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Center Pivot
Workbook

Center Pivot Workbook

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Section 1

Introduction

The center pivot is the agricultural irrigation system of choice because of its low labor and maintenance requirements, convenience, flexibility, performance and easy operation. Center pivot systems conserve valuable resources such as water, energy, money and time.

The first center pivot irrigation system was produced in the 1950s and was propelled by water. Today, pivots are driven by electric or oil hydraulic motors. Energy requirements have been decreased and application efficiency has been increased through lowering evaporation losses with LESA (Low Elevation Spray Application) and LEPA (Low Energy Precision Application).

Wise selection of a center pivot system will result in good water management and conservation, low operating costs, and future flexibility. Purchasers of center pivot systems must specify:

- Mainline size and outlet spacing
- Length, including the number of towers
- Drive mechanisms
- Application rate of the pivot
- Type of water applicator

Exercise 1

1. When properly designed, equipped and operated, what resources does the center pivot system conserve?

   a. Energy

   b. Money

   c. Water

   d. Time

   e. All of the above

2. Which of the following must be specified when purchasing a center pivot system?

   a. Mainline size and outlet spacing

   b. Type of water application

   c. Drive mechanisms and application rate of the pivot

   d. Type of water applicator

   e. All of the above

Section 2

Pivot Costs

Total cost of a pivot system depends on factors such as system length and coverage area, power units and type of water applicator, as well as water supply system costs, which may include groundwater well construction, turbine pumps, etc.

The pivot system commonly used for general pricing purposes is a "quarter-mile system," which is 1300 feet long and irrigates 120 acres. A quarter-mile system costs $325 to $375 per acre, excluding the cost of groundwater well construction, turbine pumps and power units. Longer systems usually cost less on a per-acre basis. For example, a half-mile system (2600 feet) irrigates about 500 acres at a cost of $200 to $250 per acre.

The relatively high cost of a center pivot system often can be offset by advantages such as:

♦ Reduced labor and tillage

♦ Improved water distribution

♦ More efficient pumping

♦ Lower water requirements

♦ More timely irrigation

♦ Flexibility and convenience, which with certain options includes

  • Remote control via phone lines and radio to start or stop irrigation, identify pivot field location, increase or decrease travel speed, and reverse direction

  • Application of chemicals and fertilizers

  • Programmable control panels and injection unit controls

  • Towable pivot machines to irrigate additional tracts of land

Exercise 2

1. Cost of a pivot system depends on

   a. Pivot system length

   b. Cost of groundwater well construction

   c. Cost of turbine pumps

   d. Cost of power units

   e. All of the above

2. Advantages of a center pivot system are

   a. Improved water distribution and lower water requirements

   b. Reduced labor and tillage

   c. More efficient pumping and timely irrigation

   d. Flexibility and convenience

   e. All of the above

3. Towable pivot machines are available, so that additional tracts of land can be irrigated with the same machine

   a. True

   b. False

Section 4

Understanding the Design Printout

The design computer printout provides required information about the center pivot and how it will perform on a particular tract of land. A portion of a typical design printout is shown in Figure 3. It includes:

- Pivot-design flow rate
- Irrigated acreage under the pivot
- Elevation change in the field as measured from the pivot point
- Operating pressure and mainline friction loss
- Pressure regulator rating in psi
- Type of water applicator and applicator spacing and position from mainline
- Nozzle size for each applicator
- Water applicator nozzle pressure
- Maximum travel speed
- Precipitation chart

A sample precipitation chart is shown in Figure 4. The chart identifies irrigation amounts (in inches of water applied) for optional travel-speed settings, gear reduction ratios and tire size.

It is essential to use correct information about available water supply (in gpm) and changes in field elevation to design the pivot, so that accurate irrigation amounts, operating pressure requirements and pressure-regulator needs can be determined.

Exercise 4

1. Information about the center pivot and how it will perform can be obtained from a design computer printout which includes:

   a. Information about nozzle size and pressure

   b. Information about pivot travel speed

   c. Information about system capacity and irrigated acreage

   d. Elevation changes in the field

   e. All of the above

2. In Figure 4, the pivot applies 1.27 inches of water at 20% timer setting. What is the expected time in hours to complete a circle at this speed setting?

   a. 37.8

   b. 189.2

   c. 113.5

   d. 126.1

   e. 90.82
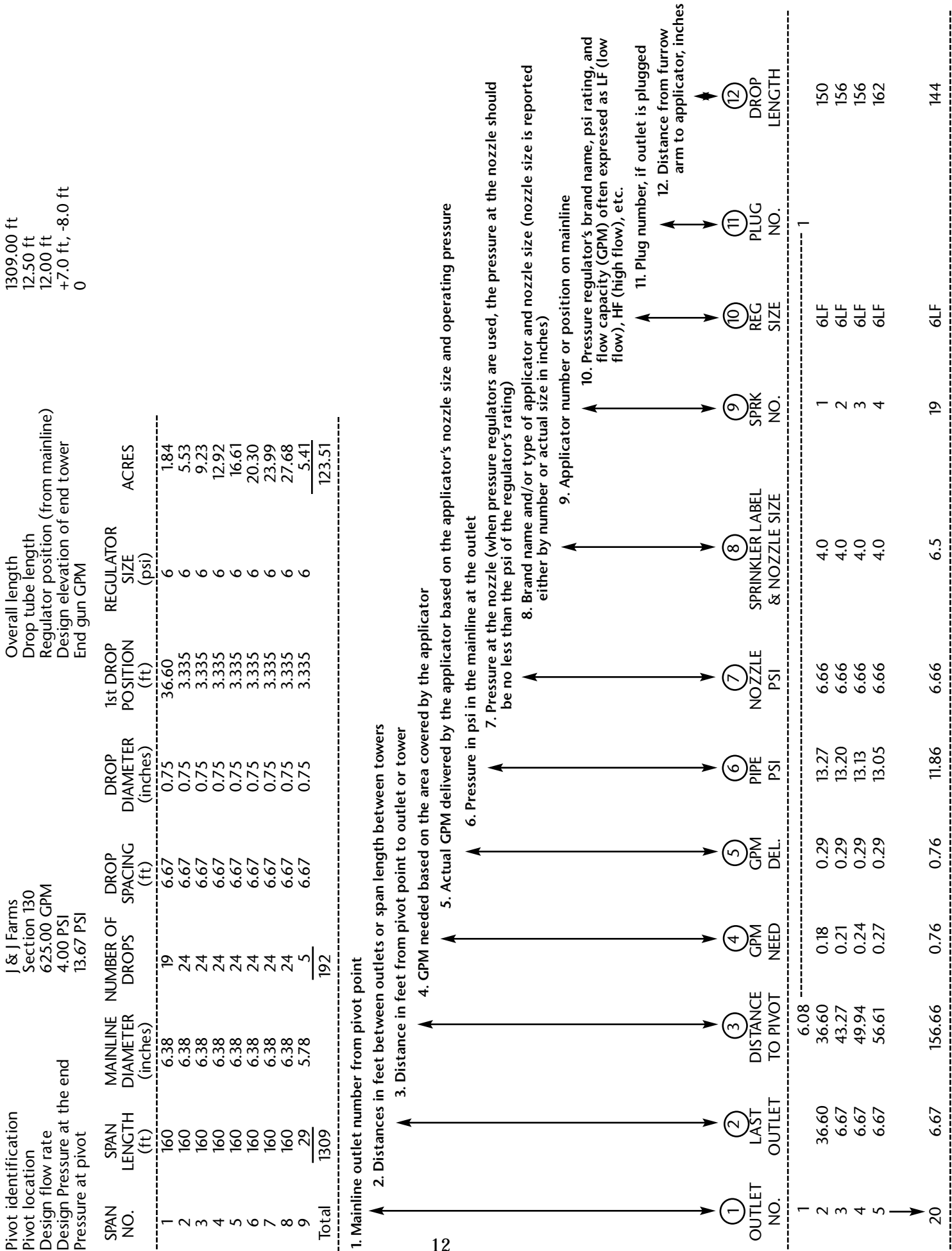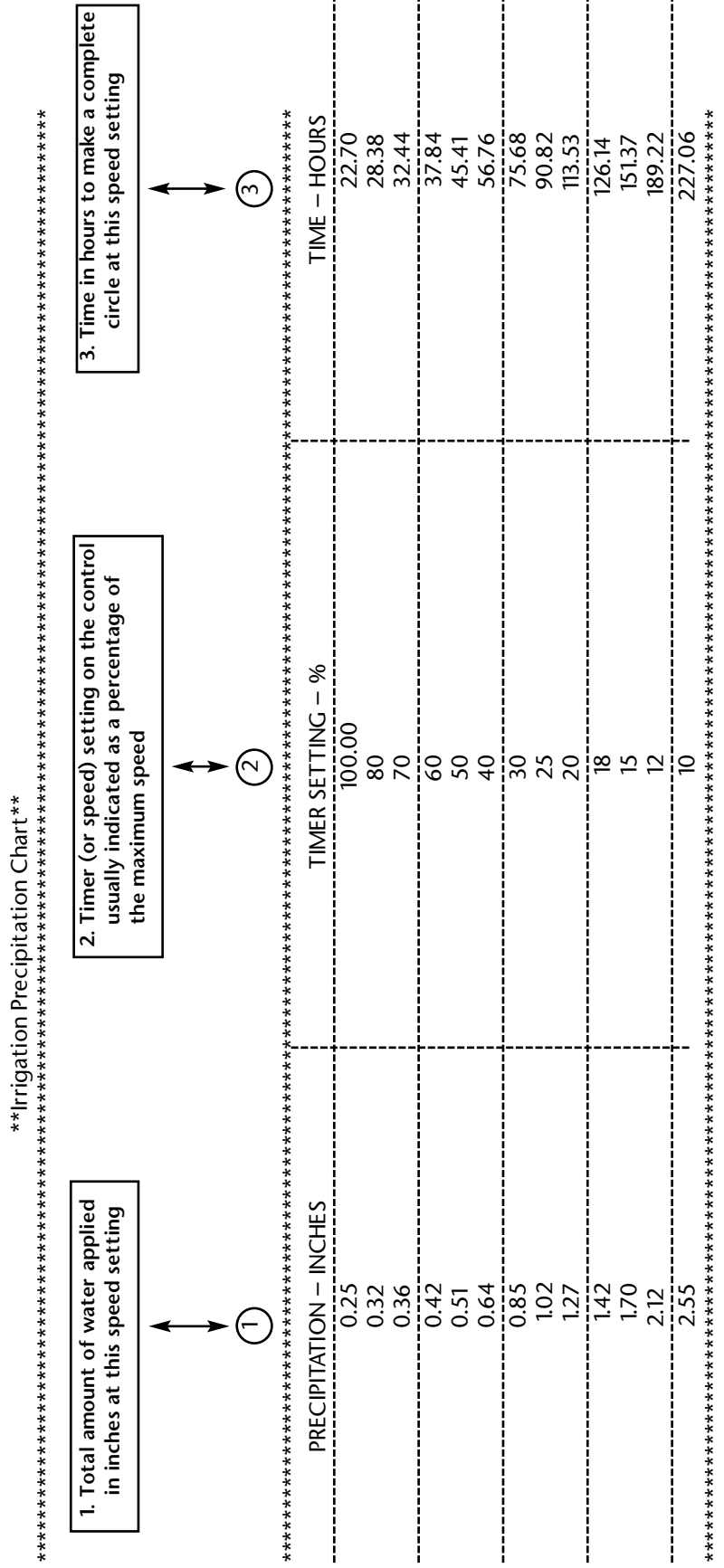
Notes

Figure 3. Sample design computer printout.

Pivot identification	J & J Farms
Pivot location	Section 130
Design flow rate	625.00 GPM
Design Pressure at the end	4.00 PSI
Pressure at pivot	13.67 PSI

Overall length	1309.00 ft
Drop tube length	12.50 ft
Regulator position (from mainline)	12.00 ft
Design elevation of end tower	+7.0 ft, -8.0 ft
End gun GPM	0

SPAN NO.	SPAN LENGTH (ft)	MAINLINE DIAMETER (inches)	NUMBER OF DROPS	DROP SPACING (ft)	DROP DIAMETER (inches)	1st DROP POSITION (ft)	REGULATOR SIZE (psi)	ACRES
1	160	6.38	19	6.67	0.75	36.60	6	1.84
2	160	6.38	24	6.67	0.75	3.335	6	5.53
3	160	6.38	24	6.67	0.75	3.335	6	9.23
4	160	6.38	24	6.67	0.75	3.335	6	12.92
5	160	6.38	24	6.67	0.75	3.335	6	16.61
6	160	6.38	24	6.67	0.75	3.335	6	20.30
7	160	6.38	24	6.67	0.75	3.335	6	23.99
8	160	6.38	24	6.67	0.75	3.335	6	27.68
9	29	5.78	5	6.67	0.75	3.335	6	5.41
Total	1309		192					123.51

OUTLET NO. ①	LAST OUTLET ②	DISTANCE TO PIVOT ③	GPM NEED ④	GPM DEL. ⑤	PIPE PSI ⑥	NOZZLE PSI ⑦	SPRINKLER LABEL & NOZZLE SIZE ⑧	SPRK NO. ⑨	REG SIZE ⑩	PLUG NO. ⑪	DROP LENGTH ⑫
1		6.08									
2	36.60	36.60	0.18	0.29	13.27	6.66	4.0	1	6LF		150
3	6.67	43.27	0.21	0.29	13.20	6.66	4.0	2	6LF		156
4	6.67	49.94	0.24	0.29	13.13	6.66	4.0	3	6LF		156
5	6.67	56.61	0.27	0.29	13.05	6.66	4.0	4	6LF		162
20	6.67	156.66	0.76	0.76	11.86	6.66	6.5	19	6LF	1	144

1. Mainline outlet number from pivot point
2. Distances in feet between outlets or span length between towers
3. Distance in feet from pivot point to outlet or tower
4. GPM needed based on the area covered by the applicator
5. Actual GPM delivered by the applicator based on the applicator's nozzle size and operating pressure
6. Pressure in psi in the mainline at the outlet
7. Pressure at the nozzle (when pressure regulators are used, the pressure at the nozzle should be no less than the psi of the regulator's rating)
8. Brand name and/or type of applicator and nozzle size (nozzle size is reported either by number or actual size in inches)
9. Applicator number or position on mainline
10. Pressure regulator's brand name, psi rating, and flow capacity (GPM) often expressed as LF (low flow), HF (high flow), etc.
11. Plug number, if outlet is plugged
12. Distance from furrow arm to applicator, inches

Figure 3. Sample design computer printout. (continued)

Tower 1										
21	160.00	160.00	6.67	11.79	0.79	0.76	6.66	6.5	20	6LF	144
22	163.33		6.67	11.72	0.82	0.88	6.66	7.0	21	6LF	144
23	170.00		6.67	11.65	0.85	0.88	6.66	7.0	22	6LF	150
24	176.67		6.67	11.58	0.89	0.88	6.66	7.0	23	6LF	150
25	183.84	190.01	6.67	11.50	0.92	0.88	6.66	7.0	24	6LF	156
44	316.67		6.67	10.20	1.53	1.61	6.66	9.5	43	6LF	144

Tower 2										
45	320.00	160.00	6.67	10.03	1.56	1.61	6.66	9.5	44	6LF	144
46	330.00	323.33	6.67	9.96	1.59	1.61	6.66	9.5	45	6LF	144

Figure 4. Sample precipitation chart.

IRRIGATOR – XXXXX

MOTOR SIZE (HP) = 1
LOADED MOTOR RPM = 1745
CENTER GEAR BOX RATIO = 58T01

WHEEL GEAR BOX RATIO = 50T01
TIRE SIZE = 11.2 X 24.0
LAST TOWER MAX. SPEED (FPM) = 5.90

Irrigation Precipitation Chart

1. Total amount of water applied in inches at this speed setting

2. Timer (or speed) setting on the control usually indicated as a percentage of the maximum speed

3. Time in hours to make a complete circle at this speed setting

PRECIPITATION – INCHES ①	TIMER SETTING – % ②	TIME – HOURS ③
0.25	100.00	22.70
0.32	80	28.38
0.36	70	32.44
0.42	60	37.84
0.51	50	45.41
0.64	40	56.76
0.85	30	75.68
1.02	25	90.82
1.27	20	113.53
1.42	18	126.14
1.70	15	151.37
2.12	12	189.22
2.55	10	227.06

Section 5

System Capacity

A pivot's irrigation-system capacity is determined by gallons per minute (gpm) and number of acres irrigated. System capacity is expressed in terms of:

    a) Total flow rate in gpm, or

    b) Application rate in gpm per acre

Knowing a system's capacity in gpm per acre helps in irrigation water management. Table 2 shows the relationship between gpm per acre and irrigation amounts. These irrigation amounts apply to all irrigation systems having the same capacity in gpm per acre. The amounts do not include application losses and apply to systems operating 24 hours a day.

To determine your system's capacity, select desired irrigation amounts in inches and multiply the corresponding gpm per acre by the number of acres you are irrigating. For example, if you irrigate 120 acres with 4.0 gpm per acre, 480 gpm (120 acres H 4 gpm) are required to apply 0.21 inches of water per day, 1.50 inches per week and 6.40 inches in 30 days.

Exercise 5

1. What is the system capacity if you want to irrigate 200 acres with 6.0 gpm per acre?

    a. 12.0 gpm

    b. 120.0 gpm

    c. 1200.0 gpm

    d. 400.0 gpm

    e. 206.0 gpm

2. For the system in question 1, what will be the total amount of water applied (in inches) to the 200 acre field after 60 days?

    a. 382 inches

    b. 19.1 inches

    c. 120.0 inches

    d. 191.0 inches

    e. 22.6 inches

Table 2. Daily and seasonal irrigation capacity for irrigation systems operating 24 hours per day.

gpm/acre	Inch/day	Inch/week	Inches in irrigation days				
			30	45	60	80	100
1.5	.08	.55	2.4	3.8	4.8	6.4	8.0
2.0	.11	.75	3.2	4.8	6.4	8.5	10.6
3.0	.16	1.10	4.8	7.2	9.5	12.7	15.9
4.0	.21	1.50	6.4	9.5	12.7	17.0	21.2
5.0	.27	1.85	8.0	11.9	15.9	21.2	26.5
6.0	.32	2.25	9.5	14.3	19.1	25.4	31.8
7.0	.37	2.60	11.1	16.7	22.6	29.7	37.1

Section 7

Pressure Regulators

Pressure regulators are "pressure killers." They reduce pressure at the water-delivery nozzle so that the appropriate amount of water is applied by each applicator. Selection of nozzle size is based on the rated delivery psi of the pressure regulators. Pressure regulator psi rating influences system design, appropriate operating pressure, total energy requirements and costs of pivot irrigation. However, pressure regulators are not necessarily needed at all sites.

For the same application rate, nozzles used with 10 psi regulators will be smaller than those used with 6 psi regulators. Low-rated (low psi) pressure regulators, if used, allow the center pivot to be designed for minimum operating pressures.

Pressure regulators require energy to function properly. Water-pressure losses within the regulator can be 3 psi or more. So, entrance (or inlet) water pressure should be 3 psi more than the regulator pressure rating. Six-psi regulators should have 9 psi at the inlet; 10-psi regulators, 13 psi; 15-psi regulators, 18 psi; and 20-psi regulators, 23 psi. Regulators do not function properly at operating pressures less than their rating plus 3 psi.

The pressure at the inlet side of a regulator should be monitored with a gauge installed in the last drop at the outer end of the pivot, upstream and adjacent to the regulator. The pressure at this point should be checked when the machine is up slope (or at the highest elevation with relation to the pivot point). Another gauge located in the first drop in span one will monitor operating pressure when the center pivot is located down slope.

Table 5 shows how variations in terrain elevations influence mainline operating pressures. Elevation changes in the field have the largest impact on center pivots with lower design pressures. From the first to the last drop on a pivot, operating pressure at the nozzle should vary not more than 20 percent from design operating pressure. Pressure regulators usually are not necessary if elevation does not change more than 5 feet from the pad to the end of the pivot (i.e., operating pressure and pumping costs usually will not increase significantly). Where elevation changes are greater than 5 feet, the choice is between increasing operating pressure (and,

Table 5. Percent variation in system operating pressure created by changes in land elevation for a quarter-mile pivot. Maintain less than 20 percent variation.

| Elevation change | | System design pressure (psi)* | | | | |
| | | 6 | 10 | 20 | 30 | 40 |
Feet	psi			% variation		
2.3	1	16.5	10.0	5.0	3.3	2.5
4.6	2	33.0	20.0	10.0	6.6	5.0
6.9	3	50.0	30.0	15.0	10.0	7.5
9.2	4		40.0	20.0	13.3	10.0
11.5	5		50.0	25.0	16.6	12.5
13.9	6			30.0	20.0	15.0
16.2	7				23.3	17.5
18.5	8				26.6	20.0

*pressure at the nozzle

probably, pumping costs) and using pressure regulators. This decision is site specific and should be made by comparing the extra costs of pressure regulators to the increased pumping costs without them. (Note: As shown in Table 5, every additional 2.3 feet of elevation requires an additional 1 psi of operating pressure.)

In situations where water-flow rate, and, thus, operating pressure, vary significantly during a growing season, perhaps from seasonal variations in groundwater pumping levels, design flow rate (or system capacity) and use of pressure regulators should be evaluated carefully. If water pressure drops below that required to operate the regulators, poor water application and uniformity will result. In contrast, if design operating pressure is high, pumping costs will be unnecessarily high. When operating pressure decreases to less than that required, the solution is to renozzle for the reduced number of gallons per minute. The amount of water flow in the mainline decreases or increases operating pressure for the nozzles installed.

Exercise 7

1. Pressure regulators are devices used to reduce pressure at the water delivery nozzle so that the appropriate amount of water is applied.

   a. True

   b. False

2. Change in land elevation will result in variation in the center pivot operating pressure. A quarter-mile pivot was designed with 20 psi nozzle pressure. What is the percent variation of pressure for an elevation change of 9.2 feet?

   a. 5.0 psi

   b. 10.0 psi

   c. 15.0 psi

   d. 20.0 psi

   e. 25.0 psi

Section 8

Water Applicators

Pads

Several types of spray applicators are available, each with various pad options. Low-pressure spray applicators can be used with flat, concave or convex pads that direct the water spray pattern horizontally, upward and downward at minimum angles. Spray applicator pads also vary in number and depth of grooves, thus, in the size of water droplets they produce. Fine droplets may reduce erosion and runoff but are less efficient because of their susceptibility to evaporation and wind drift.

Some growers prefer to use coarse pads that produce large droplets and to control runoff and erosion with agronomic and management practices. Little data has been published about the performance of various pad arrangements. In the absence of personal experience and local information, following the manufacturer's recommendations is likely the best strategy for choosing pad configuration. Pads are inexpensive, and some growers purchase several groove configurations and experiment to determine which works best in their operations.

Impact Sprinklers

High-pressure impact sprinklers mounted on the center pivot mainline were prevalent in the 1960s when energy prices were low and water conservation did not seem so important. Now, such sprinklers are recommended only for special situations, such as land application of wastewater, where large nozzles and high evaporation can be beneficial. Impact sprinklers usually are installed directly on the mainline and release water upward at 15 to 27 degrees.

High-pressure impact sprinklers normally produce undistorted water pattern diameters in the range from 50 to more than 100 feet. Water application losses average 25 to 35 percent or more. Low angle, 7-degree sprinklers somewhat reduce water loss and pattern diameter but do not significantly decrease operating pressure. End guns are higher volume (gpm) impact sprinklers with lower application and distribution efficiencies and high energy requirements, so they are not recommended.

Low-Pressure Applicators

Very few center pivots in Texas are now equipped with impact sprinklers, because improved applicator and design technologies produce more responsible irrigation-water management. These new applicators operate at low water pressure and work well with current center pivot designs. Low-pressure applicators require less energy and, when appropriately positioned, ensure that most of the water pumped gets to the crop. Growers must choose which low-pressure applicator to use and how close to ground level to place the nozzles.

Generally, the lower the operating pressure requirements, the better. When applicators are spaced 60 to 80 inches apart, nozzle operating pressure can be as low as 6 psi, but more applicators will be required than with wider spacings (15 to 30 feet). Water application is most efficient when applicators are positioned 16 to 18 inches above ground level, so that water is applied within the crop canopy. Spray, bubble or direct soil discharge modes can be used.

Field testing has shown that when there is no wind, low-pressure applicators positioned 5 to 7 feet above ground can apply water with up to 90 percent efficiency. However, as the wind speed increases, the amount of water lost to evaporation increases rapidly. In one study, wind speeds of 15 and 20 miles per hour created evaporative losses of 17 and 30+ percent, respectively. In another study on the southern High Plains of Texas, water loss from a linear-move system was as high as 94 percent when wind speed averaged 22 miles per hour with gusts of 34 miles per hour. Evaporation loss is significantly influenced by wind speed, relative humidity and temperature.

MESA

With Mid-Elevation Spray Application (MESA), water applicators are located approximately midway between the mainline and ground level. Water is applied above the crop canopy, even on tall crops such as corn and sugar cane. Rigid drops or flexible drop hoses are attached to the mainline gooseneck or furrow arm and extend down to the water applicator (Fig. 5). Weights should be used, combined with flexible drop hose.

Nozzle pressure varies, depending on type of water applicator and pad arrangement selected. While some applicators require 20 to 30 psi operating pressure, improved designs require only 6 to10 psi for conventional 8 ½- to 10-foot mainline outlet and drop spacing. Operating pressures can be lowered to 6 psi or less when spray applicators are positioned 60 to 80 inches apart. With wider spacings, such as for wobbler and rotator applicators, manufacturers' recommended nozzle operating pressure is greater.

Research has shown that in corn production, 10 to 12 percent of the water applied by above-canopy irrigation is lost by wetting the foliage. More is lost to evaporation. Field comparisons indicate 20 to 25 percent more water loss from MESA above-crop-canopy irrigation than from LESA and LEPA within-crop-canopy center pivot systems.

LESA

Low Elevation Spray Application (LESA) applicators are positioned 12 to 18 inches above ground level or high enough to allow space for wheel tracking. Less crop foliage is wetted, especially when crops are planted in a circle, and less water is lost to evaporation. LESA applicators usually are spaced 60 to 80 inches apart, corresponding to two crop rows. The usual arrangement is illustrated in Figure 6. Each applicator is attached to a flexible drop hose, which is connected to a gooseneck or furrow arm on the mainline (Fig. 7). Weights help stabilize the applicator in winds and allow it to work through plants in straight crop rows. Nozzle pressure as low as 6 psi is best with a correctly chosen water applicator. Water-application efficiency usually averages 85 to 90 percent, but may be less in more open, lower-profile crops such as cotton.

LESA center pivots can be converted easily to LEPA with an applicator adapter that includes a connection to attach a drag sock or hose. Optimal spacing for LESA drops is no wider than 80 inches, but with appropriate installation and management, LESA drops placed on earlier, conventional 8 ½- to 10-foot spacing can be successful.

Corn should be planted in circle rows, and water sprayed underneath primary foliage. Some growers have been successful using LESA irrigation in straight corn rows at conventional outlet spacing, using a flat, coarse pad that sprays water horizontally. Grain sorghum and soybeans also can be planted in straight rows. For wheat, when plant foliage causes significantly uneven water distribution, swing the applicator over the truss

Figure 5. Drop arrangement.

Figure 6. Drops with LESA applicators.

Figure 7. LESA applicator.

rod to raise it. (Note: When buying a new center pivot, choose a mainline outlet spacing of 60 to 80 inches, corresponding to two row widths.)

LEPA

Low Energy Precision Application (LEPA) irrigation discharges water between alternate crop rows planted in a circle. Water is applied with:

- ♦ Applicators located 12 to 18 inches above ground level, which apply water in a "bubble" pattern; or

- ♦ Drag socks or hoses that release water on the ground.

Socks help reduce furrow erosion; double-ended socks are designed to protect and maintain furrow dikes (Fig. 8). If desired, drag-sock and hose adapters can be removed from an applicator and a spray or chemigation pad attached in their place. The LEPA "quad" applicator delivers a bubble water pattern (Fig. 9) that can be reset to optional spray for germination, chemigation and other in-field adjustments (Fig. 10).

LEPA applicators typically are placed 60 to 80 inches apart, corresponding to twice the row spacing. Thus, the middle of one is wet, and the next is dry. Dry middles allow more rainfall to be stored. Applicators are arranged to maintain a dry row for the pivot wheels when the crop is

Figure 9. LEPA bubble pattern.
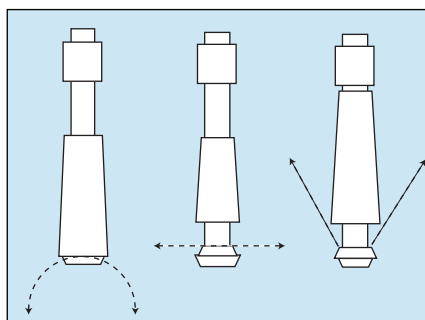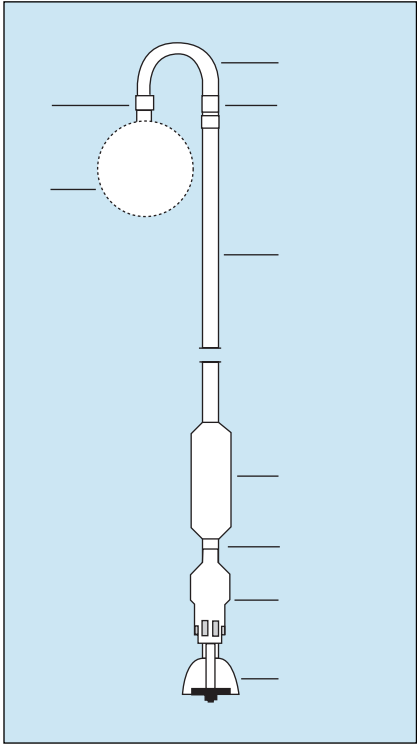
Figure 10. Multi-functional LEPA head.

planted in a circle. Research and field tests show that crop production is the same whether water is applied in every furrow or in alternate furrows. Applicator nozzle operating pressure is typically 6 psi.

Field tests show that with LEPA, 95 to 98 percent of the irrigation water pumped gets to the crop. Water application is precise and concentrated, requiring a higher degree of planning and management, especially in clay soils. Center pivots equipped with LEPA applicators provide maximum water-application efficiency at minimum operating pressure. LEPA can be used successfully in circles or in straight rows and is especially beneficial for low profile crops such as cotton and peanuts. LEPA is even more beneficial where water is limited.

Figure 8. Double-ended sock.

Exercise 9

1. What is LESA?

   a. Low Energy Spray Application

   b. Low Elevation Spray Application

   c. Low Elevation Specific Application

   d. Low Energy Specific Application

   e. None of the above

2. What is LEPA?

   a. Low Energy Pivot Application

   b. Low Elevation Power Application

   c. Low Elevation Precision Application

   d. Low Energy Precision Application

   e. None of the above

3. Impact sprinklers are usually installed directly on the mainline and release water upward at 15 to 27 degrees.

   a. True

   b. False

4. Low-pressure applicators require more energy.

   a. True

   b. False

5. When appropriately positioned, low-pressure applicators ensure that most of the water pumped gets to the crop.

   a. True

   b. False

5. MESA is:

   a. Medium Elevation Sprinkler Application

   b. Mid-elevation Spray Application

   c. Mid-elevation Sprinkler Application

   d. Medium Elevation Spray Application

   e. None of the above

6. Low Elevation Spray Application (LESA) applicators are positioned 12 to 18 inches above ground level and are usually spaced 60 to 80 inches apart.

   a. True

   b. False

7. Which of the following is correct about LEPA?

   a. Low Energy Precision Application

   b. Applicators are located 12 to 18 inches above ground level

   c. Applicators are placed 60 to 80 inches apart

   d. 95 to 98 percent of the irrigation water pumped gets to the crop

   e. All of the above

8. On the following figure, identify the location of each of the following: Weight, applicator, mainline outlet, gooseneck, pivot mainline.

Section 10

Converting Existing Pivots to LEPA

Water outlets on older center pivot mainlines typically are spaced 8 $\frac{1}{2}$ to 10 feet apart. Because LEPA drops are placed between every other crop row, additional outlets are needed. For example, for row spacing of 30 inches, drops are needed every 60 inches (5 feet). Likewise, for 36-inch row spacing, drops are placed every 72 inches (6 feet). Two methods can be used to install additional drops and applicators:

1) Converting the existing outlets with tees, pipe and clamps or

2) Adding additional mainline outlets

Installation is quicker if a platform is placed underneath the pivot mainline. The platform can be made of planks placed across the truss rods or the sideboards of a truck. A tractor equipped with a front end loader provides an even better platform.

Using Existing Outlets

First, the existing gooseneck is removed, and crosses, tees or elbows are connected to the mainline outlets as needed. One early system used drip-irrigation tees with galvanized or plastic pipe cut to extend from the outlet point to the drop location. A galvanized elbow was used to connect the drop to the extension pipe. Such an elbow should be clamped to the mainline to maintain the drop position (Fig. 11). Now, specially manufactured fittings and clamps are available to simplify the process. This type of system includes double-barb gooseneck and truss-rod hose sling as shown in Figure 12.
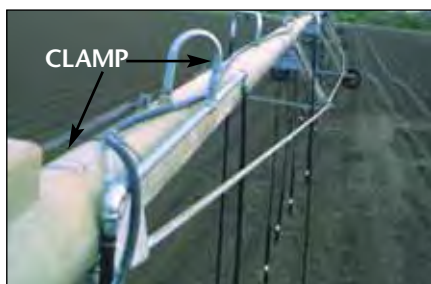

Figure 12.a. A double barb gooseneck.

Figure 12.b. A truss-rod hose sling.

Adding Outlets

It is less costly to convert to LEPA by adding outlets than to purchase the tees, plumbing, clamps and labor required to convert existing outlets. New mainline outlets can be installed quickly using a swedge coupler made of metal alloy. An appropriately sized hole is drilled into the pivot mainline at the correct spacing (Fig. 13). The swedge coupler is then inserted into this

Figure 11. Adding drops.

CLAMP

Figure 13. Drilling for swedge coupler.

hole. The manufacturer recommends that a small amount of sealant be used with the swedge coupler to ensure a leak-proof connection. A standard hydraulic press (body hydraulic punch equipped with a pull-type cylinder) is attached to the coupler with a special screw-in fitting. The press is used to compress the coupler against the inside of the mainline pipe, making a water-tight seal (Fig. 14). The swedge coupler compresses quite easily; be careful not to over-compress it. Regular goosenecks or furrow arms are then screwed into the coupler (Fig. 15).

Outlets also can be added by welding threaded ³⁄₄-inch female couplings into the existing mainline. Since welding destroys galvanized coating, welded couplings should be used only on ungal-

vanized mainlines. As with the swedge coupler, goosenecks and drops can be used with welded couplings.

Other Conversion Tips

When water is pumped into a center pivot, it fills the mainline and the drops. The weight of the water causes the pivot to lower or "squat." With 160-foot spans, the pivot mainline will be lowered approximately 5 inches at the center of the span. Likewise, when filled with water, a 185-foot span will be about 7 inches lower at its center. Length of the hose drops should account for this change, so that when the system is running, all LEPA heads are about the same height above the ground. Center pivot manufacturers can provide appropriate drop-hose cut lengths. Goosenecks or furrow arms and drops are installed alternately on each side of the mainline to help equalize stresses on the pivot structure for high profile crops. Also, when crops are not planted in circles, having drops on both sides of the mainline helps prevent all the water from being dumped into the same furrows as the system parallels crop rows.

Figure 14. Installing swedge coupler.

Figure 15. Swedge coupler installed.

Exercise 10

1. To install additional drops and applicators, one can convert the existing outlets with tees, pipe and clamps, or add additional mainline outlets.

   a. True

   b. False

2. Specially manufactured fittings and clamps, called double-barbed slings, are now available to simply the adding of additional drops.

   a. True

   b. False

Section 11

Accessories and Other Considerations

A permanently installed, continuously functioning flow meter measures the actual amount of irrigation water applied and is recommended. It is used for irrigation-water management, in conjunction with the design printout. In addition, properly located pressure gauges monitor system performance and, combined with the flow meter, provide immediate warning of water deficiency and other system failures. Two pressure gauges are needed on the center pivot, one at the end of the system, usually in the last drop upstream from the applicator or regulator, and one at the pivot point. A third one in the first drop of span one will monitor operating pressure when the machine is down slope with relation to the pivot point.

On older equipment, conventional mainline outlets were spaced every 8 ½ to 10 feet. New center pivots should have 60- or 80-inch mainline outlet spacing, even if this reduced spacing is not required by the water applicator initially selected. Manufacturers continue to develop more efficient applicators, designed to be spaced closer together to achieve maximum irrigation efficiency and pumping economy.

Ordering your pivot with closer mainline outlet spacing will ensure that in the future it can be quickly and inexpensively be equipped with new applicator designs. Retrofitting mainline outlet spacing typically costs $5,000 to $7,000 more than specifying such spacing at the time of initial purchase. As with any other crop production investment, a center pivot should be purchased only after careful analysis. Compare past crop production per acre-inch of irrigation applied to the production projected with center pivot irrigation (use Table 2 and consider the reduced cost of labor and tillage); also consider how much water is available. Then answer the question: Will a center pivot cost or make money in my operation? But remember, personal preference also is an important consideration.

Exercise 11

1. Two pressure gauges are needed on a center pivot for proper management.

   a. True

   b. False

2. Close outlet spacing should always be ordered on a new pivot.

   a. True

   b. False

3. A flow meter is used along with the pressure gauges to provide immediate warnings of problems.

   a. True

   b. False

Section 12

Pivot Management

Pivot management is centered around knowing the number of inches of water applied. The system design printout includes a precipitation chart listing total inches applied for various central control panel speed settings. If a precipitation chart (Fig. 4) is not provided, contact the dealer who first sold the pivot to obtain a copy. Dealers usually keep copies of computer design printouts indefinitely. When a precipitation chart is not available, use Table 6 to determine irrigation amounts based on flow rate and time required to complete a circle. For other sizes of pivots or travel speeds, irrigation inches can be calculated using the first equation below. Keep in mind that the equations assume 100 percent water-application efficiency. Reduce the amounts by 2 to 5 percent for LEPA, 5 to 10 percent for LESA, 20 percent for MESA, and 35 to 40 percent for impact sprinklers. Calculations for pivots of other lengths can be made using the formulas below.

Table 6. Inches of water applied by a 1,290-foot center pivot* with 100 percent water application efficiency.

Pivot GPM	Hours to complete 120-acre circle					
	12	24	48	72	96	120
400	0.09	0.18	0.36	0.53	0.71	0.89
500	0.11	0.22	0.44	0.67	0.89	1.11
600	0.13	0.27	0.53	0.80	1.06	1.33
700	0.16	0.31	0.62	0.93	1.24	1.55
800	0.18	0.36	0.71	1.07	1.42	1.78
900	0.20	0.40	0.80	1.20	1.60	2.00
1000	0.22	0.44	0.89	1.33	1.78	2.22
1100	0.24	0.49	0.98	1.47	1.95	2.44
End tower feet/hour	667	334	167	111	83	67
Acres/hour	10	5	2.5	1.7	1.3	1

*1,275 feet from pivot to end tower + 15-foot end section

1. Inches applied =
$$\frac{\text{Pivot GPM x hours to complete circle}}{450 \times \text{acres in circle}}$$

2. Acres per hour =
$$\frac{\text{Acres in circle}}{\text{Hours to complete circle}}$$

3. End tower speed in feet per hour =
$$\frac{\text{Distance from pivot to end tower in feet x 2 x 3.14}}{\text{Hours to make circle}}$$

4. Number of feet the end of machine must move per acre =
$$\frac{87,120}{\text{Distance (feet) from pivot to outside wetting pattern}}$$

Runoff Management

Runoff from center pivot irrigation can be controlled through matching water application to soil infiltration by changing the optional speed control settings. Agronomic methods of runoff control include furrow diking (or "chain" diking for pastures), farming in a circular pattern, deep chiseling of clay sub-soils, maintaining crop residue, adding organic matter, and using tillage practices that leave the soil "open."

Farming in the round is one of the best methods of controlling runoff and improving water distribution. When crops are planted in a circle, the pivot never dumps all the water in a few furrows, as it may when it parallels straight rows. Circle farming begins by marking the circular path of the pivot wheels as they make a revolution without water. The tower tire tracks then become a guide for row lay out and planting. If the mainline span length (distance between towers) does not accommodate an even number of crop rows, adjust the guide marker so that the tower wheels travel between crop rows.

Furrow diking is a mechanical tillage operation that places mounds of soil at selected intervals across the furrow between crop rows to form small water storage basins. Rather than running off, rainfall or irrigation water is trapped and stored in the basins until it soaks into the soil (Fig. 8).

Furrow diking reduces runoff and increases yields in both dry land and irrigated crops. A similar practice for permanent pastures, called chain diking, involves dragging a chain-like implement that leaves water-collecting depressions.

Exercise 12

1. How many feet must the end of a center pivot move per acre if the distance from the pivot to outside wetting pattern is 600 feet?

   a. 135.1

   b. 145.2

   c. 155.3

   d. 165.4

   e. 175.5

2. Methods of runoff control include which of the following:

   a. Furrow diking and using tillage practices that leave the soil "open."

   b. Farming in a circular pattern

   c. Deep chiseling of clay sub-soils

   d. Maintaining crop residue and adding organic matter

   e. All of the above

3. How long will it take for a 1,290 foot long pivot to complete a 120 acre circle and apply 1.07 inches of water with a flow rate of 800 gpm?

   12

   120

   72

Section 13
Irrigation Scheduling

ET-Based

Maximum crop production and quality are achieved when crops are irrigated frequently with amounts that match their water use or ET (evapotranspiration), commonly twice weekly with center pivots. Texas has three PET (Potential Evapotrans-piration) weather- station and crop-water-use reporting networks, located at Amarillo, College Station and Lubbock. These networks report daily crop water use based on research. One strategy used by growers is to sum the daily crop water use (ET) reported for the previous 3 to 4 days, then set the pivot central control panel to apply an amount of water equal to that sum. (For more information on PET networks, contact your county Extension office.)

The PET networks report daily crop water-use for full irrigation. Most center pivots operating on the Texas South Plains and High Plains are planned and designed for insufficient capacity (gpm) to supply full daily crop water-use. Growers with insufficient center pivot capacity should use a high water management strategy to ensure that the soil root zone is filled with water by rainfall, pre-watering or early-season irrigation before daily crop water-use exceeds irrigation capacity. Most soils, such as Pullman, Sherm, Olton and Acuff series soils, can store approximately 2 inches of available water per foot of topsoil. Sandy soils store less. Sandy loam soils typically store 1 inch or more of available water per foot of topsoil. The county soil survey available from the Natural Resources Conservation Service lists available water storage capacity for most soils. Be sure to use the value for the soil at the actual center pivot site.

Soil Moisture-Based

Soil-moisture monitoring is recommended and complements ET-based scheduling, particularly when rainfall occurs during the irrigation season. Soil-moisture monitoring devices such as tensiometers and watermark and gypsum block sensors can identify existing soil moisture, monitor moisture changes, locate depth of water penetration, and indicate crop rooting depths. These three types of sensors' moisture absorption and loss are similar to that of the surrounding soil.

Gypsum block and watermark sensors are read using resistance meters. Watermark sensors respond more quickly and more accurately than do gypsum blocks but cost more. Readings may be taken weekly during the early growing season. During the crop's primary-water-use periods, readings should be taken two or three times each week for more timely management.

Tensiometers have gauges that measure soil moisture pressures in centibars. Tensiometers are highly accurate but are most useful in lighter, frequently irrigated soils.

Plotting sensor readings on computer spreadsheets or on graph paper helps track and interpret them to manage irrigation. The example shown in Figure 16 describes using gypsum blocks to measure soil moisture in wheat production.

A single block or tensiometer installed at a depth of 12 to 18 inches will measure moisture in the upper root zone; another installed at 36 inches will measure deep moisture. Sensors usually are installed at three depths — 12, 24 and 36 inches — and at a representative location in the field where soil is uniform. They should not be placed on extreme slopes or in low areas where water may pond. Select a location within the next to the last center pivot span but away from the wheel tracks.

Locate sensors within the crop row so they do not interfere with tractor equipment. Follow manufacturers' recommendations on preparing sensors. To obtain accurate readings, the sensing tip must make firm contact with undisturbed soil. The soil auger used to install sensors must be no more than $\frac{1}{8}$ inch larger than the sensing unit.

Exercise 13

1. Maximum crop production and quality are achieved when crops are irrigated frequently with amounts that match their water use or ET (evapotranspiration).

   a. True

   b. False

2. The following is a soil-moisture monitoring device:

   a. Tensiometer

   b. Watermark

   c. Gypsum block sensor

   d. All of the above

   e. None of the above

3. Soil moisture monitoring devices can do which of the following:

   a. Identify existing soil moisture

   b. Monitor moisture changes

   c. Locate the depth of water penetration

   d. Indicate crop rooting depths

   e. All of the above
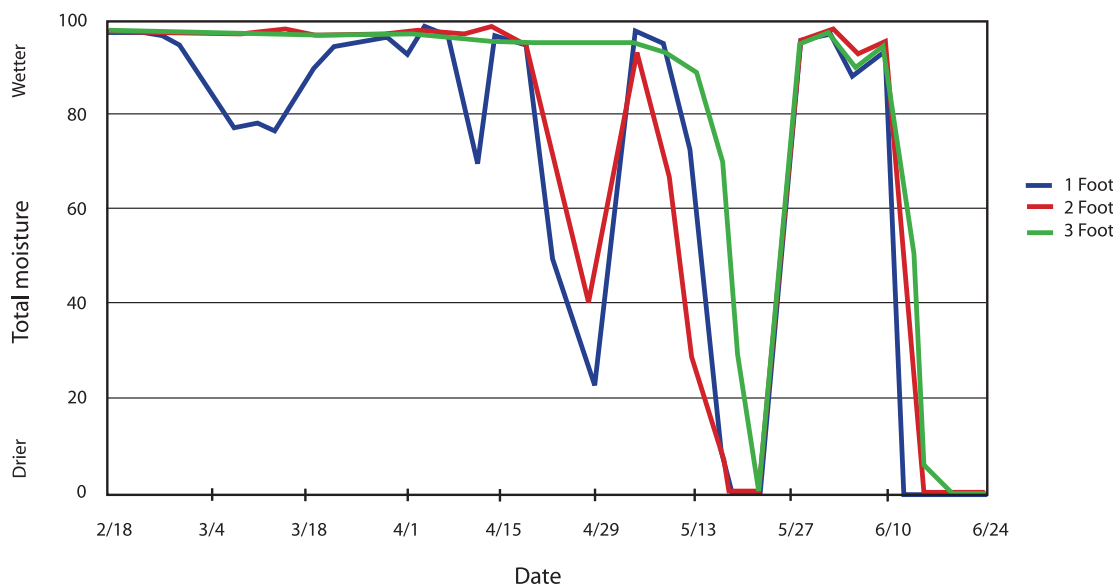

Figure 16a. Soil moisture measurements in a wheat field. Soil moisture should not fall below a reading of 40 to 60 for most soil types.
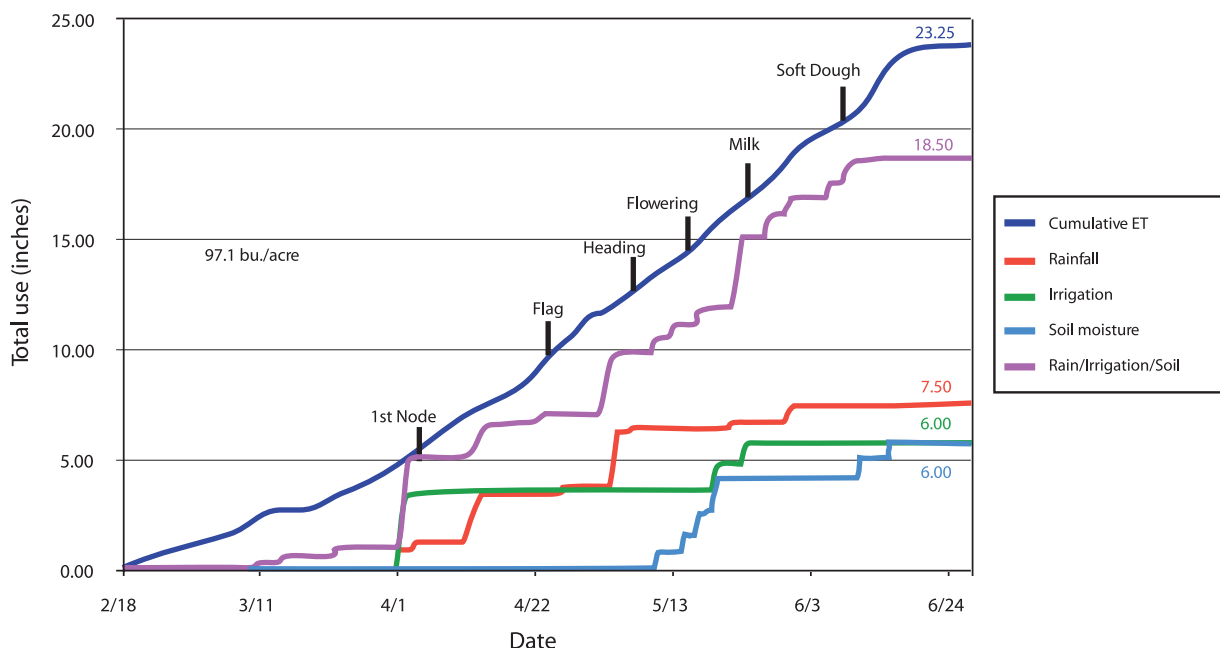
Figure 16b. Cumulative ET and total water supplied to the wheat field in Figure 15a.

Section 14
Chemigation

Chemigation

Chemigation uses irrigation water to apply an approved chemical (fertilizer, herbicide, insecticide, fungicide or nematicide) through the center pivot. Chemigation is an advanced concept. Labels of pesticides and other chemicals must state whether a product is approved for application in this way. If so, application instructions will be provided on the label.

EPA regulations require use of specific safety-control equipment and devices designed to prevent accidental spills and contamination of water supplies. Using proper chemigation safety equipment and procedures also aids the grower by providing consistent, precise and continuous chemical injection, thus reducing the amounts (and costs) of chemicals applied. As in Texas, other states' regulatory agencies may have their own requirements in addition to those of the EPA. For more information, contact your county Extension office or state department of agriculture.

The advantages of chemigation include:

◆ **Uniformity of application.** With a properly designed irrigation system, both water and chemicals can be applied uniformly, resulting in excellent distribution of the water-chemical mixture.

◆ **Precise application.** Chemicals can be applied in correct concentrations where they are needed.

◆ **Economics.** Chemigation is usually less expensive than other application methods and often requires smaller amounts of chemicals.

◆ **Reduced soil compaction and crop damage.** Because conventional in-field spray equipment may not be needed, chemigation may reduce tractor-wheel soil compaction and crop damage.

◆ **Operator safety.** Because an operator need not be continuously present in a field during applications, chemigation reduces human contact with chemical drift and reduces exposure during frequent tank fillings and other tasks.

Chemigation does have disadvantages, however; they include:

◆ **Skill and knowledge required.** Chemicals always must be applied correctly and safely. Chemigation requires skill in calibration, knowledge of irrigation and chemigation equipment, and an understanding of chemical and irrigation scheduling concepts.

◆ **Additional equipment.** Proper injection and safety devices are essential; growers must comply with these legal requirements.

Fertigation

Application of fertilizers using irrigation water (fertigation) often is referred to as "spoon-feeding" the crop. Fertigation is common and has many benefits. Most fertigation uses soluble or liquid formulations of nitrogen, phosphorus, potassium, magnesium, calcium, sulfur and boron.

Nitrogen is most commonly applied because crops need large amounts of it. Keep in mind that because nitrogen is highly soluble and has the potential to leach, its application needs to be managed carefully. Several nitrogen formulations can be used for fertigation, as shown in Table 7. Be sure solid formulations are dissolved completely in water before being metered into the irrigation system. (Up to three 80-pound bags of nitrogen fertilizer can be dissolved in a 55-gallon drum.) Complete mixing may require initially agitating the mixture for several hours and then throughout the injection process.

The advantages of fertigation include:

◆ Nutrients can be applied based on crop needs any time during the growing season.

◆ Mobile nutrients such as nitrogen can be regulated with the amount of water applied, so that they are available for rapid use by crops.

◆ If the irrigation system distributes water uniformly, nutrients can be applied uniformly over the field.

Table 7. Amount of fertilizers needed to apply specific amounts of nitrogen.

Kind of fertilizer	Pounds of N per acre				
	20	40	60	80	100
	Pounds per acre of fertilizer needed for rate of N listed above				
Solid					
Ammonium nitrate (33.5% nitrogen)	60	120	180	240	300
Ammonium sulfate (20.5% nitrogen)	98	196	294	392	488
Urea (45% nitrogen)	44	89	133	177	222
	Gallons per acre of fertilizer needed for rate of N listed above				
Solutions					
Urea-ammonium nitrate (28% nitrogen)	6.7	13.4	20	26.8	33.4
Urea-ammonium nitrate (32% nitrogen)	5.7	11.4	17	22.8	28.5
Ammonium nitrate (21% nitrogen)	8.9	17.8	26.7	35.6	44.5

◆ Some tillage operations may be eliminated, especially if fertilization coincides with the application of herbicides or insecticides. However, do not simultaneously inject two chemicals without knowing whether they are compatible with each other and with the irrigation water.

◆ Groundwater contamination is less likely with fertigation because less fertilizer is applied at any given time. Application can correspond to periods of maximum crop need.

◆ There is minimal crop damage during fertilizer application.

Fertigation does have some disadvantages, however; these include:

◆ Fertilizer distribution is only as uniform as irrigation water distribution. Use pressure gauges to ensure that the center pivot maintains proper pressures.

◆ Lower-cost fertilizer materials such as anhydrous ammonia often cannot be applied using fertigation.

◆ Fertilizer placement cannot be localized, as in banding.

◆ Ammonia solutions are not recommended for fertigation because ammonia is volatile and too much will be lost during the application process. Also, ammonia solutions may precipitate lime and magnesium salts, which are common in irrigation water. Resulting precipitates can build up on the inside of irrigation pipelines and clog nozzles. Besides ammonia, various polyphosphates (e.g., 10-34-0) and iron carriers can react with soluble calcium, magnesium and sulfate salts to form precipitates. The quality of irrigation water should be evaluated before using fertilizers that may create precipitates.

◆ Many fertilizer solutions are corrosive. Fertigation injection pumps and fittings constructed of cast iron, aluminum, stainless steel and some forms of plastic are less subject to corrosion and failure, but those made of brass, copper and bronze are easily corroded.

Know the materials contained in all pump, mixing and injector components in direct contact with concentrated fertilizer solutions. Table 8 describes the corrosion potential of various metals when they come into direct contact with common commercial fertilizer solutions.

Table 8. Relative corrosion of various metals after 4 days of immersion in solutions of commercial fertilizers.*

| Fertilizer | pH of solution | Kind of metal | | | | |
		Galvanized iron	Sheet aluminum	Stainless steel	Bronze	Yellow brass
		Relative corrosion				
Calcium nitrate	5.6	Moderate	None	None	Slight	Slight
Sodium nitrate	8.6	Slight	Moderate	None	None	None
Ammonium nitrate	5.9	Severe	Slight	None	High	High
Ammonium sulfate	5.0	High	Slight	None	High	Moderate
Urea	7.6	Slight	None	None	None	None
Phosphoric acid	0.4	Severe	Moderate	Slight	Moderate	Moderate
Di-ammonium phosphate	8.0	Slight	Moderate	None	Severe	Severe
Complete fertilizer 17-17-10	7.3	Moderate	Slight	None	Severe	Severe

*Solutions of 100 pounds of material in 100 gallons of water.

Exercise 14

1. Chemigation using irrigation water to apply an approved chemical (fertilizer, herbicide, insecticide, fungicide or nematicide) through the center pivot.

   a. True

   b. False

2. What are the advantages of chemigation?

   a. Uniformity and precision of application

   b. Economics and timeliness

   c. Reduced soil compaction and crop damage

   d. Operator safety

   e. All of the above

3. What are the disadvantages of chemigation?

   a. Requires skill in calibration

   b. Proper injection and safety devices are essential

   c. Grower must be in compliance with legal requirements

   d. Requires knowledge of the irrigation and chemigation equipment

   e. All of the above

4. What are the advantages of fertigation?

   a. Nutrients can be spoon-fed to the crop

   b. Groundwater contamination less likely

   c. Some tillage operations may be eliminated

   d. All of the above

5. What are the disadvantages of fertigation?

   a. Fertilizer distribution is only as uniform as the distribution of irrigation water

   b. Fertilizer placement cannot be localized

   c. Some fertilizer solutions are corrosive

   d. Lower-cost fertilizer materials often can not be used

   e. All of the above

Section 15
Center Pivot Buyer's Check List

Pivot Design

___ Actual lowest and highest elevations in field with relation to the pivot point were used in the computer design printout.

___ Actual measured flow rate and pressure available from pump or water source was used in the computer design printout.

___ Friction loss in pivot mainline is no greater than 10 psi for quarter-mile long systems.

___ Mainline outlets are spaced a maximum of 60 to 80 inches apart or, alternately, no farther apart than two times the crop row spacing.

___ For non-leveled fields, less than 20 percent pressure variation in system-design operating pressure is maintained when pivot is positioned at highest and lowest points in the field (computer design printout provided for each case).

___ Pressure regulators were evaluated for fields with more than 5 feet of elevation change from pad to the highest or the lowest points in the field.

___ Tower wheels and motor sizes were selected based on soil type and slope following manufacturers' recommendations.

___ Dealer has provided a copy of pivot design printout.

Applicators

___ Design has no end gun.

___ Consideration was given to equipping the pivot with either LEPA or LESA applicators as follows:

    1. LEPA (low elevation precision application)

      Option 1:

      • Multi-functional LEPA head with an operating pressure requirement of 6 psi, positioned 1 to 1.5 feet above the ground, spaced at 2 times the crop row spacing. Flexible drop hose from goose neck or furrow arm on mainline to applicator, equipped with a plastic or a metal weight

      Option 2:

      • Spray applicator with operating pressure requirement no greater than 10 psi, located 1 to 1.5 feet above the ground. For row crops, spray applicator is equipped with a switchable plate to allow for attachment of a drag hose or double-ended sock

      • Flexible drop hose from gooseneck or furrow arm on mainline to applicator, equipped with a plastic or a metal weight

    2. LESA (low elevation spray application)

    Spray applicators with operating pressure requirement no greater than 10 psi, located 1 to 2 feet above ground

    Flexible drop hose from gooseneck or furrow arm on mainline to applicator, equipped with a polyweight or another type of weight

Installation and Water and Power Supply

___ Pivot pad has been constructed to manufacturer's specifications.

___ Subsurface water-supply pipeline to pivot point is sized to keep water velocity at or below 5 feet per second.

___ Power supply has been connected to pivot following manufacturer's specifications. Power supply may be a power unit alone, a power unit and generator, or subsurface power lines.

Accessories

___ System includes propeller flow meter or other type of flow measurement device having accuracy to + 3 percent and instantaneous flow rate (i.e., gpm) and totalizer (acre-ft, ft³, etc.) indicators installed in water-supply pipeline near pivot point. These indicators should be placed in a straight section that is 10 pipe diameters upstream and 5 pipe diameters downstream from the flow meter.

___ System includes two pressure gauges, one on the mainline near the pivot point and one in the last drop, located just above the applicator or pressure regulator.

___ System includes a computer control panel for fields with soil changes and/or multi-crop situations.

___ System has remote control/monitoring system (optional).

___ System includes a chemigation unit meeting federal safety requirements and tied into computer control panel or power shut-off system with a positive displacement injector pump sized according to the pivot flow rate.

Center Pivot
Workbook

Produced by Agricultural Communications, The Texas A&M University System

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