## Chapter 5  Selecting an Irrigation Method

### Contents

<table>
<thead>
<tr>
<th>SC652.0505a</th>
<th>General</th>
<th>5-13</th>
</tr>
</thead>
<tbody>
<tr>
<td>SC652.0505b</td>
<td>Irrigation Methods</td>
<td>5-13</td>
</tr>
<tr>
<td>(1)</td>
<td>Surface Irrigation</td>
<td>5-13</td>
</tr>
<tr>
<td>(2)</td>
<td>Subsurface (water table control) Irrigation</td>
<td>5-14</td>
</tr>
<tr>
<td>(3)</td>
<td>Sprinkler Irrigation</td>
<td>5-14</td>
</tr>
<tr>
<td>(4)</td>
<td>Microirrigation</td>
<td>5-15</td>
</tr>
<tr>
<td>SC652.0505c</td>
<td>Factors Affecting the Selection of an Irrigation Method</td>
<td>5-15</td>
</tr>
<tr>
<td>(1)</td>
<td>General</td>
<td>5-15</td>
</tr>
<tr>
<td>(2)</td>
<td>Topography</td>
<td>5-16</td>
</tr>
<tr>
<td>(3)</td>
<td>Drainage</td>
<td>5-16</td>
</tr>
<tr>
<td>(4)</td>
<td>Water Intake Rate</td>
<td>5-16</td>
</tr>
<tr>
<td>(5)</td>
<td>Winds Action</td>
<td>5-17</td>
</tr>
<tr>
<td>SC652.0505d</td>
<td>Narrowing the Selection</td>
<td>5-17</td>
</tr>
<tr>
<td>(1)</td>
<td>Permanent Solid-Set</td>
<td>5-18</td>
</tr>
<tr>
<td>(2)</td>
<td>Traveling Gun</td>
<td>5-19</td>
</tr>
<tr>
<td>(3)</td>
<td>Center Pivot</td>
<td>5-21</td>
</tr>
<tr>
<td>(i)</td>
<td>Pivot Components and Options</td>
<td>5-24</td>
</tr>
<tr>
<td>(a)</td>
<td>Locomotive power</td>
<td>5-24</td>
</tr>
<tr>
<td>(b)</td>
<td>Nozzle/sprinkler package</td>
<td>5-25</td>
</tr>
<tr>
<td>(c)</td>
<td>Sprinkler Height Position (MESA, LEPA, LESA, LPIC)</td>
<td>5-26</td>
</tr>
<tr>
<td>(d)</td>
<td>End guns and Booster pumps</td>
<td>5-29</td>
</tr>
<tr>
<td>(e)</td>
<td>Folding section</td>
<td>5-30</td>
</tr>
<tr>
<td>(f)</td>
<td>Towable pivots</td>
<td>5-30</td>
</tr>
<tr>
<td>(4)</td>
<td>Linear/Lateral Move Description</td>
<td>5-31</td>
</tr>
<tr>
<td>(i)</td>
<td>Sprinkler package</td>
<td>5-32</td>
</tr>
<tr>
<td>(ii)</td>
<td>Power supply</td>
<td>5-32</td>
</tr>
<tr>
<td>(iii)</td>
<td>Guidance system</td>
<td>5-32</td>
</tr>
<tr>
<td>(iv)</td>
<td>Water supply</td>
<td>5-32</td>
</tr>
<tr>
<td>(5)</td>
<td>Microirrigation Description</td>
<td>5-32</td>
</tr>
<tr>
<td>(i)</td>
<td>System Components and Options</td>
<td>5-33</td>
</tr>
<tr>
<td>(6)</td>
<td>Hydroponics</td>
<td>5-33</td>
</tr>
</tbody>
</table>
Chapter 5  Selecting an Irrigation Method

Part 652
Irrigation Guide

SC652.0505e  Summary of adaptability and limitations of irrigation methods and systems 5-37

Microirrigation, General 5-37
  Point Source (Drip Emitter) 5-38
  Line Source (Tape/Tubing) 5-38
  Microspray/Microsprinkler 5-39
  Subsurface Drip Irrigation (SDI) 5-39
  Hydroponics 5-39
Subsurface (water table control) Irrigation 5-40
Sprinkler Systems 5-40
  Center Pivot 5-40
  Linear Move 5-41
  Traveling Gun 5-41
  Solid-Set, Permanent 5-41
  Solid-Set, Portable and Hand Move Laterals 5-42

Figures

SC5-1  Solid-set sprinkler system and methods to move laterals for portable systems 5-18
SC5-2  Cable-tow guns and hoses stored for the off season 5-19
SC5-3  Cable-tow traveler in tobacco field 5-20
SC5-4  Hard-hose, hose-pull traveler and gun 5-20
SC5-5  Basic Center Pivot Tower 5-21
SC5-6  Driver Tower in middle of center pivot 5-22
SC5-6a  Outermost Drive Unit and wheel cart 5-22
SC5-7  Full circle center pivot pattern in nearly round field 5-23
SC5-8  High/Medium pressure, low angle impact sprinkler on top of pivot lateral 5-25
SC5-9  Low pressure, fixed distance spray nozzles on top of pivot lateral 5-26
SC5-10  Typical MESA drop nozzle sprinkler package 5-27
SC5-11  Typical LEPA bubbler pad system 5-28
SC5-12  Low pressure nozzle system with gooseneck adapter and flexible tubing 5-28
SC5-13  End gun on pivot system 5-29
SC5-14  End gun and permanent solid set on same farm 5-29
SC5-15  Towable system using a three-wheeled pivot tower 5-30
SC5-15a  Hose feed, electric linear move pivot 5-31
SC5-16  Schematic of typical drip hydroponic system 5-33
SC5-17 (a - d)  Typical hydroponic system showing pumped and floating setup 5-34
SC5-18  Typical orchard microirrigation system layout 5-36
SC5-19  Typical mixed vegetable microirrigation system layout 5-36

Tables

SC5-10  Typical life span and annual maintenance cost percentage for irrigation system and components 5-43
652.0505  State Supplement

(a)  General
South Carolina growers produce a wide variety of orchard, row, forage, vegetable, and specialty crops under irrigation. Producers include large family and corporate farms irrigating thousands of acres, medium sized farms, small family farms, and individuals watering crops for the first time. All of these use irrigation to supplement South Carolina’s generally abundant, but poorly distributed, rainfall.

Considering the diversity of crops, scale of operation, and experience of irrigators, selecting the irrigation system for a specific site is not always straightforward. Some sites are adaptable to several methods of irrigation, but final selection will be based upon factors such as crop type, initial cost, operating cost, labor availability, farming methods, and personal experience or preference.

(b)  Irrigation Methods
South Carolina uses mostly sprinkler and microirrigation, with some use of subsurface (water table control) irrigation, and very limited use of surface systems. In one way or another, these basic methods simulate natural processes by which plants obtain water. Most irrigation application methods and systems can be automated to some degree. The amount of automation may be an important factor to some growers.

(1)  Surface Irrigation
Historically, the earliest irrigation systems simulated the natural process of seasonal flooding. Crops could be planted in newly replenished floodplains as flood waters receded. Areas outside of the floodplains could also be used by diverting river flows to these areas through channels. Later, water from snowmelt and mountain streams was captured in reservoirs, and canals or pipelines were used to carry water great distances. When pumps became available, water from surface and groundwater sources could be lifted and transported great distances from its source to irrigate crop fields and bring former deserts to life.

Surface irrigation has been used less frequently in humid regions. In certain cases close to rivers or places with natural lakes, bayous, cypress ponds, and fresh water marshes, farmers have developed local systems for water supply and delivery. As recently as 2000, surveys of irrigation in South Carolina reported almost 1600 acres of surface irrigation (2000, Clemson University Cooperative Extension Service). However, aerial surveillance shows that, in the past, more extensive areas were irrigated using surface irrigation.

In a few humid areas, surface irrigation was integrated into the drainage plan for a farming region. Canal systems built to aid drainage and remove storm water can also provide water for surface irrigation. This has been the case notably in south Florida, but also in other selected areas of the Southeastern Flatwoods.
As elsewhere in the U.S., surface irrigation systems are on the decline in South Carolina. Although several large reservoirs have been built in the state, they were commissioned for other uses and the system of canals and pipelines needed to move water to distant farms was never developed for South Carolina. In the past, the region’s precipitation was usually considered adequate for small farm sustenance and modest levels of crop production. Given the land ownership patterns, industrial, commercial and residential development, and alternative demands for water in reservoirs and rivers, it is unlikely that any regional system of irrigation water delivery could be implemented in the future. It is unlikely that new surface water irrigation systems will be built in the state.

(2) Subsurface (water table control) Irrigation
Subsurface irrigation, sometimes called seepage irrigation, includes water table control to emulate the natural process by which plants extract water from water tables lying below their rooting depth (moisture replacement zone). The Carolina Bays, Coastal Flatwoods, low river terraces, and other landforms that require drainage to become productive create opportunities for modifying the drainage system to become a drainage subsurface irrigation system.

Typically, drainage systems use both surface ditches and underground tubing to remove excess water after precipitation events, mainly in winter and spring, to support farming operations and maintain an aerated root zone. Drainage of excess water results in a water table that serves as a water source for crops. As soil moisture is depleted by deepening roots, they reach a zone where capillary movement can lift water from the water table.

That same drainage system can continue to meet crop water needs if water is added to the drainage system to sustain a water table. The surface of the water table differs in “topography” when water is added to a drain than one where the drain is removing water, but managed correctly, this subsurface irrigation can be an effective and efficient method of irrigation.

The average depth of the water table can be controlled by structures in the outflow or canal system, and water can be pumped back into the drainage system from wells or other water sources. The drainage system continues to function to remove stormwater including excess precipitation that has infiltrated the soil. Several successful combined systems have been installed in the Carolinas. Note that this method does not include subsurface drip irrigation (SDI).

(3) Sprinkler Irrigation
At their ideal, sprinkler irrigation systems are designed to simulate natural precipitation, although without the excessive intensity that accompanies some downpours. In the humid region, sprinkling water is an obvious way to “fill the gaps” in the natural rainfall distribution. Water droplets are formed by sending pressurized streams of water into the air usually through mechanical heads designed to split the stream, add rotation, and/or interrupt it. Water is delivered to the outlets through portable hoses, pipe and tubing that may be set up temporarily or permanently in the field.
Sprinklers are the most widely used irrigation systems in South Carolina. Over the years these have changed from predominantly portable pipe systems with sprinklers on riser pipes to traveler systems supplied by large hoses to labor saving center pivots. Center pivots are now the predominant form of irrigation in the state for field crops, and certain vegetables, as well as sod farms.

Sprinkler irrigation systems are adaptable for use on most crops and irrigable soils. Particular care is needed in the design and operation of a sprinkler system with low application rates (0.15 to 0.25 in/hr) and on soils (generally fine textured) with low infiltration rates. Principal concerns with low application rates are set time, increased system cost, acceptable distribution uniformity, wind drift, evaporation, and system operational requirements.

For example, with an application rate of 0.15 inch per hour, set time would have to be nearly 10 hours to apply a net irrigation application of 1 inch. It is recommended that sprinkler systems apply water at a rate greater than 0.15 inch per hour for improved wind resistance. In areas of high temperature, wind, or both, minimum application rate and volume should be higher because of potential losses from evaporation and wind drift. For frost control, where evaporation and wind drift potential are low, an application rate of 0.10 to 0.15 inch per hour is common. See NEH Part 623 and Section 15, Chapter 11 "Sprinkler Irrigation" for more information.

(4) Microirrigation

Crop, shrubs and trees obtain their water from soil in the places roots explore. Several modern irrigation systems have attempted to deliver water directly to the root (moisture replacement) zone through row based or plant-by-plant based irrigation. Water is delivered to plants through either drip emitters on flexible tubing (vineyards/orchards) or lateral lines with emitters embedded in the tape/tube wall (vegetables and row crops). Tubing may be placed on trellises (as in grapes), on the soil surface (as in blueberries), or buried below the surface (as in nuts). Burying the tape/tube provides protection and keeps it in place. A variant of this drip irrigation is subsurface drip irrigation (SDI), which places tubing typically at depths of 8 to about 18 inch below the soil surface using a permanent installation. Farming operations might dictate the depth of SDI drip tape/tubing. A related targeted irrigation uses micro sprinklers to spread the water onto the surface under the drip line of shrubs and trees. Areas without roots, especially between trees do not receive this targeted water.

Microirrigation systems find diverse applications in the state, particularly in small systems and those used for high value crops. They are used in all areas of the state.

(e) Factors Affecting the Selection of an Irrigation Method

(1) General

Each irrigation method and system has specific site applicability, capability, and limitations. Broad factors that should be considered are:

- crops to be grown
- topography or physical site conditions
- water supply
- climate
- energy available
- chemigation
- operation and management skills
- environmental concerns
- soils
- farming equipment
- costs
In selecting an irrigation method and system, various factors must be considered. Refer to NEH Part 652, Chapter 5 for selection guidance on site conditions and adaptability and limitations of irrigations methods and systems. NEH Part 652, Chapter 11 provides economic considerations and evaluations; an important criteria for not only deciding whether or not to “irrigated” in the humid South Carolina, but also when selecting an irrigation method. When selecting an irrigation method, primary concerns in South Carolina include available water supply, low water holding capacity sandy soils, adaptability to the crops grown, cost effectiveness of the system, level of management, low irrigation experience, and labor requirements.

(2) Topography
Almost any topography can be modified to accommodate irrigation. However, given the availability of existing cropland and orchards that can be irrigated with minimal land modification, extensive leveling or bench terracing will rarely be economical in South Carolina’s competitive marketplace.

If the topography is level or can be made level, all irrigation methods are potentially feasible. In South Carolina’s cleared Flatwoods, Carolina Bays, and certain river floodplains and terraces found mostly in the Middle and Lower Coastal Plains physiographic regions (Supplement Chapter 1, Fig. SC1-11), fields of hundreds to thousands of acres can be found that would fit this description. Most of those, however, have some limitation that will affect the method or even feasibility of irrigation.

Smaller fields of a few to occasionally hundreds of acres that are nearly level can be found even in upland regions, increasing irrigation options. However, in the well weathered topography of South Carolina’s Blue Ridge, Piedmont, and Upper Coastal Plain physiographic regions, most fields requiring irrigation contain sloping and complex topography that is better suited to sprinkler and microirrigation methods.

(3) Drainage
For the drainage/subsurface (water table control) irrigation method, special drainage related conditions are required. Generally speaking, a closed drainage system – high water table with a mostly impermeable layer - is required so that added water will not be lost by deep percolation or lateral movement off site. Essential it is like trying to keep a layer of water in a flat roasting pan even as it evaporates from the pan. If the pan has holes or lacks sides, there is no hope of operating subsurface irrigation efficiently.

Other irrigation methods are less sensitive to drainage, except that surface irrigation may require deep or well-drained soil to keep return flow from creating a perched water table in the field.

Irrigation efficiency is reduced in any field area where periodic flooding of the moisture replacement zone damages the crop. Surface drainage – removing precipitation that ponds in depressions, wheel tracks and furrows – is a common requirement of both irrigated and non-irrigated fields in the Middle and Lower Coastal Plain regions of South Carolina.

(4) Water Intake Rate
Water intake rate of the soil affects the method of irrigation selected. The sprinkler and microirrigation
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 maximum sprinkler application rate (Table SC2-18).

Intake rate for microirrigation systems will dictate the maximum application rate and number of emitters for a particular system. For subsurface irrigation 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 depth of moisture replacement zone (effective rooting depth) or a high, controllable water table. For the surface irrigation systems, high intake rates are problematic as they can limit the wetted pattern created by the emitters.

(5) Wind Action

Wind action will affect the water application efficiency for the sprinkler method. Winds during sprinkling causes small droplets to drift from target areas and increases direct evaporation of water from sprinkler droplets. Wind caused water losses are greater as temperature and wind velocity increase and as humidity, drop size, and application rates decrease.

Typically sprinkler evaporation and drift losses are in the range of 15 to 20 percent from sprinklers mounted on center pivots or vertical risers, and they may be as great as 40 to 50% with guns and sprinklers that use high pressures to cover large areas. This includes most traveler systems, fixed systems using big guns, and center pivot end guns.

Wind speed is typically not high enough to be a factor in selecting the irrigation method in South Carolina, but it will affect the selection of operating pressures and nozzle spacing and position. Drip, SDI, subsurface (water table control) irrigation, and surface systems are not directly affected by wind.

(d) Narrowing the Selection

Once the method of water application has been selected (sprinkler, microirrigation, or subsurface irrigation), it is necessary to select the specific system that is best suited to the farming operation, soil and crop requirements, and desires of the farmer. Surface irrigation is not addressed further because of its very limited use in South Carolina. The factors affecting the adaptation and operation of various irrigation systems are listed in in NEH Part 652, Chapter 5, Table 5-3 through Table 5-7.

The Farm Irrigation Rating Index (FIRI) is an excel worksheet which provides good documentation of the effects of change, including annual practices. FIRI is a procedure for comparing improvements or changes to irrigation systems and management in the planning process. FIRI helps the field office by:

1. Plan irrigation water management improvements with farmers,
2. Estimate the amount of water conserved by improved management,
3. Estimate the amount of runoff and deep percolation to identify potential reductions in erosion, salinity, and pollutants, and
4. Provide a useful tool for follow-up and document the farmer's accomplishments in water management.
(1) PERMANENT SOLID-SET

**Description** –
Solid-set systems use sprinklers installed in fixed positions along and between lateral lines and optimized by throw patterns and distances to provide relatively uniform application to a field area (Fig. SC5-1). They may be very small (back yard garden sized) or very large (hundreds of acres of trees, vegetables or field crops).

Older solid-set systems were typically assembled from aluminum tubing placed in the field after planting and initial field operations. Risers with sprinklers were mounted on every second or third tubing section. They were often left in place throughout the growing season. Though effective they required significant seasonal labor to set up, and pipe sections were prone to pulling apart or leaking.

![Solid-set sprinkler systems and methods to move laterals for the portable systems](image)

**Figure SC5-1** Solid-set sprinkler systems and methods to move laterals for the portable systems

Permanent solid-set systems are defined as a water distribution 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 and tubing.

Permanent and other solid-set systems are normally designed for spacing of 40 feet x 40 feet, 40 feet x 60 feet, and 60 feet x 60 feet. When these systems are used in orchards, the spacing may be somewhat different to conform to tree spacing. The actual spacing is 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 (psi) 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 65 percent for daytime operation to 80 percent for nighttime operation.

(2) TRAVELING GUN

Description –

Traveling guns are of two general types 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 (Figs. SC5-2 and SC5-3). 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 that 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 2 1/2-inch to 5-inch and in lengths from 330 feet to 1320 feet.

![Figure SC5-2](image_url)  
Figure SC5-2  Cable-tow guns and hoses stored for the off season

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 (Fig. SC5-4). 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 4 1/2-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.
Both traveling guns use a high capacity nozzle ranging from 50 to 1000 gallons per minute. Normally, the sprinkler pressure will be 70 to 100 pounds per square inch (psi). A large capacity cable-tow traveler will require a minimum pump discharge pressure of 125 psi on reasonably flat terrain 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 65 percent. Under certain conditions higher efficiencies can be obtained with low angle guns.
(3) 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 (Fig. SC5-5). 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 trusses and cables 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.

![Center Pivot System](image)

**Figure SC5-5** The basic center pivot tower provides water and electricity to the lateral, anchors the structure around which the lateral rotates, and often supports control panels and monitoring gages.

Each drive unit has a power device mounted on it that drives the wheels, tracks, or skids on which the unit moves (Fig. SC5-6). The rate at which the drive unit and lateral pipe advance around the pivot is determined by the speed of the outermost drive unit (Fig. SC 5-6a). Alignment devices detect any drive units that become misaligned. Either the units are sped 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.
Figure SC5-6  Drive towers support a section of the lateral, contain cables and switches to help align it, and use electric motors, gears and wheels to move it.

Figure SC5-6a  Shows the outermost drive unit and wheel setup on a pivot tower.

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. Because center pivots operate in a circular pattern, they most readily fit circular and square field shapes (Fig. SC5-7). This provides the flexibility to move the pivot forward or backward, and in normal operation completion of a single irrigation rotation returns the pivot to the start of what may be a two to three day watering cycle. Thus it is positioned at the beginning of the driest area of the field ready for the next operation.
Despite the obvious advantage of operating in a full circle, about 30 percent of center pivots in Georgia and South Carolina are installed in rectangular or other shaped fields and operated in a part-circle “windshield wiper” setup requiring the pivot to operate alternately backwards and forwards. Initial investment cost of center pivots per acre is least for full circle operations. For a given length of center pivot, the cost per acre increases significantly as irrigated acreage decreases (i.e., under partial circle applications). Generally, center pivots are not economical for fields smaller than about 40 ac in size.

The disadvantages of driving back over the wettest part of the field - compaction and damage to soil structure - can be partially offset by using a smaller nozzle package that applies 1/2 the water or use part circle nozzles near the tower.

It is not only field shapes but also field obstacles that lead to this part circle operation. Buildings, utility poles or rights-of-way, fences, roads, ponds, wetlands, and wooded areas all create obstacles that prevent full circle operation or require multiple smaller pivots to cover a field. Generally speaking, the long life and labor saving features of a center pivot outweigh the disadvantages of the less convenient "wiper" operation of a pivot. Modern pivots can be automated to stop and shut down at the obstacle or even to reverse direction.

In the Southeast, where groundwater quality is generally considered to be non-corrosive, center pivots can last 30 years or more. A water quality test would expose any potential corrosive issues. Probably the most widespread problem concerns acidity (alkalinity) and dissolved solids and their effect upon metal parts of irrigation systems.

The initial investments in field improvements, including removing trees and other obstacles, draining depressions, bridging ditches and small ponds, and soil conservation structures are easily written off during the life cycle of the pivot. Repairs to maintain the system include some replacement of dry rotted tires on towers, occasionally the inexpensive tower motors burn out, and rubber gaskets at various joints may need replacement.
Sprinkler packages and/or nozzles need replacement at regular intervals of 7 to 10 years to maintain design application rates and uniformity.

Modern center pivots have electric or electronic control panels. Both offer options for automation. Electronic control panels are also suitable for fully automated control if pumping systems are interlinked. Remote control and/or monitoring are also possible through phone, radio, or other wireless networks. These investments further free an operator, and allow scheduling that takes advantage of off peak power rates (for utility supplied power) and optimal weather conditions of nighttime, if the pivot has been designed with sufficient capacity.

Increasingly, center pivots are finding their way into animal operations. With appropriate nozzle packages, they are a convenient tool for spreading liquid animal wastes and partially treated lagoon water. In cattle and dairy operations, the pivot can be fully integrated into an animal grazing operation. Pivot fields are divided into conveniently shaped paddocks. Pastures are most productive when watered, so animal loading can be increased and animals can be moved to fresh paddocks while the last section is watered and recovering from grazing. Several systems have been developed to allow pivots to drive through or over electric or other fencing. In South Carolina, Georgia and Florida, many of the pivots are fitted with misting systems to help cool the animals, improving summer feed conversion and milk production. The cattle will graze in the vicinity of the mist, so the pivot itself becomes a means of moving cattle to fresher forage.

(i) Pivot Component and Options

(a) Locomotive power –
There have been four methods of powering center pivot systems: (1) hydraulic water drive, utilizing pistons, rotary sprinklers, or turbines; (2) hydraulic oil drive, using pistons, rotary motors, or piston-cables; (3) air-pressure piston drive; and (4) electric motor drive.

Hydraulic water-driven center pivot systems are powered by water from the sprinkler lateral pipe with pressures from about 60 to 120 pounds per square inch 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.

In oil-powered systems, the oil 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 pounds per square inch oil pressure in the oil lines. There is still one manufacturer supplying these in the Southeast.

The electric-drive center pivot systems have motors of 1/2, 3/4, 1 or 1 1/2 horsepower 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 that convey utility supplied electric power to the pivot. Almost all pivots being installed in the Southeast use electric motors to move the pivot.
(b) Nozzle/sprinkler packages –

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 (variable sized) 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 foot lateral. The recommended high pivot operating pressure using this nozzle 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 (Fig. SC5-8). 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 medium pivot pressure of 45 to 75 psi.

The third sprinkler arrangement has fixed sprinklers with spray type nozzles (Fig. SC5-9). Low pivot pressures from 20 to 40 psi are suitable for spray nozzle operations.

The spray type center pivot lateral (low pressure) has the smallest drops, but the highest peak application and the shortest duration of application. Rates vary from 6 to 12 inches per hour at the end of a 1300 foot lateral. The medium sized sprinkler type lateral has the next highest application rates with a peak varying from 2 to 3 inches per hour. The variable sized sprinkler type lateral (high pressure) gives the largest drops, but the lowest peak application rates, from 1.0 to 1.5 inches per hour.
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.

(c) Sprinkler Height Position: MESA, LEPA, LESA, LPIC –
While high pressure sprinkler packages on center pivots result in the lowest instantaneous application rates, they also can result in significant spray drift and evaporative losses since droplets are travelling through the air over long distances. Additionally, pressurizing water to maintain high nozzle outlet pressure uses significantly more energy. Cost effective improvements to both water and energy efficiency have been achieved by converting existing center pivot sprinkler packages and pumps and designing new systems with only low pressure sprinkler packages. The fuel and electricity savings alone led to conversion to low pressure systems beginning in the early 1990’s. In Georgia, almost 80% of its 15,000 center pivots had been converted to low pressure sprinkler packages by the year 2000.

MESA appears to be the most commonly installed sprinkler package in South Carolina. For this type of package, the sprinkler high above the ground is 3 to 7 feet (Fig. SC5-10).
The push to low pressure and water conservation has led to a variety of improvements in sprinkler arrangement, spacing, and design. Because of the water saving advantages, NRCS has recognized several of these improvements. Conservation Practice Standard 442, Sprinkler System includes specific guidelines for the MESA and LEPA application. The following applications are available for most pivot systems.

- **Mid-Elevation Spray Application (MESA)** moves the spray head higher in the mature canopy, preferably from 3 to 7 feet, a height that may differ by the crop choice. (Fig. SC5-10)

- **Low Energy Precision Application (LEPA)** packages discharge water at the ground using drag socks or less than 18 inches from the ground using bubble pads. They require additional field manipulation such as furrow diking and circular planting patterns. But they are virtually resistant to the effects of wind. (Fig SC5-11)

- **Low Elevation Spray Application (LESA)** packages are similar to LEPA but use spray nozzles rather than bubblers to spread the water further from the discharge point, which is still within 18 inches of the soil surface.

- **Low Pressure In-Canopy (LPIC)** packages are similar to LEPA but use spray heads closely spaced and within 12 to 36 inches from the soil.

All of these packages drop the nozzle from its typical position on top of the lateral to lower levels using gooseneck adapters and usually flexible tubing (Fig. SC5-12).
Figure SC5-11  Typical LEPA bubbler pads discharge water near the surface virtually eliminating spray drift, but runoff must be managed with furrow dikes and residues

Figure SC5-12  Low pressure nozzle system with gooseneck adapter and flexible tubing

Weights keep the lightweight sprinklers in place as plants, wind, and water spray shift them around, and pressure compensating devices on each assure low nozzle discharge pressures are maintained closely.

Other low pressure packages keep spray nozzles on drops that stay above the plant canopies but below the truss rods supporting the lateral. These have less water conservation benefit than in-canopy packages, but gain on uniformity of distribution.
(d) **End guns and booster pumps** –
End guns are large sprinkler guns similar to those used on some athletic field solid-set systems or even on some traveler systems (Fig. SC5-13 and Fig. SC5-14).

![End gun image]

**Figure SC5-13**  End guns can extend the wetted area of the pivot and partially fill in corners, but they also increase water losses, operating much like a big gun on a traveler

![Sod farm image]

**Figure SC5-14**  Sod farm using end guns to fill in pivot corners (background) with permanent solid-set system in foreground

Placed on the end of the pivot lateral, they can extend the reach of the pivot 10 to 15 percent in area with a relatively low additional cost. They are particularly valuable in filling in part of the corners of square or
odd shaped fields. While the rigid lateral may be limited in length by obstacles, water from the end gun can extend the reach into areas beyond that lateral. Switches of various types can be used to independently cut off spray from an end gun or the main pivot.

This is particularly necessary when that spray would cover roadways or neighbors’ property, and cutoffs will help improve water and energy use efficiency when they eliminate off target application to non-crop areas. With some low pressure pivots, booster pumps may be used to pressurize water for the end gun alone to meet its nozzle discharge pressure. With or without booster pumps, end guns use can reduce uniformity of the remaining pivot if not properly designed or operated, and the end gun sprinklers create a zone with spray drift and evaporation losses similar to traveler sprinklers.

(e) Folding sections –
A more complex way to fill the corners around a pivot is to use cornering systems. These extensions of center pivots use a variety of structures with drive towers to move out as a pivot reaches a corner area. Essentially they temporarily lengthen the pivot. Folding pivot sections are complex and thus subject to breakdowns. Most use buried guidance cables, low voltage wires, whose position is followed by magnetic sensors to guide the unfolding/refolding movement. With the high costs of these systems, few are installed.

(f) Towable pivots –
Small to medium sized center pivots can be supplied as towable irrigation systems and used in two or more fields sequentially (Fig. SC5-15). The towable pivot tower is mounted on wheels, and the drive towers have wheels that can be rotated 90 degrees to allow the entire system to be towed in a straight line behind a tractor.

![Towable system using a three wheeled pivot tower with vertical supply line](image)

At the new location the pivot is anchored with stabilizers and tie-downs. A flexible hose or pipe connection is made between a riser supplied by permanent buried pipe and the pivot’s vertical supply pipe.
A generator, also towable, is moved into position to power the control panel and drive tower motors. Wheels on drive towers are then rotated back for normal pivot operation.

Towable units spread the center pivot’s high purchase price over more crop areas, but they increase operating costs. Many towable pivot users move the system only once per year, with the pivot rotating between fields with the most valuable crop. Others plant early and late (irrigation) season crops, like corn and cotton/peanut/soybean in the adjacent field. When the corn irrigation season ends, it is time to move and irrigate the later summer crop. In time, most towable users fix its position, and purchase another pivot for the alternate field location(s). Towable units also find applications in sod farming.

The center pivot system ranges in energy use from low to medium. There are numerous options for water efficiency improvements and automated operation. Examples include the ability of fertilizers and certain chemicals to be applied through the center pivot, which increases the value and use of the system. Center pivots are often the system of choice for application of wastewater on forage and grain crops, which also helps save freshwater resources. Because most pivots can handle solids, advanced filtration may not be necessary. The ability to automate system operation via remote control is another advantage of center pivots.

(4) LINEAR/LATERAL MOVE

Description –
Linear move sprinklers systems are constructed with many of the same components as center pivots. Laterals are the same truss supported pipe structures as used in pivots with each end supported by a drive unit mounted on wheels. Multi-span units are common, as they are with pivots, and alignment of the spans is accomplished as with pivots. However, the basic motion differs. With neither end fixed, the entire lateral moves perpendicular to the lateral pipe span. All of a rectangular field can be covered by the linear move systems and they are ideal for long linear fields.

Figure SC5-15a  Hose-feed, electric linear pivot with a two wheel cart
(i) Sprinkler packages –
Packages on linear move systems have uniformly spaced sprinklers or sprays, usually mounted on drop tubing. MESA and other systems are appropriate conservation adaptations. Unlike pivots, ground speed, sprinkler coverage, and instantaneous application rates are the same end to end.

(ii) Power supply –
Linear move systems must have an on board electric generator. One drive tower is strengthened to support a diesel or propane engine and generator, but otherwise wiring and control of other towers is the same as for center pivots.

(iii) Guidance systems –
Linear move systems use one of three guidance systems on the guidance control tower. This tower can be an end drive unit or any drive unit within. (1) Small systems may use a guide wire that is followed by control arms extending fore and aft perpendicular to the lateral at the guidance tower. As the control arm bends, switches on adjacent towers adjust to move the lateral pipe to keep it perpendicular to the wire. (2) A similar system puts skids on the control arms. Rather than a wire, they follow a plowed furrow in the ground. (3) A buried low voltage wire is detected by magnetic sensors on the control arms. All three of the control systems can keep the linear moving in a straight line or actually allow a linear to curve or even turn to better fit the field.

(iv) Water supply –
Supplying water presents the greatest challenge for linear systems. Smaller length fields can be supplied by a hose that is dragged from one or more fixed risers to the moving inlet pipe mounted on a drive tower. The hose is similar to that used on travelers, but manipulating it is more difficult since it is usually not mounted on a hose reel.

A second system uses a series of precisely spaced risers. Mechanism on the drive/inlet tower makes a forward connection and breaks an aft connection as the system moves over the field. Because the pipe supplying the risers is pressurized, it is not necessary for this to be in a level field.

A third system carries a siphon and water pump on a strengthened tower. The tower rides a roadway adjacent to an open, lined or unlined ditch. The ditch can be continually supplied by a well or other water supply. In South Carolina the drainage ditches used in the nearly level fields are potential water supply ditches. In one Dillon County field, two large linear move systems were recently installed using this ditch supply system. Each linear move system consists of a 2,500 foot long lateral driving over 13,000 feet and applies water to 750 acres with very large diameter lateral pipes and large pumps needed to keep this field adequately irrigated.

(5) MICROIRRIGATION

Description –
Microirrigation is the application of water directly to the soil at low rates, 0.5 to 60 gallons per hour (1 gpm), through emitters operating at low pressures, 5 to 30 psi. The objective is to continuously supply each plant with enough moisture to meet daily evapotranspiration needs without excessive water loss, erosion, or damage to plants by poor water quality or salt accumulation.
This method of irrigation is suited to vegetables, row crops, orchards, nurseries, greenhouse operations, and urban landscaping. Field application efficiency is the highest of any irrigation method. For design purposes, the application efficiency is considered to be 90 percent, although with proper operation it can be higher.

**System Components and Options**

The components of a microirrigation system can be grouped into the following general categories:

- wellhead
- zone control units
- pipeline (mainlines, manifolds, polyethylene (PE) tubing)
- micro flow device (tape/in-line tubing, drip emitters, microspray)
- flushing system

Depending on system type, site topography, soil characteristics, crop, water/fertility requirements, water availability, and water quality - the system may vary considerably in physical layout. See Figures SC5-18 and SC5-19 for typical microirrigation system layouts. The various components are discussed in detail in Supplement Chapter 6 (pg. 6-90 to 6-96).

**HYDROPONICS**

**Description**

Hydroponics is a method of growing plants using mineral nutrient solutions delivered in water only through either a pumped or floating system. This method contains similar components to a traditional microirrigation system but does not utilize soil as the growth media.

Physical layout of the system will depend on system type and scale, site topography, growth media characteristics, crop, water/fertility requirements, and water quality. Figures SC5-16 and SC5-17 show typical hydroponic system layouts.

![Schematic of typical setup of a pumped "top drip" hydroponic system](hydroponics-simplified.com)
Figure SC5-17a  Operation delivering nutrients through a pumped "flow through" system, powered by electricity (Source: herbgardening.com)

Figure SC5-17b  Solar powered operation delivering nutrients through a pumped "flow through" system (Source: stock image)
Figure SC5-17c  Float or Raft operation utilizing a deep water environment with scheduled nutrient additions (Source: myhydrogarden.com)

Figure SC5-17d  Typical root development in a Float or Raft system (Source: stock image)
Figure SC5-18  Typical orchard microirrigation system layout with drip emitters and PE tubing laterals

Figure SC5-19  Typical row crop/mixed vegetable subsurface (SDI) microirrigation system layout. Surface drip system has the same layout, except for end flush valve and associated components
(e) Summary of adaptability and limitations of irrigation methods and system

A properly designed irrigation system will be well adapted to the specific field and farm for the planned crops, cropping system, local weather, and the on-farm resources available to the grower. Each irrigation system has its strengths and weaknesses. When the right system is selected, it performs as the grower would expect and satisfies the intended irrigation duties with a minimum of repairs and low maintenance. A very important aspect to most growers is that it must have a positive cost versus benefits ratio, as it will probably be viewed as a business investment. Also refer to NEH Part 652, Chapter 5 "Selecting an Irrigation Method", for more information on the adaptability and limitations of irrigation systems. Following is a listing of generalized characteristics for some of the irrigation systems that may be encountered in the Carolinas.

Microirrigation

**General microirrigation**

Advantages:

- Capital costs can be lower than other methods since smaller pumps, motors, and pipelines are installed;
- Water application is very efficient because irrigation water is applied directly to the soil;
- Energy demands are reduced because of lower operating pressure and flow requirements;
- Low pumping rates make it possible to use shallow wells, ponds and canals as a water source;
- Labor requirements are reduced when adequate filters and water treatment, automation, and buried verses above ground distribution pipes (submains) are used;
- Highest potential application efficiency with low runoff and evaporation losses;
- Highest design distribution uniformity;
- Spoon feeding directly to root zone;
- High yields and excellent quality;
- Low water use enables small water supplies to be utilized. However, higher production capacity of microirrigation may reduce or negate any water supply reductions;
- Requires 50% of the water needed for an overhead system;
- Pipe network can be smaller than high pressure/flow systems and therefore less costly;
- Disease control is high since leaves are not wetted;
- Extensive automation is possible;
- Field operations can continue while irrigating;
- Adaptable to irregular shaped fields;
- Entire system can be operated at one time;
- Damage to crops is reduced in areas of poor water quality;
- Optimum moisture conditions can be maintained and drying cycles reduced;
- Smaller pumps and motors may use single phase electricity in areas where 3 phase electricity is not available. In orchard crops, weed growth between rows is reduced since water is normally applied to the canopy area;
- Have the capability of applying fertilizers and other agrichemicals;
- These systems may be used on sites with steep slopes and erosive soils where runoff and pollution are a problem; and
- In many applications water is conserved because travel lanes and other spaces between plants are not irrigated.
Disadvantages:

- Horizontal moisture redistribution is limited in sandy soils requiring more emitters per row or per tree canopy;
- Clogging can result from sand, organic growths, organic and chemical precipitations that enter the laterals, and roots may clog buried emitters;
- Salt build up in soils may result in areas of poor water quality;
- Requires a high degree of management skills and input. Automation may assist, but components used in soil water monitoring, shut off devices, advanced timing, and remote control require additional skill;
- The life expectancy of many drip system components is lower than with other irrigation methods;
- Lateral surface tape must be replaced each year or so, and in some cases with each crop change;
- Disposal of the plastic tape (and associated plastic mulch) can be a problem in locations that do not have recycling options nearby;
- High degree of filtration and pressure regulation required;
- High maintenance requirement;
- Skilled labor is needed for annual installations and in-season repair;
- Requires good quality water supply and properly designed filtration system to prevent emitter clogging;
- May require water treatment through chlorination to kill algae, bacteria, or precipitate iron out of water supply;
- Rodent and insect damage to plastic tape/hose can be a problem;
- Not adaptable to frost protection; and
- Initial investment and annual costs are higher than some other methods.

**Drip Emitter (Point Source)**

Advantages:

- Adaptable for irrigating orchards, berries, and vineyards;
- With pressure compensation, can be operated on undulating topography and odd shaped fields; and
- Application uniformity not affected by wind when emitters are within 18 inches of the ground surface.

Disadvantages:

- Without pressure compensation, each plant row will require a PRV (pressure regulating valve) to maintain distribution uniformity.

**Lateral Tape/Tubing (Line Source)**

Advantage:

- Best adaptable to irrigating fresh vegetables and row crops;
- Application uniformity not affected by wind; and
- Flexible tubing with in-line emitter life is usually 5-7 years.

Disadvantage:

- May not be suitable on steep or undulating topography without PC (pressure compensating) micro flow device; and
- Tape life is usually 1-2 years or less depending on tape thickness and in-season maintenance.
**Microspray/Microsprinkler**

**Advantage:**
- Adaptable for irrigating orchards, nursery trees and container stock;
- Provides a wide selection of spray patterns in orchards, vineyards, and small fruit operations.

**Disadvantage:**
- Higher evaporation losses;
- Higher maintenance from grass/weed growth under canopy; and
- Application uniformity can be affected by wind.

**Subsurface Drip Irrigation (SDI)**

**Advantage:**
- Material and installation costs are spread over several years (+15 years);
- Small and even oddly shaped fields can be irrigated; and
- There is no annual removal and disposal cost for the tape.

**Disadvantages:**
- Water is usually not available for germination or activation of herbicides in dry planting seasons. There is only limited upward migration to the seedbed if tubing is placed below 12 inches deep for fine textured soils and 6 inches in sandy soils;
- Vertical water losses are difficult to detect and prevent;
- A regular schedule of flushing, chemical treatment, and chlorination is required;
- Tubing leaks are difficult to detect, especially in sandy soil. Repairing leaks is also labor intensive;
- Up front cost due to the permanent Flushing Manifold requirement.

**Hydroponics**

**Advantages:**
- Soil is not required;
- Desired nutrient environment can be easily provided for plant growth;
- Lower water costs as water is reused in these systems;
- Less water is lost through evaporation and runoff;
- No mulching, tilling or weeding; and
- Easy to harvest.

**Disadvantages:**
- Limited production in comparison to conventional field farming;
- Initial setup cost is high, as the necessary equipment is costly;
- Technical skill is required to maintain the equipment and develop the appropriate nutrient solutions;
- Hydroponic systems are influenced by power outages, unless solar powered;
- If a disease appears, all plants in the container will be affected;
- Waterborne diseases can quickly spread through the hydroponic system; and
- If the system fails, rapid plant death may occur because no soil to act as buffer.
**Subsurface (water table control) Irrigation**

**Advantages:**
- Adaptable to soils with low available water holding capacity and high intake rates;
- Low installation and operating costs, especially if a drainage system is already present;
- The capability of the dual system for providing drainage where needed; and
- Easily integrated with other irrigation systems.

**Disadvantages:**
- High labor and management inputs unless water level control structures are installed;
- Sudden heavy rains during the irrigation mode may flood the crop root zone;
- Problems with creating and maintaining a level water table throughout the field;
- Maintenance of open ditches and/or drain lines with water level control structures;
- Limited number of locations have the site characteristics for its use;
- Generally, more water will 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;
- Loss of crop land due to the surface ditches of laterals or supplying buried laterals;
- Topography must be level or slopes very gentle and uniform; and
- Soil must have either a natural high water table or impermeable layer in the substratum.

**Sprinkler Systems**

**Center Pivot**

**Advantages:**
- Suitable for chemigation and wastewater application;
- Increasingly farmers are finding their simplicity of operation outweighs the initially high investment cost;
- Irrigates circular area and corners with end guns or corner arms;
- High uniformity and high efficiency with low volume and low pressure drop nozzles;
- Adaptable for irrigating corn, cotton, peanuts, soybeans, potatoes, vegetables, field crops, and alfalfa hay;
- Easily automated; and
- Low labor requirement.

**Disadvantages:**
- Require fields with no obstructions for full circle operation;
- Application rates are usually high, especially at the outer end of the pivot, resulting in excess runoff on low intake soils;
- There is a tendency for wheels to cut deep ruts in some soils;
- High initial cost; and
- Requires uniform topography with slopes <10%.
Linear Move
Advantages:
- Adaptable for irrigating corn, cotton, peanuts, soybeans, potatoes, vegetables, field crops, and alfalfa hay;
- Easily automated;
- Uniform instantaneous water application rate along the entire length of the lateral;
- Complete coverage of rectangular fields common in the state; and
- Potentially low labor requirements, although that will depend upon water supply method.

Disadvantages:
- Limited field size if supplied by hose;
- Necessity to have a nearly level field if using a ditch water supply method or less than 10%;
- Requires rectangular fields;
- Higher labor than a center pivot but less than a hand move system; and
- Higher per acre cost, as compared with center pivot, although the system cost may include pumps and generators not included in the pivot cost.

Traveling Gun
Advantages:
- Adaptable to many field sizes and shapes;
- Adaptable to topography from level to rolling;
- Adaptable for irrigating corn, cotton, peanuts, soybeans, potatoes, vegetables, alfalfa and small grains;
- Less labor than hand move laterals;
- Can be moved easily to irrigate several fields; and
- Their moderate cost makes them an entry level system for many farmers starting to irrigate.

Disadvantages:
- Water distribution is seriously affected by wind, causing non-cropped areas to be wetted;
- High application rates may exceed soil infiltration rates thus creating the potential for runoff;
- High energy is required for operation;
- They require alleyways (towpaths) for row crops, although the skip-row patterns used in most tobacco and some cotton fields easily accommodate this pattern;
- Require high operating pressures and high power pumping units; and
- Low efficiency due to high evaporation and runoff potential.

Solid-Set, Permanent
Advantages:
- Adapted to irregularly shaped fields and rolling terrain, as well as uniform ones;
- Adaptable for frost and freeze protection of sensitive plants and trees;
- Allows for light applications at frequent intervals;
- Adaptable to irrigating blueberries, brambles, container nursery, orchards, and trees;
- Entire system can be operated at one time for frost control or crop cooling at low application rates < 0.15 in/hr;
- Can be used to apply agrichemicals and fertilizers when permitted;
- Easily automated; and
- Permanent systems require little labor, although keeping weedy growth out of riser rows can require small machinery and manual labor.
Disadvantages:
- Very high installation cost for burying laterals and mains and setting risers;
- Riser alleys remove a portion of the field from production;
- Fixed and permanent setup restricts rotations when different field arrangements are needed to accommodate specialized machinery;
- Moderate energy costs due to pipe elbow and friction losses and sprinkler nozzle pressures;
- High initial cost versus hand move laterals systems; and
- Wind drift and evaporation problems with low application rates < 0.15 in/hr.

**Solid-Set, Portable and Hand Move Laterals**

Advantages:
- Adaptable to irregular fields and rolling terrain;
- Allows for light applications at frequent intervals;
- Adaptable for high value crops such as strawberries, tomatoes, vegetables, and nursery stock;
- Can be used to germinate crops that will later be drip irrigated; and
- Entire system can be operated at one time for frost control at low application rates < 0.15 in/hr.

Disadvantages:
- High initial cost of needing sufficient lateral pipe and sprinklers to cover the entire field;
- Wind drift and evaporation problems with low application rates < 0.15 in/hr;
- Not easily automated;
- Highest labor costs;
- Efficiency is lower than permanently installed solid set due to leaky pipe connections; and
- Caution must be taken during tillage and harvest operations to prevent damage to pipeline, risers and sprinkler heads.

Table SC5-10 displays the estimated typical life and annual maintenance for irrigation system components. See NEH Part 652, Irrigation Guide, Chapter 11, Economic Evaluations, for additional information on developing and comparing typical capital and operating costs for selected irrigation systems.
## Table SC5-10: Typical life and annual maintenance cost percentage for irrigation system components

<table>
<thead>
<tr>
<th>System and components</th>
<th>Life (yr)</th>
<th>Annual maint. (% of cost)</th>
<th>System and components</th>
<th>Life (yr)</th>
<th>Annual maint. (% of cost)</th>
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<tbody>
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<td>Semi-rigid, buried Semi-rigid, surface</td>
<td>10 - 20</td>
<td>5</td>
<td>reinforced concrete</td>
<td>20 +</td>
<td>1</td>
</tr>
<tr>
<td>thin wall, buried Flexible, thin wall, surface</td>
<td>10</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>thin wall, surface</td>
<td>1 - 5</td>
<td>10</td>
<td>Land grading, leveling</td>
<td>2/</td>
<td></td>
</tr>
<tr>
<td>Components:</td>
<td></td>
<td></td>
<td>Reservoirs</td>
<td>3/</td>
<td></td>
</tr>
<tr>
<td>Emitters &amp; heads</td>
<td>5 - 10</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Filters, injectors, valves</td>
<td>10 +</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1/ With no disturbance from tillage and harvest equipment.
2/ Indefinite with adequate maintenance.
3/ Indefinite with adequate maintenance of structures, watershed.