose reel. When the machine is operating, check the travel speed to ensure that it is operating at the desired speed and that it maintains the speed. Check the speed near the beginning, middle and near the end of the run. Use the travel tables furnished by the manufacturer to set the speed to give the desired application, but check to see if the machine is performing as specified.

The cable-tow traveler is a versatile machine that can be used to apply animal wastes. The water drive units will be less satisfactory than some of the engine drive units. On the water drive units (water piston, water turbine and water motor) solids may tend to clog the drive mechanism. Check with a dealer on recommendations on using the machine for land application of wastewater. Generally, swine wastewater from a lagoon can be satisfactorily handled with any machine; swine pit wastewater, poultry, beef and dairy waste will have enough large and fibrous solids to possibly cause problems on some machines.

Hose-Pull Systems

The hose-pull traveler is fairly easy to operate. On low growing crops that a tractor can straddle, an alley is not needed. A tractor or other prime mover is used to unwind the hose and move the sprinkler cart and hose from the hose reel to the far end of the field. Depending upon the size of the sprinkler, the first alley will be 90 to 125 feet from the edge of the field. Some water will be wasted outside the field, but it is necessary to do this to adequately irrigate the edge of the field. It should be allowed to operate for 30 to 45 minutes before the hose reel is placed in gear. The sprinkler cart is then pulled through the field at speed to give the correct application of water. The sprinkler may be stopped 90 to 120 feet from the near end of the field and allowed to operate for 30 to 45 minutes to irrigate that end. The sprinkler may be operated in a full or part circle mode. Some growers will leave a pie-shaped section in front of the sprinkler unirrigated so that the sprinkler cart is operating on dry ground.

The hose and sprinkler cart travels best in a straight line, but due to the thick wall and heavy weight of the hose when it is full of water, it will follow some contour. Ridges will also aid in allowing the hose to follow a contour. Experience with operation of the machine will dictate the amount of contour that can be handled.

Spacing of alleys or travel lanes through the field will depend upon the particular sprinkler being used, i.e., diameter of coverage. Normal distance between travel lanes is 70 percent of the sprinkler wetted diameter. With prevailing winds, this may need to be adjusted. With different machines available, lane spacing will probably be from 220 to 330 feet.

Moving the hose-pull traveler is relatively easy. Once the sprinkler cart has reached the end of a row, the pump is shut down, the supply line is disconnected, and the hose reel is moved to the next lane with a tractor. Then the supply line is reconnected, and the sprinkler cart is moved to the far end of the next lane. The pump is then restarted. One man should be able to make the move in 30 to 45 minutes. All of the hose-pull travelers use stabilizers on the hose reel.

These are dropped to the ground when the machine is operating so that the hose reel will not tip over. On some of the machines, the hose reel is mounted on a turntable. With these models, an area on both sides of a center alley or road can be irrigated without moving the reel. With other machines, it will be necessary to turn the machine 180° to irrigate on both sides of a center alley.

Comparison of Cable-Tow and Hose-Pull Systems

In comparing the cable-tow traveler to the hose-pull traveler, one comes to the following conclusions:

1. The hose-pull traveler can be moved in a shorter length of time because there is no hose to reel in and no cable to unwind.

2. The hose-pull traveler will require more pressure to operate at comparable gallonage because the friction loss through the hose and drive mechanism is usually greater.

3. The initial cost of the hose-pull traveler will usually be greater than the cable-tow traveler.

4. Speed control, that is, uniform speed throughout the run may be more difficult to obtain with the hose-pull traveler. However, this will depend on the drive mechanism and the adjustment by the individual operator. Several companies now offer a speed compensation device as standard equipment or as an optional feature.

5. The hose-pull machines with auxiliary engine drive are being used for land application of wastewater. On these machines, only the sprinkler cart is subjected to the wastewater, whereas on the cable-tow traveler the entire machine is subjected to the waste water.

6. On the hose-pull traveler, only the amount of hose that is needed must be wound off the reel, whereas on the cable-tow traveler all the hose must be wound off the reel and the hose stretched out to allow water to flow through the hose.

7. The hose-pull traveler does not require a separate anchor; the cable-tow traveler requires an anchor, such as a tree, tractor, or earth anchor to which the cable is attached.

8. The hose on the hose-pull machine is pulled in a relatively straight line. On the cable-tow machine, the hose is pulled in a loop. In areas with obstructions, this could result in more hose damage on the cable-tow machine.

9. A travel lane is not required for the hose to travel for the hose-pull machine. Except in low growing crops, a travel lane is required for the cable-tow machine.

10. With the hose-pull machine, it is not necessary to walk to the middle of the field to connect or disconnect the hose to the supply line as is necessary with the cable-tow machine.

### Advantages and Disadvantages of Travelers

The advantages of travelers are: (1) adaptable to many field sizes and shapes, (2) adaptable to topography from level to rolling, and (3) can be moved easily to irrigate several fields. The disadvantages of travelers are (1) they require alleyways for row crops, (2) water distribution is seriously affected by wind, (3) high application rates, and (4) high energy requirements for operation.

## CENTER PIVOT

### Description

A center pivot system consists of a single sprinkler lateral with one end anchored to a fixed pivot structure and the other end continuously moving around the pivot while applying water. The water is supplied from the source to the lateral through the pivot. The lateral pipe with sprinklers is supported on drive units and suspended by cables or by trusses between the drive units. The drive units are mounted on wheels, tracks or skids that are located 80 to 250 feet apart along the length of the lateral pipe, which may vary from 200 to 2600 feet.

Each drive unit has a power device mounted on it that drives the wheels, tracks, or skids on which the unit moves. The rate at which the drive unit and lateral pipe advance around the pivot is determined by the speed of the outermost drive unit. Alignment devices detect any drive units that become misaligned. Either the units are speeded up or slowed, as needed. Thus, the advance by the outermost drive unit sets off a chain reaction of advances, beginning with the second drive unit from the outer end and progressing along the lateral to the pivot. Should the alignment system fail and any drive unit become too far out of alignment, a safety device stops the whole system automatically before the lateral can be damaged.

There are four methods of powering a center pivot sprinkler system: hydraulic water drive, which utilizes pistons, rotary sprinklers, or turbines; electric motor drive; hydraulic oil drive, using pistons, rotary motors, or piston-cables; and air-pressure piston drive.

Hydraulic water-driven center pivot systems are powered by water from the sprinkler lateral pipe with pressures from about 60 to 120 psi at the pivot. Water used to drive the systems is discharged to the field. On the piston-drive systems, each piston-drive unit activates a set of trojan bars. The trojan bars engage wheel lugs to turn the drive unit wheels. The rotary sprinkler and turbine drive systems transmit power to the wheels of each drive unit through a gear box. Other systems use a chain and sprocket mechanism connecting the gear box and the drive wheels.

The electric-drive center pivot systems have motors of 1/2, 3/4, 1 or 1½ hp mounted on each drive unit. Most systems operate with 440-volt or 480-volt, 3-phase 60-cycle electric power. Electric power is supplied by an engine-driven generator located at the pivot, or through underground cables which convey electric power to wiring on the moving lateral.

In oil-powered systems, the soil-supply and return-flow pipelines extend from the oil pressure pump and oil reservoir to the piston or rotary motors located on each drive unit. The oil pump is powered by an electric motor or internal combustion engine and maintains 600 to 2000 psi oil pressure in the oil lines.

The cable-drive system has one oil-pressure powered hydraulic cylinder at the pivot point. As the cylinder reciprocates, propelling power is transmitted to each drive unit through a steel cable that extends from the hydraulic piston to the outer drive unit.

Water is applied to the soil along a center pivot lateral at a low rate near the pivot to progressively higher rates toward the outer end. The application rate varies along the lateral because the length of time water is applied to the field decreases from the pivot to the outer end due to the increasing travel speed of the lateral.

The type of sprinklers, their spacing along the lateral, and the diameter of area covered from an individual sprinkler affect the application rates along a center-pivot lateral. There are three common variations in sprinkler types and arrangements along the lateral, all of which can produce uniform water distribution.

The small to large sprinkler arrangement uses some of the smallest agricultural sprinklers near the pivot, gradually increasing sprinkler size to large sprinklers at the outer end of the lateral, with 35 to 40 sprinklers used on a 1300 ft. lateral. Recommended pivot operating pressure using this nozzling concept varies from 60 to 100 psi.

There is a sprinkler arrangement using the same medium-sized sprinklers with variations in nozzle size and sprinkler spacing along the lateral. The widest spacing of sprinklers is near the pivot and the closest spacing at the outer end of the lateral. These laterals have 80 to 100 sprinklers normally operated with a pivot pressure of 45 to 75 psi.

The third sprinkler arrangement has fixed sprinklers with spray-type nozzles. Low pivot pressures from 20 to 40 psi are suitable for spray nozzle operations.

The spray-type center pivot lateral has the smallest drops, but the highest peak application and the shortest duration of application. Rates vary from 6 to 12 in./hr at the end of a 1300 ft. lateral. The medium-sized sprinkler type lateral has the next highest application rates with a peak varying from 2 to 3 in./hr. The variable sized sprinkler-type lateral gives the largest drops, but the lowest peak application rates, from 1.0 to 1.5 in./hr.

The application rates are determined by the nozzle size, nozzle pressure, sprinkler spacing, length of lateral and sprinkler types used. Once these items are fixed by the manufacturer, the application rate for that point along the lateral is fixed and will not be changed by varying the speed of lateral rotation. Changing the lateral speed only changes the depth of water applied.

When water application rates exceed soil intake rates, surface runoff can occur. Runoff results in poor water distribution, lower water application efficiency, and potential erosion. This problem is inherent in the design of all center-pivot irrigation systems but is more serious with low-pressure systems due to the very high peak application rates associated with this design. Crop production practices can be managed to significantly reduce the runoff potential.

## Advantages and Disadvantages

The advantages of a center pivot system are the low labor reqirement, its adaptability to circular or square blocks with an addition of an end gun, its suitability to chemigation. The disadvantages are that it requires a field with no obstructions, application rates are usually high, especially at the outer end of the pivot, resulting in excess runoff on low intake soils, and there is a tendancy for wheels to cut deep ruts in some soils. The center pivot system ranges in energy use from low to medium.

Table 5-2 lists the factors affecting the selection of sprinkler irrigation systems.

Table 5-2. Factors Affecting the Selection of Sprinkler Irrigation Systems

| Type of System | Maximum Slope | Approximate System Water Application Rate Min. | Max. | Shape of Field | Field Surface Conditions | Maximum Height of Crop | Labor Required | Size of Single System | Approx. Initial Cost[1] | Average Operating Cost[2] | Adaptable to: Cooling & Frost Protection | Chemical Application | Fertilizer Application | Liquid Animal Waste Distribution |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | % | in/hr | | - | - | ft | man-hours / ac-in | acre | $/acre | $/ac-in | - | - | - | - |
| MULTI-SPRINKLER Permanent and Solid Set | No limit | .05 | 2 | Any shape | No limit | No limit | 0.04 | 1 or > | 950-1200 | 3.00-3.50 | Yes | | | |
| Center Pivot High Pressure (80 psi @ pivot) | 20 | 1 | 1.5 | Circular, square or retangular | Clear of obstructions, path for towers | 8-10 | 0.05 | 1.5-200 | 400-450 | 3.75-4.50 | | | | |
| Medium Pressure (60 psi @ pivot) | 20 | 2 | 3 | | | 8-10 | 0.05 | 1.5-200 | 350-400 | 3.00-3.50 | No | Yes | Yes | Yes |
| Low Pressure (30 psi @ pivot) | 20 | 6 | 12 | | | 8-10 | 0.05 | 1.5-200 | 300-350 | 2.00-2.50 | | | | |
| SINGLE-SPRINKLER Manual Move | 15 | 0.25 | 1.0 | Any shape | Safe operation of tractor | | 1.00 | 40-80 | 300-350 | 8.00-9.00 | | | | |
| Self-Propelled Cable-tow | 15 | 0.25 | 1.0 | Rectangular | Lane for winch and hose | No Limit | 0.25 | 40-100 | 300-350 | 6.00-6.50 | | | | |
| Hose-drag | No limit | 0.25 | 1.0 | Rectangular | Lane for sprinkler cart | | 0.10 | 40-100 | 400-450 | 6.00-6.50 | | | | |

1/ 1982 prices. Cost based on water supply existing (well, reservoir, etc.) at the field. Cost includes pump, power unit, and distribution system.

2/ 1982 prices. Includes fuel and labor cost only. Fuel cost based upon average factory data for fuel consumption by diesel powered systems in good repair. All systems' cost based on a pumping lift of 70 feet.

# TRICKLE IRRIGATION

## DESCRIPTION

Trickle irrigation is the efficient application of water to the soil at low rates, 0.5 to 50 gallons per hour (gph), through emitters operating at low pressures, 5 to 30 psi. Emitters may be orifices, porous tubing or perforated tubing and may be placed on or underground. The objective is to continuously supply each plant with enough moisture to meet evapotranspiration needs without excessive water loss, erosion, or damage to plants by poor water quality. This method of irrigation is suited to orchard and row crops, nurseries, greenhouse operations, and urban landscaping. Field application efficiency is the highest of any irrigation method. For design purposes, the application efficiency can be as high as 90 percent.

## SYSTEM COMPONENTS

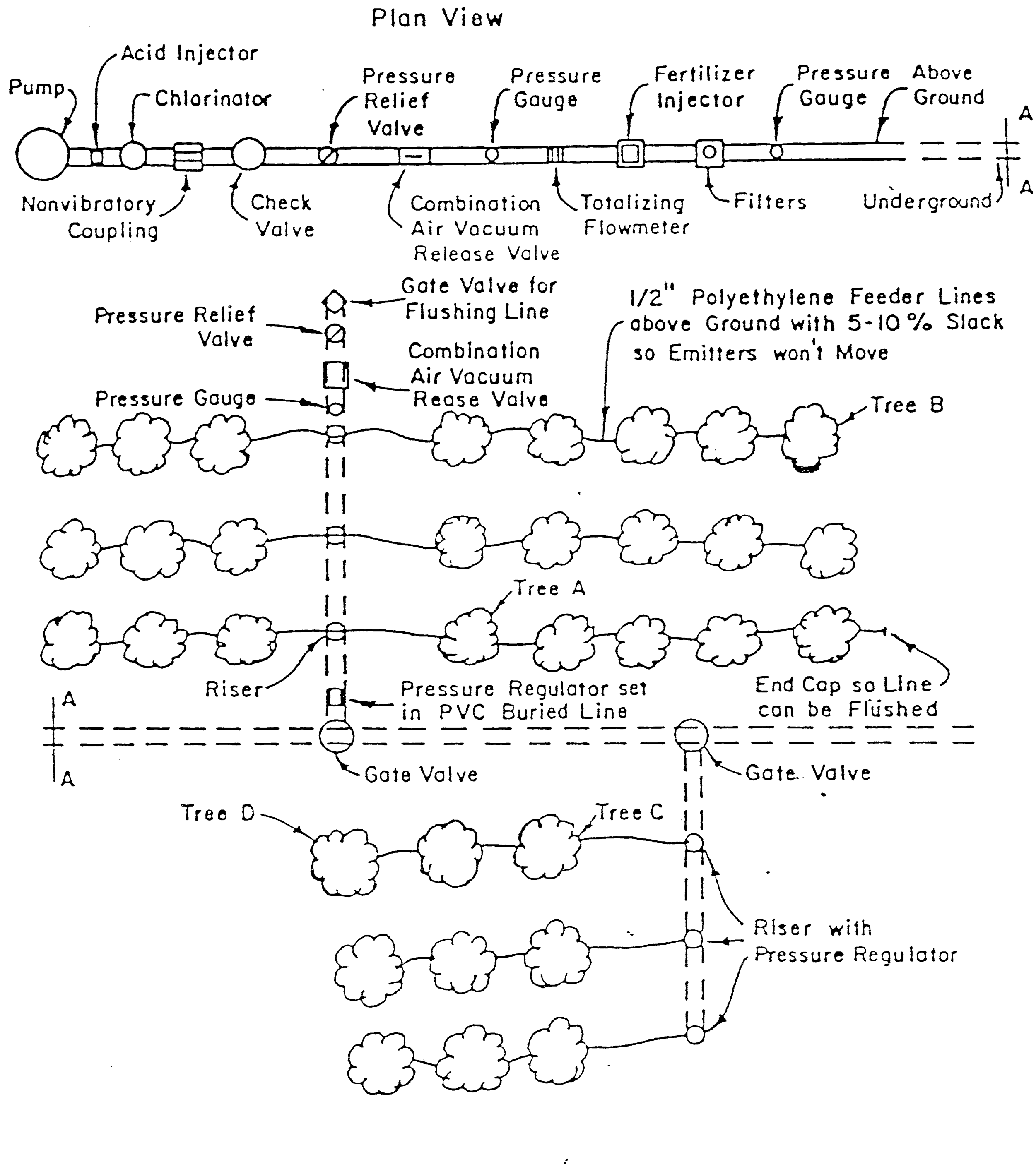
Figure 5-5 shows a typical trickle irrigation system. The various components are discussed below.

### Emitters

The system and its performance are based on a specific discharge for each emitter at a design pressure. Therefore, companies providing emitters need to furnish performance curves that show gph flow rates vs. pressure for each size of emitter to be used. Permissible flow rate is usually +10%[1] of the average flow rate, therefore, these performance curves are needed to determine the permissible pressure variation. See Figure 5-6 for a typical performance curve for a trickle emitter. Using Figure 5-6, the permissible variation in flow rate for a 1.0 gph flow rate is from 0.9 gph to 1.1 gph. The pressure corresponding to 0.9 gph and 1.1 gph is 12.5 psi and 17.3 psi. The maximum pressure loss between the first and last emitter would then be 4.8 psi (17.3 psi - 12.5 psi).

Emitters generally fall under two categories - those that apply water by the drip process at flow rates of ½ to 2 gph and those that apply water by spraying at flow rates of 8 to 50 gph. The wetted pattern of the drip type emitter is controlled by soil texture. This in turn determines the number of emitters needed to wet the crop's canopy area. On deep, coarse sandy soils, the water tends to percolate straight down resulting in a small wetted diameter. On finer textured soils, there is more lateral movement of the water resulting in larger wetted diameters. A test should be run on the site to be irrigated to determine lateral movement. Table 5-3 shows the estimated wetted areas for different soil textures and rooting depths. The emitters that apply water by spraying provide a larger wetted pattern, normally 10 - 15 feet in diameter hence requiring fewer emitters per canopy area. This type is well suited for the deep sandy soils. Figure 5-7 shows a comparison of idealized wetting patterns in a homogeneous fine sandy soil under a drip and a spray emitter.

1/ Minimum SCS criteria is to allow up to 15% variation (Std. 441) in the design discharge rate.


Plan View
Acid Injector
Pump
Chlorinator
Pressure Relief Valve
Pressure Gauge
Fertilizer Injector
Pressure Gauge
Above Ground
A
A
Nonvibratory Coupling
Check Valve
Combination Air Vacuum Release Valve
Totalizing Flowmeter
Filters
Underground
Gate Valve for Flushing Line
Pressure Relief Valve
Combination Air Vacuum Rease Valve
Pressure Gauge
1/2" Polyethylene Feeder Lines above Ground with 5-10 % Slack so Emitters won't Move
Tree B
Tree A
Riser
Pressure Regulator set in PVC Buried Line
End Cap so Line can be Flushed
A
A
Gate Valve
Gate Valve
Tree D
Tree C
Riser with Pressure Regulator

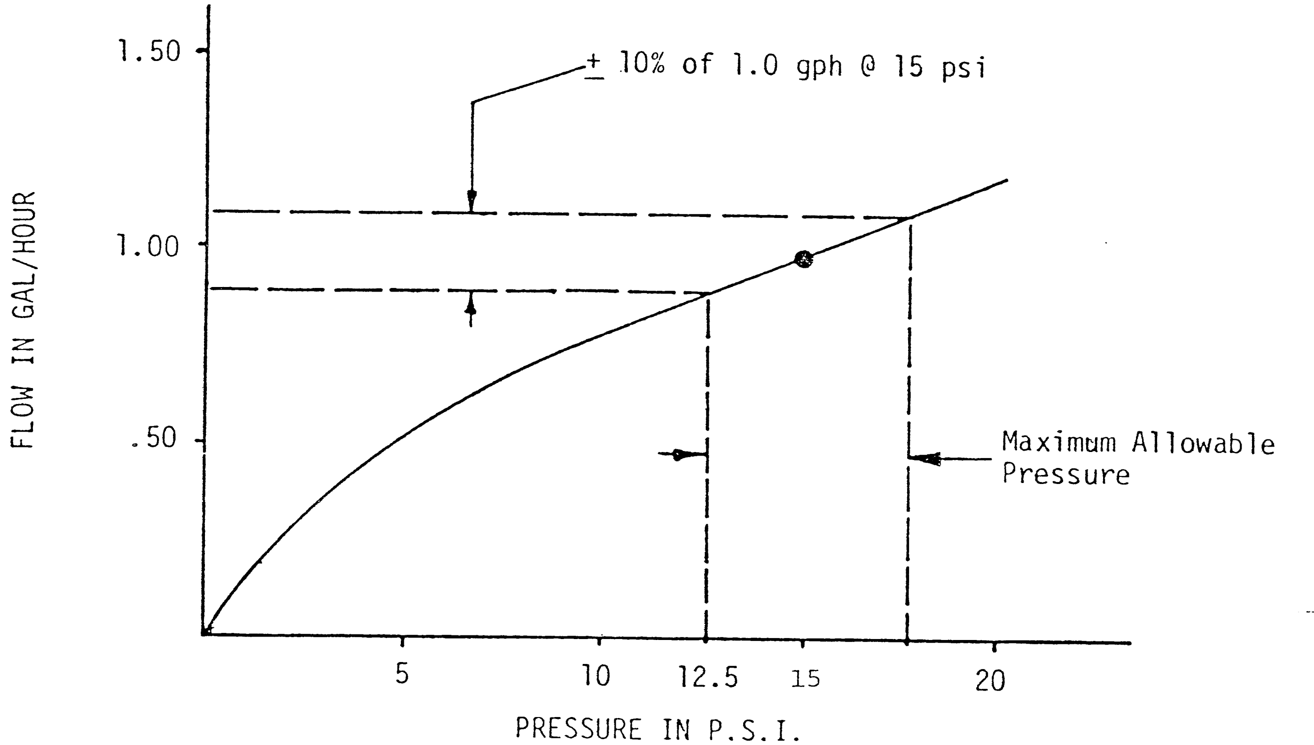



Figure 5-6. Typical Performance Curve for Trickle Emitter

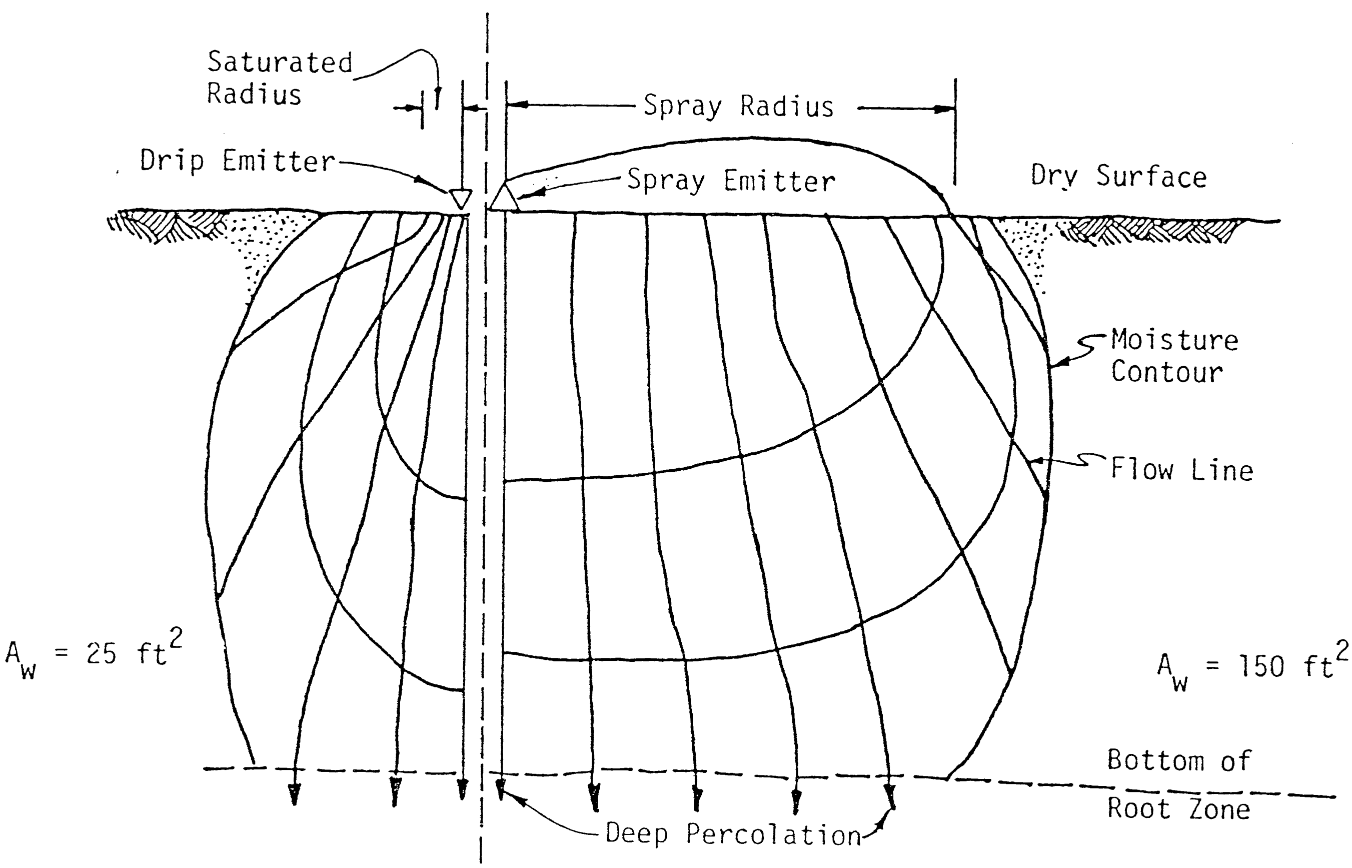



Figure 5-7. Comparison of idealized wetting patterns in a homogeneous fine sandy soil under a drip and a spray emitter.

Table 5-3. Estimated wetted areas for different soil textures, rooting or soil depths, and degrees of soil stratification from a 1.0 gph trickle emitter under normal field operation.

| Soil or Root Depth and Soil Texture[1] | Degree of Soil Stratification[2] | | |
|---|---|---|---|
| | Homogeneous | Stratified | Layered[3] |
| | Equivalent Wetted Soil Area[4] | | |
| | $S'_e \times S_w$ ft x ft | $S'_e \times S_w$ ft x ft | $S'_e \times S_w$ ft x ft |
| Depth 2.5 ft | | | |
| Coarse | 1.2 x 1.5 | 2.0 x 2.5 | 2.8 x 3.5 |
| Medium | 2.4 x 3.0 | 3.2 x 4.0 | 4.0 x 5.0 |
| Fine | 2.8 x 3.5 | 4.0 x 5.0 | 4.8 x 6.0 |
| Depth 5 ft | | | |
| Coarse | 2.0 x 2.5 | 3.6 x 4.5 | 4.8 x 6.0 |
| Medium | 3.2 x 4.0 | 5.6 x 7.0 | 7.2 x 9.0 |
| Fine | 4.0 x 5.0 | 5.2 x 6.5 | 6.4 x 8.0 |

1 Coarse includes coarse to medium sands, medium includes loamy sands to loams, fine includes sandy clay loam to clays (if clays are cracked, treat like coarse to medium soils).

2 Most all soils are stratified or layered. Stratified refers to relatively uniform texture but with some particle orientation and/or some compaction layering which gives higher horizontal than vertical permeability. Layered refers to changes in texture with depth as well as particle orientation and moderate compaction.

3 For soils with extreme layering and compaction which causes extensive stratification, the $S'_e$ and $S_w$ may be as much as twice as large.

4 The equivalent wetted rectangular area dimensions, $S'_e$ and $S_w$, are 0.8 times the wetted diameter and the wetted diameter, respectively.

## Lateral Lines

Lateral lines normally are designed so that when operating at the design pressure, the discharge rate of any emitter served by the lateral will not exceed a variation of ±10 percent of the design discharge rate. [SCS max. is ±15 percent (Std. 441).]

Lateral lines supply water to the emitters. Polyethylene or similar material is used for the lateral lines. The most common sizes used are the ½ inch, 3/4 inch, 1 inch, and 1¼ inch. Normally, this material is installed above ground; therefore, it is important that it be purchased from a reputable dealer that recommends it for this use. Below ground installation should be considered where feasible. This will extend the life of the material and protect it from damage.

Slack is left in the lateral line so that temperature variations will not pull the emitters away from their initial position. When computing friction loss in lateral lines, it is important to use the correct tables for the inside diameter of pipe being installed. Inside diameters vary, depending on the manufacturer and materials used.

Lateral lines are connected to buried main lines and sub-main lines through risers, flexible PVC, or other acceptable means. Pressure regulators may be installed on each riser where extreme elevation variations exist, and the allowable pressure variation must be controlled in the lateral lines. Use of pressure regulators increases costs and maintenance and should not be installed where there is not a real need.

Lateral lines are capped on the outlet end by means of a screw cap or other device. This is removed periodically so the line can be flushed to remove sediment and other debris.

## Main and Sub-main Lines

Main and sub-mains are permanent pipelines normally constructed of thermoplastic materials that deliver water to the lateral lines. They are buried below ground and installed in accordance with good engineering practice. The buried pipe shall have a settled minimum cover based on pipe diameter, sufficient to provide protection from traffic, cultivation practices, and freezes. Mains and sub-mains must be designed and installed according to the provisions of the appropriate technical guide for irrigation pipelines. (Irrigation Water Conveyance, Std. 430AA through 430GG)

## Pumps

Two types of pumps are most often used - the vertical turbine or centrifugal. The centrifugal has the advantage of lower initial cost and easier installation. The vertical turbine pump has longer life and a lower operating cost. The vertical turbine can operate in a wider range of pressures and water supply without injuring the pump. Since these pumps will operate for 12 to 18 hours a day during peak water use, automatic pump controls should be used to protect the pump from hazards such as electricity cutoff (for electric motor drive) and cutoff of supply water.

Fertilizer Injectors

Fertilizer should be injected upstream of the filters so unfiltered fertilizer will not plug the lateral lines and emitters.

Chemical Injectors

Chlorinators are optional, depending on the quality of water used. Guidelines for application of liquid chlorine to inhibit iron and slime clogging should be obtained either from manufacturers, Appendix E of this Guide, or other reputable sources.

Tensiometers or Other Soil Moisture Checks

Tensiometers, neutron probes, and soil moisture locks have been used to check the soil moisture condition. Normally, a check is made at a depth where the main root concentration is found. A second soil moisture check is made below the main root zone. When water is reaching this area, the irrigation should be stopped. For tree crops, tensiometers could be placed at an 18" and 36" depth and near the point of application of drip emitters, (about 9 inches from 1 GPH emitters as per verbal conservation with Dr. Jim Aiken, Clemson University.)

Valves

Gate valves, check valves, air valves, pressure release valves, flush out valves, etc., are to be installed as needed.

Filters

A filtration system shall be provided at the system inlet. The type of filter needed depends on the emitter selected and the quality of the water supply. It is best to use the emitter manufacturer's recommendations in selecting a filtration system. Three types of filters are used and are sometimes used in combinations. For instance, a sand separator may be used in very dirty water backed up by a screen filter. Sometimes a screen filter is used downstream from a sand filter in case of failure of the sand filter. Pressure loss of 5 to 15 psi can be expected across the filters.

1. Sand separators - sometimes used to remove sand partricles where exceptionally dirty water suply is used. The operation of a sand separator is based on the principle of centrifugal matter as small as 74 microns (200 mesh) provided that this material is heavier than water. This is a relatively inexpensive filtration system.

2. Screen filters - 20 mesh to 200 mesh screens are used to remove sediment and other foreign material. The industry is in the process of making automatic cleaning devices available. The filters will remove sand, debris, organic material, some minerals, and some silt.

3. Sand filter - looks much like a swimming pool sand filter. Normal design provides 1 sq. ft. of filter area to 20 gpm system capacity. For dirty water, this may go to 1 sq. ft. to 15 gpm. Sand filters can be automated to operate when there is a 5 to 10 psi differential across the filter.

## ADVANTAGES AND DISADVANTAGES

The advantages of trickle systems are:

1. Costs are lower since smaller pumps, motors, and pipelines are installed.
2. Water application is more efficient because irrigation water is applied directly to the soil. This results in lower water use and energy demands because of lower presssures. Low pumping rates make it possible to use shallow wells, ponds and canals as a water source.
3. Labor requirements are reduced when adequate filters and water treatment are used.
4. Damage to crops is reduced in areas of poor water quality.
5. Optimum moisture conditions can be maintained and drying cycles reduced.
6. In orchard crops, weed growth between rows is reduced since water is normally applied to the canopy area.
7. There is better scheduling of irrigation for more effective use of rainfall.
8. Smaller pumps and motors may use single phase electricity in areas where three phase electricity is not available.
9. These systems have the capability of applying fertilizers and other agents, hence reducing operations.
10. These systems may be used on sites with steep slopes and erosive soils where runoff and pollution are a problem.
11. Water conservation due to travel lanes and other spaces between plants that are not irrigated.

The disadvantages of trickle systems are:

1. Moisture distribution is limited in sandy soils requiring more emitters per tree canopy.
2. Clogging can result from sand, organic growths, organic and chemical precipitations.
3. Life expectancy of systems is low.
4. Salt build-up in soils may result in areas of poor water quality.
5. Requires a high degree of management skills.

Table 5-4 lists factors affecting the selection of trickle irrigation systems.

Table 5-4. Factors Affecting the Selection of Trickle Irrigation Systems

| Type of System | Maximum Slope | Maximum Water Intake Rate Soils | Shape of Field | Adaptable to | | | Labor Required | Approx. Initial Cost [1] | Average Oper. Cost [2] |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Orchard & Vineyards | Row Crops (row or bedded) | Sown, Drilled or Sodded Crops | | | |
| | % | (in. per hr.) | - | - | - | - | man-hr / ac-inch | $/acre | $/ac-inch |
| Point-Source Emitters | No Limit | Any | Any Shape | Yes | No | No | 0.15 | 600-800 | 2.25-2.50 |
| Line-Source Emitters | No Limit | Any | | No | Yes | No | 0.15 | 600-800 | 2.25-2.50 |
| Subsurface | 5 | 1.5 | | No | Yes | Yes | 0.15 | 600-800 | 2.25-2.50 |
| Bubbler | 5 | 3 | | Yes | No | No | 0.15 | 600-800 | 2.25-2.50 |
| Spray | No Limit | Any | | Yes | No | No | 0.15 | 600-800 | 2.25-2.50 |

1/ 1982 prices. Cost based on water supply existing (well, reservoir, etc.) at the field. Cost includes pump, power unit, and distribution system.

2/ 1982 prices. Includes fuel and labor cost only. Fuel cost based upon average factory data for fuel consumption by diesel powered systems in good repair. System costs are based on a pumping lift of 70 feet and an emitter pressure of 15 psi.

## GENERAL

Subirrigation involves the application of water on level to gently sloping slightly wet to wet soils to create an artificial or perched water table over some natural barrier that restricts deep percolation. Moisture reaches the plants through capillary movement. The basic principle of this method of irrigation is the control of the water table to supply moisture to plants from a subsurface zone saturated with free water.

Irrigation water can be introduced by either open ditches or underground conduits. The water table is maintained at some predetermined depth below the ground surface, usually 24 to 36 inches, depending on the rooting characteristics of the crop grown. The water table can be regulated by controlling the drainage scheme as it applies to subsurface water. Instead of removing subsurface water to make deeper rooting possible, drainage is curtailed and water is added to keep the water table high enough to provide adequate moisture to the root zone through capillary action within the soil. However, the drainage system is still responsible for removing excess surface water and maintaining control of subsurface water so that the water table does not remain in the root zone for a long enough period to cause crop damage.

The plan for drainage becomes more critical when the drainage facilities will be used for subirrigation. A planner must be assured of a number of items, as follows:

1. Ample water supply during dry season.

2. Naturally high water table, or a very slowly permeable soil layer below the root zone on which an artificially elevated water table can be maintained without excessive losses through deep percolation.

3. Rapidly permeable layer immediately below the topsoil that will allow comparatively free lateral movement of water.

4. Uniform and nearly level topography permitting complete and even distribution of water.

5. A well planned system of mains, laterals and structures which will permit orderly movement of water to all parts of the area.

6. Adequate outlet for drainage of the system.

## SITE INVESTIGATION

It is important that the site be thoroughly investigated. Major items to be investigated are:

1. Soils. Normally, the soils used for subirrigation systems are classified as poorly drained or very poorly drained. The following soil characteristics are of major importance.

   a. Effective depth. The depth of soil material favorable for root growth should be at least 20 inches for most crops.

   b. Thickness of the first significant layer below topsoil. This may be the water-conducting layer. Thickness should be at least 12 inches. It should not exceed 36 inches where success of the irrigation system depends upon a very slowly permeable zone below.

   c. The hydraulic conductivity of the topsoil should be medium (5 in./hr) to high (20 in./hr), otherwise laterals will need to be closely spaced for good crop response.

   d. Natural wetness. Presence of a naturally high water table is indicated by wetness class. Should be slightly wet to very wet. Moderately wet is optimum.

   e. Permeability rate of first significant layer below topsoil should be at least 5 inches per hour if it is a major water conducting layer.

   f. Permeability of second significant layer below topsoil should not exceed 0.05 inch per hour. The importance of this layer depends largely upon depth. Ideally, artificial saturation of the soil should be based upon a naturally high water table and not upon a relatively impermeable layer, even though the natural water table itself may be "perched" in this manner. Since this layer is often only moderately deep, the permeability value may not provide key information.

   g. Underlying material. The nature of the material underlying the soil may be especially important. In communities underlain by porous limestone or marl cut by ditches and canals, maintaining a high water table may be difficult or impractical.

2. Topography. Normally, the land slope should not exceed one percent. When slopes are greater than one percent, the water table is difficult to build and maintain, the number of structures become excessive, and drainage water velocities may become erosive. Many times it is feasible to level the land prior to installing the system.

3. Drainage Outlet. The outlet must be investigated and must be evaluated as to its adequacy to provide the necessary drainage or steps taken to make it adequate. Many broad areas in the State do not have an adequate natural outlet. In such cases, the selected field area is ditched and diked around the perimeter to keep out water from other drainage areas. Pumps are then installed for drainage

outlet control. Water storage areas may have to be installed for the pumped system so that increased runoff will not cause offsite damages.

4. Water supply. There must be adequate water for irrigation. A supply rate of eight gallons per minute per acre is usually adequate for most crops.

## ADVANTAGES AND DISADVANTAGES

The major disadvantage of some subirrigation systems is that generally more water may be used because of distribution losses and other inefficiencies. Estimated irrigation efficiency of these systems may be as low as 50 to 60 percent. With proper management, the irrigation efficiency could be increased significantly. Another disadvantage of the open ditch subirrigation system is the loss of crop land due to the ditches. The advantages of subirrigation systems are the low initial installation costs, low operating costs, utilization of ground water for crop production, and their capability for providing drainage where needed.

## OPEN DITCH SYSTEM

### Description

The open ditch system consists of water being supplied to the main supply ditch at the high point of the field. Irrigation water is conveyed by gravity through the entire field area with lateral ditches. Laterals are located to run from the main ditch on the contour or with less than about 1.0 foot vertical variation from end to end. Structures are used to restage the water at about 1.0 foot intervals or less so that water will back into the laterals and move laterally to raise the water table. See Figure 5-8.

Main ditches usually require control structures at or near 0.5 ft. vertical intervals, except on the steeper slopes where a structure is required at each lateral. The variation in depth to water table can then be controlled by one structure to stay within the 0.5 ft. permissible variation. A greater variation than this will usually result in part of the area being under-irrigated and part being too wet for shallow rooted crops.

Structures in ditches should be designed with removable gates so that designed drainage will not be impeded and the water levels still controlled for irrigation. A properly designed subirrigation system will prove to be equally valuable as a drainage system during the rainy season if properly managed.

Laterals should be on nearly flat gradients with a variation of not more than 0.5 ft. from end to end. The length of lateral to be supplied from one end should not be more than 1200 feet except in extreme cases. Laterals will, in most cases, be spaced from 60 to 200 feet, depending on the characteristics of the soil that govern the lateral movement of water through it and the degree of water table management desired. Due to drainage requirements, a spacing greater than 200 feet is not desirable. With a spacing of 60 feet or less, 10 percent or more of the field may be in ditches, and thus spacing becomes critical.

Main and secondary distribution ditches will be designed (Manning's Formula) to carry necessary discharges. On a large system, dimensions of a channel in its lower reaches might be determined by requirements for drainage. Dikes for transporting water against grade to higher elevation for distribution should be designed according to sound and accepted principles.

### Determining Water Table Levels

In order to know when to start irrigating and when to stop applying water, it is important to determine the depth to the water table below the ground surface. This determination can be made by using a simple gauge made from pipe 1½-inches in diameter and approximately 48 inches long, perforated with 1/8-inch holes. A gauge should be placed near the center of each 40 acres, spaced equidistant from laterals, and set upright in the ground with approximately 6 inches above the ground surface. The desired depth to the water table will vary with the crop stage and the rooting characteristics of the crop grown. Experience in the area will generally reveal the desired depth of the water table for the crop to be grown.

## UNDERGROUND CONDUIT

### DESCRIPTION

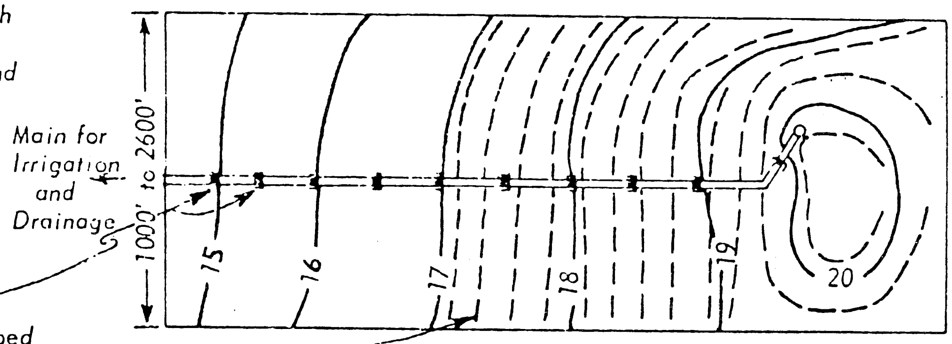
The function of underground conduits for irrigation is basically the same as the open ditch method. Lateral ditches are replaced by lateral pipelines which are usually perforated corrugated plastic tubing (drain tubing). Water is supplied through the drain tubing - regulating the water table. The water table is usually held just below the root zone where capillary movement of water due to tractive force of soil particles draw water up into the root zone.

As in the open ditch method of subirrigation, structures are needed to control the water table at its desired elevation. Structures, whether in an open ditch main or in a conduit main line, are designed to be adjustable so water can be released during excessive rainfall and water can be contained at the desired elevation during irrigation pumping. See Figure 5-8.

### ADVANTAGES AND DISADVANTAGES

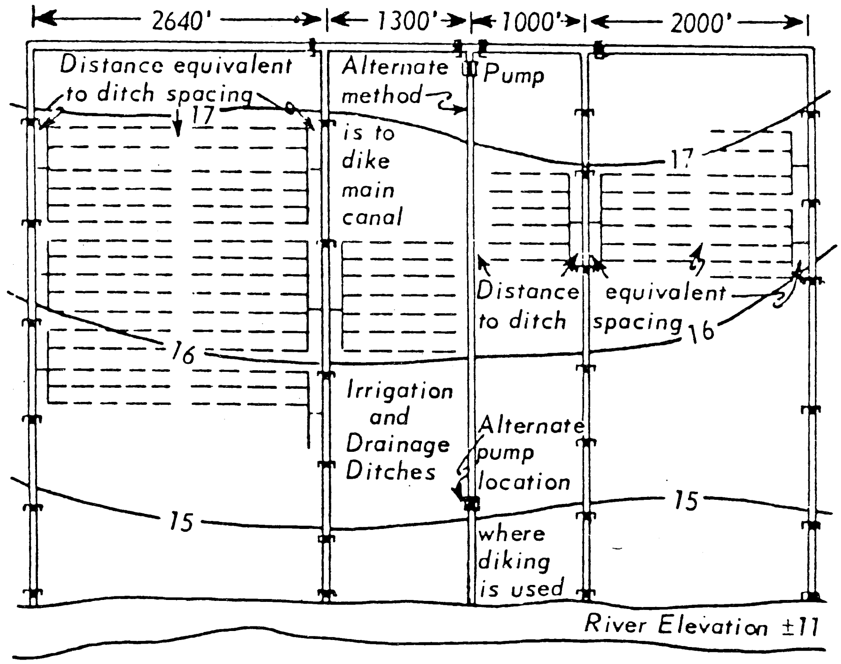
The advantages of the underground conduit are that it does not take up surface area, can be installed closer and deeper than ditches, low maintenance, and not influenced by cropping pattern. The disadvantages are higher initial cost than open ditches, requires mesh filter in sandy soils and may require special design in soils high in soluble iron. For more information on filter requirements for various soils, refer to the South Carolina Drainage Guide.

*Small irrigation system with well at high point. Entire system acts as drainage and irrigation system.*




NOTE:
1. *Water is controlled at .5' interval.*
2. *Field laterals are stopped a distance from edge of field equal to half the lateral spacings.*

*Large Irrigation System. Water supply is pumped from deep ditch that connects with river. Where soil permits, an alternate system is to locate pump near river and dike central supply ditch to the high ground distribution point.*




LEGEND
- --- Lateral
- Water Control Structure
- Pump
- 15 Contour Line
- o Well

NOTE:
*In each of the above illustrations, the field laterals are stopped short of the edges of the irrigated field and drainage ditches a distance of at least one-half the lateral spacing. This permits easy access to the area with heavy equipment without crossing the laterals.*

Figure 5-8. Typical Subirrigation Layouts

## CHEMIGATION

Chemigation can be defined as the application of a chemical (fertilizer, herbicide, insecticide, fungicide, nematicide, etc.) via an irrigation system by injecting the chemical into water flowing through the system. Although the term chemigation is relatively new, the concept of applying fertilizer in the form of animal manures in the irrigation water likely began soon after the use of irrigation. Advances in irrigation systems and injection equipment design have stimulated research which has resulted in the chemigation application of herbicides (herbigation), fungicides (fungigation), nematicides (nemagation), and insecticides (insectigation). Chemigation is used for both soil and foliar applied chemicals; however, several factors should be considered before attempting to use chemigation as a means of applying chemicals.

Application of chemicals by chemigation occurs only where the irrigation water is applied; therefore, surface and trickle/drip type irrigation systems have only been successful for soil applied chemicals. Application of both soil and foliar applied chemicals have been successful with sprinkler irrigation systems.

Uniformity of chemical distribution is an essential element of successful chemigation and is proportional to the uniformity of water distribution by the irrigation system. The uniformity of application of water or chemicals by an irrigation system or sprayer is often expressed as the coefficient of uniformity (CU). The CU of properly calibrated ground based sprayers ranges from 50 to 92%, while aircraft normally obtain a CU of about 70%. Most types of sprinkler irrigation systems can be designed and operated to achieve CU's of 85% or greater; however, many solid set and portable pipe systems achieve CU factors of only 70-75%. Traveling gun type systems normally achieve a CU of 80% or less under optimum conditions, and most farmers achieve CU's of less than 70%. A continuously moving lateral system, such as a center pivot, normally achieves a CU of 90% when properly nozzled and operated. As with aircraft or ground based sprayers, the CU's of sprinkler irrigation systems decrease with increased wind velocity. Competent management is necessary to fully utilize the capabilities of chemigation.

The high CU's of center pivot and linear move systems make them ideally suited for total chemigation. The operator must determine whether the lower uniformity of other types of sprinkler irrigation systems is acceptable for chemigation. The minimum level of acceptable uniformity will vary, depending on the chemical applied. A lower CU value will be acceptable with chemicals which have a greater range of effective application rates.

When chemicals are injected into irrigation systems, there is a possibility of contamination of the water supply if the injection system is not carefully designed and maintained. The irrigator is responsible for installing an appropriate anti-syphon device to protect the water supply. See Chapter 6 for discussion on safety components necessary for chemigation.

## Application of Fertilizers

Applying fertilizer through chemigation permits nutrients to be applied to the crop as they are needed. Several applications can be made during the growing season with little if any additional cost of application. Nitrogen, especially, can be applied during periods when the crop has a heavy demand for both nitrogen and water. Corn, for example, uses nitrogen and water most rapidly during the three weeks before tasseling. About 60% of the nitrogen needs of corn must be met by silking time. Generally, it is recommended that nearly all the nitrogen for the crop should be applied by the time it is pollinating, even though appreciable uptake occurs after this time. Fertilization through irrigation can be a convenient and timely method of supplying part of the plant nutrient needs. Nitrogen is ideally suited to chemigation and is the element most often applied to corn by this method. The ideal fertilization program would be one that provides nitrogen and moisture to plant roots as they are needed so there is never a deficiency or an appreciable surplus.

The fertilizer solutions most commonly used with irrigation applications contain both the ammonium and nitrate forms of nitrogen and have 28 to 32 percent nitrogen. Considerably more care is required if anhydrous ammonia is used. Because the per-unit cost for ammonia has been less than for solution forms of nitrogen, producers have shown an interest in applying ammonia in sprinkler water. Also, relative to solution forms of nitrogen, ammonia offers advantages in terms of economics and energy requirements for production and transportation.

Application of ammonia in sprinkler water, though attractive in terms of fertilizer costs, presents definite potential hazards unless special precautions are taken. Nitrogen can be lost to the atmosphere as ammonia gas and precipitation deposits can form which reduce the carrying capacity of irrigation pipes and may clog sprinklers.

A potential solution to precipitation and ammonia volatilization problems is acidification (adding sulfuric acid) of irrigation water prior to injection of ammonia. In the past, application of sulfuric acid with ammonia in water has not been economically feasible. If the price of sulfuric acid comes down, this approach may have real value. Ammonia use would become feasible. Although the ammonia form will be held a little more tightly in the soil than the nitrate form, the ammonium form will be rapidly changed to nitrate when the moisture, temperature, and aeration conditions in soils favor root growth. The fertilizer solution is injected into the irrigation delivery pipe--usually near the water pump. Safety devices must be installed to prevent the nitrogen solution from moving back into the water source if there is an interruption in pumping.

Almost any fraction of the total nitrogen application can be made successfully by chemigation. It is suggested that, under most conditions, not more than about one-third of the total intended nitrogen be applied in this manner.

Single applications of 20 to 30 pounds of actual nitrogen per acre are the most practical. There is probably little reason to apply nitrogen after silking, unless there are still symptoms of a deficiency of this element.

Although some phosphorus and potassium fertilizers may be applied by chemigation, they probably are applied more satisfactorily ahead of planting. Then, they are available to the crop as soon as root exploration of the soil begins. Phosphorus, especially, does not move down through the soil readily so, therefore, does not become available for benefitting early growth. On sandy soils where the need for potash may be high, it might be applied with nitrogen to coincide with the rapidly increasing amount needed for the period of rapid vegetative development. Where both potash and nitrogen may be needed later in the growth of a crop, it would be possible to add a liquid mixed fertilizer such as a 7-0-7 or similar grade. Adjustments would simply have to be made with the injection pump to ensure that an adequate amount of nutrient is applied.

Some phosphorus-containing fertilizers are corrosive, especially to brass or copper fittings. Some phosphate materials do not have sufficient solubility to be used satisfactorily in chemigation. If the irrigation water contains appreciable amounts of calcium, calcium phosphate may precipitate and clog nozzles, or screens, or both. Some solutions may also cause leaf burning if applied in too great a concentration.

Sulfur may become deficient on some sandy soils. This nutrient could be added by irrigation using nitrogen solutions containing sulfur. Several major nitrogren and 2 to 5 percent sulfur. Probably this should be done if there has been no other sulfur applied earlier in the year with conventional mixed fertilizer.

Micronutrients can be applied through irrigation systems. If a deficiency is positively identified in a growing crop, this may be the most satisfactory method of correction for that crop. However, the best ways to correct such deficiencies for successive crops probably are to apply micronutrient materials to the soil before planting or to the plants by foliar application as soon as the deficiency is recognized. Foliar applications of micro-nutrients seem to be most effective if they are not washed off the leaves by irrigation water or rain.

In order to capitalize on the convenience of applying nutrients, herbicides, or other agricultural chemicals through an overhead irrigation system, accurate amounts evenly distributed over the field must be accomplished. In the material which follows, equations are presented that will be useful in calculating the rate of material that must be added using either a center pivot or self-propelled gun traveler to apply selected sources of nitrogen. Application of other nutrients either as clear liquid mixed fertilizers, single nutrients, such as potash dissolved in water, or micronutrients dissolved in water,can also be applied using the same equation.

Fertilizer sources suitable for fertigation must be completely water soluble. Table 5-5 lists possible source of fertilizers for fertigation.

TABLE 5-5. COMMON SOURCES OF FERTILIZERS FOR USE WITH IRRIGATED SYSTEMS

| Nutrient | Source |
|---|---|
| Nitrogen | Urea ammonia nitrate solutions are best. Soluble dry fertilizers can be dissolved under special circumstances. Aqua and anhydrous ammonia are not recommended due to problems with corrosion and volitilization. |
| Phosphorus | This is not recommended. Phosphorus is immobile in soils and is best applied with ground equipment. If used in irrigation systems, phosphorus compounds will have corrosion and precipitation problems. |
| Potassium | Pure (white in color) source of potassium chloride is best. This is not commonly used because most potassium sources are not completely water soluble. |
| Sulfur | Sulfur-sulfate source is the best. |
| Micronutrients | Several sources are possible depending on crop needs. The Cooperative Extension Service offices maintain information on the suitability of the materials for use in irrigation systems. |

Several cautions are needed when planning to apply fertilizer with irrigation water.

1. This is not foliar feeding. Soil application rates of nutrients should be based on current soil and plant testing.

2. Crops can be burned by improper application techniques.

3. Scheduling may be a problem during adverse weather conditions.

4. Nonuniform applications are a problem. Poor irrigation patterns are commonly on the ends of center pivot systems.

5. Fertilizers should be injected into the system with the first water flow. Fertilizers injected into a system already in operation may take considerable time to reach the perimeter.

6. This does not replace a basic fertility program. Lime, immobile nutrients, preplant or starter fertilizers still require conventional application practices.

Using Center Pivot to Apply Fertilizer

$$GPH = \frac{100\ AN}{P\ H\ W}$$

GPH = Liquid fertilizer to inject in gallons per hour

A = Total area actually irrigated in acres per revolution

N = Actual nitrogen (or other nutrients) to be applied, lbs/acre

H = Hours per revolution of system

P = Percent N (or other nutrients) in fertilizer

W = Weight of one gallon of liquid fertilizer, in lbs.

Example: 160-acre system, 80 hours/revolution, appy 50 lbs. of actual N, using 30 percent N liquid solution.

$$GPH = \frac{100 \times 160 \times 50}{30 \times 80 \times 10.65} = 31.3 \text{ gal/hr}$$

$$\text{or } \frac{31.3}{60} = .52 \text{ gal/min}$$

Using Self-Propelled Gun Traveler to apply Fertilizer

$$GPH = \frac{100\ S\ L\ N}{43{,}560\ P\ W}$$

GPH = Liquid fertilizer to inject, gallons per hour

S = Rate of sprinkler travel, feet per hour

L = Distance between sprinkler lanes, feet

N = Actual nitrogen (or other nutrients) to be applied, lbs/acre

P = Percent N (or other nutrients) of liquid fertilizer

W = Weight of one gallon of liquid fertilizer in lbs.

Example: Travel speed of 90 feet/hour, 300 feet between lanes, 50 lbs. of actual N, using 30 percent liquid nitrogen fertilizer

$$GPH = \frac{100 \times 90 \times 300 \times 50}{43{,}560 \times 30 \times 10.65} = 9.7 \text{ gal/hr}$$

$$\text{or } \frac{9.7}{60} = .162 \text{ gal/min}$$

## Application of Herbicides

Chemigation of herbicides is advantageous from the standpoint that time is saved. The effectiveness of some herbicides is increased by application through irrigation water. Several herbicides are registered for application to corn through the irrigation system. Eradicane, Sutan, Sutan and Atrazine, Lasso, and Lasso and Atrazine are currently registered to be used in this manner. Tests at the University of Nebraska have shown that these herbicides have performed well when applied through both water and electric drive center pivot systems. Furthermore, tests in Nebraska have shown that with some herbicides, the rate may be reduced when application is made by the sprinkler water. It is very likely that certain other preplant and pre-emergence herbicides could be applied through a center pivot system with good results. A careful examination of the label will determine if the herbicide can be applied in irrigation water. The current Agricultural Chemical Handbook provides information on approved herbicides for South Carolina crops.

Generally, preplant and pre-emergence herbicides must be distributed in the surface two inches of soil to be effective against germinating weed seeds. As a rule of thumb, the herbicide should be applied with about 0.5 inch of water on sandy soils and 0.75 inch of water in fine textured soils. Large amounts of water may move highly soluble herbicides too deep, especially on sandy soils. Less water may not move certain herbicides deep enough.

To ensure good performance, apply the herbicide very soon after planting. Usually the field is tilled just prior to planting, but by the time the field is finally tilled and planted, it may take four to five days. It may take the sprinkler system one or two days to complete the application. Some weed seeds may have started to germinate before the herbicide is applied. It is important that the herbicide be applied within about five days of the final tillage operation. A good procedure is to till and plant one-half the circle, then start the system and herbigate while tilling and planting the rest of the circle.

Problems could arise if highly volatile herbicides such as Eradicare and Sutan are applied in the irrigation water to soils that are already wet. For best results, apply volatile herbicides to dry soil. Also, inject the herbicides all the time while irrigating or at the beginning of the set. Don't apply herbicides at the end of a set after the soil has been wetted. Where plenty of rainfall has occurred, the irrigator may be foreced to irrigate to apply the herbicide even though soil moisture is adequate if he has no other means of applying the chemical.

If at all possible, applying herbicides through a sprinkler system should be avoided when wind speeds exceed 10 mph. Strong winds can contribute to uneven application of water and herbicide. Also, drift may occur into adjacent areas and become a problem in strong wind.

Precision injection equipment is needed for chemigation. Precise calibration is required. There is not much room for error. An overdose of certain herbicides may be phytotoxic to corn, may cause injury to the crops grown in rotation, and even sterilize the soil. On the other hand, application of herbicides at sub-optimum rates results in wasted money because of poor weed control.

The irrigation system must be capable of applying the herbicide uniformly across the entire field. This may be the chief limitation of most systems. Any sprinkler that is poorly calibrated will cause a misapplication of the herbicide. Since most irrigation systems cover relatively large areas, any mistakes in application can become quite costly. If the system shuts down and the line drains onto the field, the area may become sterilized. If an overdose of herbicide is applied at any particular point, quite a large number of acres will be affected.

Application of Insecticides and Fungicides

Use of insecticides and fungicides through irrigation systems has been successful in research. No compounds are registered for use in South Carolina with irrigation systems as research continues to look for the best formulations and rates to use. Insecticides and fungicides that are effective in irrigation systems are foliar applied, requiring a low pressure injection pump. Foliar applied chemicals need small amounts of water during application. Application rates of 0.1" to 0.3" will allow good leaf coverage without washing the chemical off the leaf surface. High speed drive motors will allow application of low amounts of water. This should be planned before the system is installed to avoid unnecessary expense.

Waste Disposal

Disposing of waste on land is not a new concept. Crops have been grown for centuries on land used for spreading manure and sewage. These materials were regarded as fertilizers, not wastes. Many kinds of grasses, vegetables, legumes, and woody plants have been subjected to waste disposal. Grass seems to be the most effective vegetation for this purpose. Many species of grass possess a high water use factor combined with abundant root production. The roots and sod retard runoff and enhance infiltration. The plant leaves pump water back into the atmosphere. Wastes become pollutants when they are introduced into the air, water, or soil in excessive amounts or otherwise become offensive in the environment.

The interaction of soils, plants, and water must be thoroughly considered before a sprinkler disposal system is installed and expected to operate successfully.

Generally, an existing irrigation system can be utilized to apply effluent to the land. The sprinkler nozzle will need to be large enough to pass the solids that are in the effluent. One of the major problems associated with sprinkler application is the corrosive nature of the effluent.

The depth of application should be such that polluted waters will not be forced into ground water supplies or runoff will occur to pollute surface water. The depth of application will be determined by the specific pollution potential, the intake rate of the soil, depth of soil, crop use of water, and climatic conditions such as temperature and rainfall. Generally, when slurry waste is applied to the land, it is best to plan for an application of one (1) inch or less. This is suggested because solids in the material soon form a sealing layer on the surface and severely restrict intake. If allowed to dry , this layer will flake and crack and again permit normal intake. If lagoon or holding pond effluent disposal is the primary purpose, an application depth up to 2.0 inches may be satisfactory.

The total depth of effluent application per season can be determined when the total concentration of plant nutrients and/or metals is known. Technical Guide Standard 633 - Waste Utilization, provides guidance in this area.

Application rates must be selected to not exceed the intake rate of the soil. See Table 2-6 (Chapter 2) of this guide for guidance in determining maximum sprinkler application rates.

When effluent disposal is planned, especially on the heavier soils, extreme care must be exercised to plan drainage systems that will dispose of excess runoff without causing erosion or pollution. Examples of this might be to divert water from the disposal area through a grass buffer or filter zone before access to surface waterways is reached.

Some of the critical considerations of sprinkler application of effluent follow:

1. Excessive rate or volume of application may result in runoff and pollution of surface water.

2. Excessive application depths may result in pollution of ground water especially on highly permeable soils.

3. Effluent may contain toxic or detrimental materials to soil or plants.

4. Odors from sprinkling may be obnoxious.

5. Effluent is highly corrosive and may shorten the useful life of equipment.

6. Solids from the effluent may coat plant leaves and reduce photosynthesis.

The system should be operated with clear water for at least the last 15 minutes to wash the system as well as remove solids from the plants.

Water driven self-propelled systems should not be used for waste disposal until checking with the manufacturers.

## Frost Protection

In South Carolina tree and orchard crops are most susceptible to freeze damage from late spring freezes when blooms and/or small fruit are present on the tree. Water application begins when air temperatures reach 34°F and continues until all danger of frost is over and the ice has melted from the fruit and trees. A low application rate around 0.12 inches/hour with a sprinkler rotating speed greater than or equal to one r.p.m. is needed to keep the ice load to a minimum. The low application rate also prevents too much water from being applied to the soil surface. This protection has been effective in protecting orchard crops down to an air temperature of 25°F.