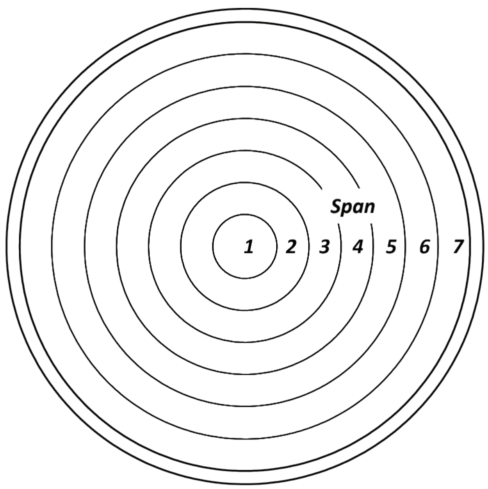
Section L

Managing sprinkler irrigation systems

The circular irrigation pattern of the center pivot results is illustrated in *Figure L-1*. The system is a typical seven to eight span pivot with span widths of 155-180 ft and a 50-ft overhang at the end of the pivot lateral. The pivot in *Figure L-1* irrigates 124 acres when there is no end gun. Since the spans at the outside end of the system travel much farther per revolution of the pivot, the outer spans irrigate greater areas than spans of the same length that are located at the center of the field. Consequently, sprinklers on the outer spans must discharge a greater volume of water than sprinklers located near the pivot point.



Span	Span end, ft	Area within the span, acres	Discharge from span gpm
1	180	2	14
2	360	7	42
3	549	12	71
4	720	16	99
5	900	21	127
6	1080	26	156
7	1269	39	184
O. Hang	1310	9	56
Total		124	750

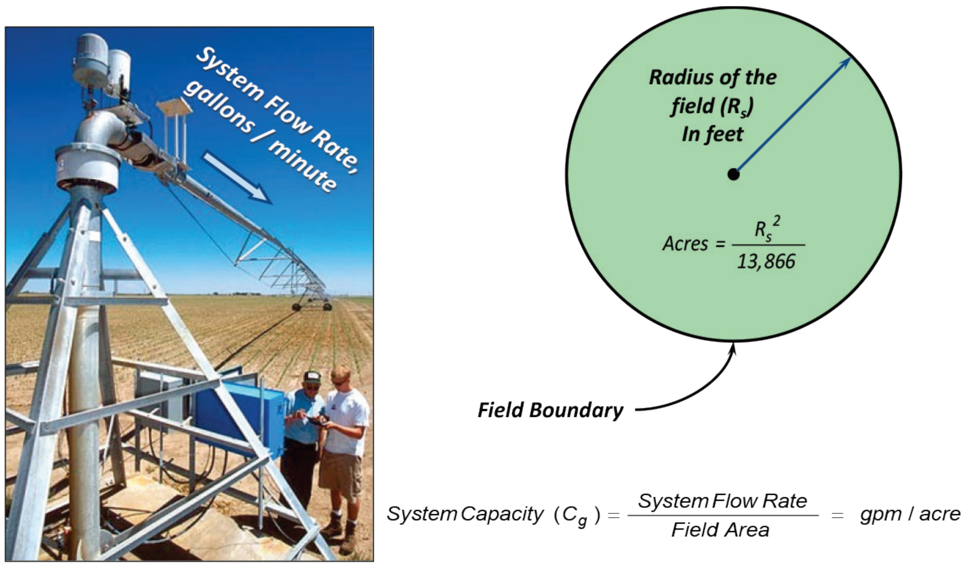
Figure L-1. Characteristics of a typical center pivot. (Note that 45% of the land area is under the outer two spans while only about 7% of the land is under the first two spans.)

Proper operation of a pivot requires installation of the correct type of sprinkler and nozzle at the proper location along the pivot pipeline. The key to proper design and installation is to determine:

- The discharge needed for each sprinkler along the lateral.
- The pressure available at each sprinkler.
- The required size of nozzle needed in each successive sprinkler to meet the discharge requirement.

System capacity

The diagrams in *Figure L-2* illustrate the system capacity. **The system capacity (C_g) is the ratio of the flow into the pivot divided by the land irrigated.** System capacity relates to the ability of an irrigation system to meet crop water needs during periods of limited precipitation and high crop water use rates. Large-system capacities provide flexibility to meet high water use rates and allow for periods when the irrigation system is shutoff for repair, maintenance, and electrical load control. Large-system capacities also contribute to higher water application rates and potentially runoff. Thus, the system capacity should be large enough to meet crop water use rates most of the time, while not being so large that they contribute to runoff problems.



Picture from USDA-ARS

Figure L-2. Definition of system capacity for a field irrigated by a center pivot.

The recommended minimum system capacity depends on the potential for annual rainfall (*Figure L-3*) and the soil texture in the field (*Table L-1*). Typically, evapotranspiration (ET) is greater and the potential for precipitation is lower in the western region of the state than the eastern region. This means that system capacity must be greater to meet crop water requirement in the west. For example, *Table L-1* shows that the minimum net capacity on a silt loam soil in Region 2 should be 4.6 gpm/ac, while the system located in the Region 1 should only be 3.85 gpm/ac, with no down time.

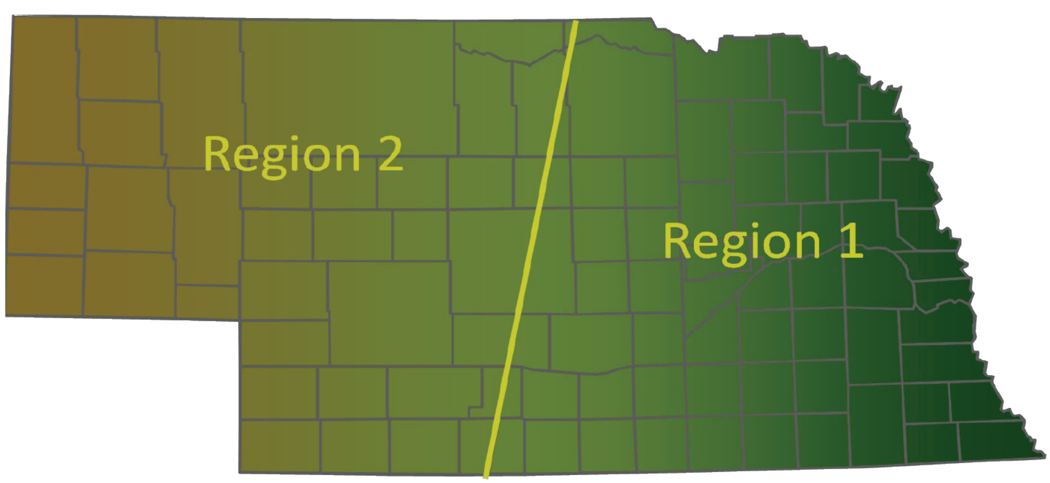


Figure L-3. Regions in Nebraska for minimum system capacity estimation.

Soil texture affects the amount of water that the soil can provide to crops during periods of high ET demand. The system capacity must be greater when less water is stored in the soil to buffer against water use during periods of high crop demand. Since sandy soil holds less water, greater system capacity is needed than for silt loam textured soil. For example, in western Nebraska the recommended minimum net capacity of 5.89 gpm/acre for sandy soil in western Nebraska compared to 4.62 gpm/acre for a silt loam soil.

The system capacity needed to match the peak ET from a crop is also listed in *Table L-1*. Peak ET is the greatest daily rate of water use that is expected by a crop over a series of three to five days. If a system has the capacity to meet this peak ET it will be able to meet the crop water needs throughout the growing season.

The values in *Table L-1* represent the net system capacity that does not account for inefficiencies or downtime for a system. The multiplier listed in *Table L-2* adjusts for the water application efficiency and the number of hours that a system does not operate during the week. For example, the net system capacity for a center pivot located on silt loam soil in eastern Nebraska is 3.85 gpm/acre. The gross or total system capacity for a system with 85% water application efficiency and 12 hours of downtime per week should be increased to 4.9 gpm/acre (1.27 × 3.85) equivalent to about 640 gpm for a traditional 130-acre field.

Table L-1. **Minimum recommended net system capacities for soil classifications and regions of Nebraska.**

	Net Capacity 9 of 10 years[1], gallons/minute/acre	
Soil Texture	**Region 1**	**Region 2**
Peak ET	**5.65**	**6.60**
Loam, Silt Loam, and		
Very Fine Sandy Loam with Silt Loam Subsoil	3.85	4.62
Sandy Clay Loam, Loam, Silt Loam, and		
Very Fine Sandy Loam with Silty Clay Subsoil	4.13	4.89
Silty Clay Loam, Clay Loam, and Fine Sandy Loam	4.24	5.07
Silty Clay	4.36	5.13
Clay and Sandy Loam	4.48	5.19
Fine Sands	4.95	5.89
Loamy Sand	4.83	5.42

[1]Flow rate per acre supplied to a field after accounting for the water application efficiency of the center pivot. The tabular values would be sufficient to meet crop water needs 9 years out of 10 or 90% of the time.

Table L-2. Multiplier for system capacity based on application efficiency and downtime.

Application Efficiency, percent	Downtime, hours/week					
	8	12	16	24	36	48
80	1.31	1.35	1.38	1.46	1.59	1.75
85	1.24	1.27	1.30	1.37	1.50	1.65
90	1.17	1.20	1.23	1.30	1.41	1.56
95	1.11	1.13	1.16	1.23	1.34	1.47

Uniformity of application

The wetted diameter of the sprinkler package is very important to the selection of sprinklers and management of a center pivot. The wetted diameter is the distance that sprinklers throw water perpendicular to the pivot lateral (*Figure L-4*). For example, wetted diameter of a Spinner low pressure spray sprinkler is 54 ft if positioned 6 ft. from the soil surface (*Figure L-4*). The wetted diameter depends on the design of the sprinkler device, the nozzle size and the pressure at the nozzle. The wetted diameter also depends on the height of the sprinkler above the surface of application when the droplets still maintain a horizontal velocity (*Figure L-7*).

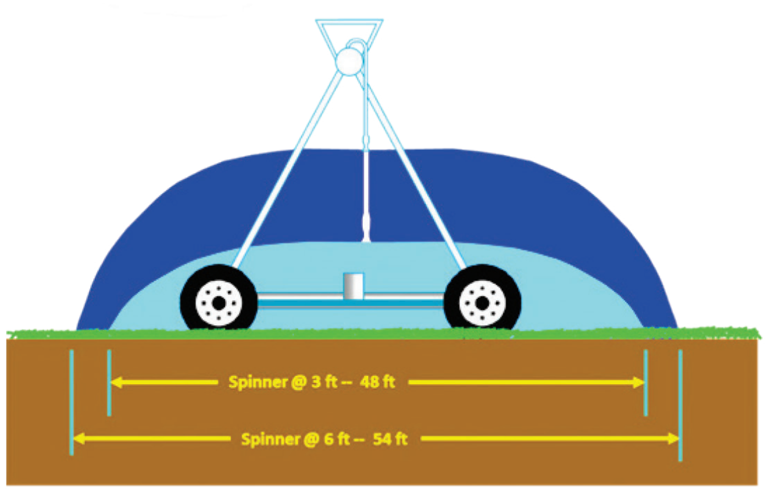


Figure L-4. Examples of the wetted diameter for Spinner devices from the Nelson Irrigation Corporation.

The efficiency of center pivots relies on maintaining high water application uniformity. The uniformity depends on the spacing of the sprinkler devices along the lateral relative to the wetted diameter of the device. Adequate sprinkler spacing provides equal opportunity to water for all crop rows. Devices placed into the canopy require a sprinkler spacing much narrower than sprinklers mounted above the canopy. However, to reduce investment costs, field managers sometimes place sprinklers too far apart and the water application uniformity declines and often the yield decreases.

The example in *Figure L-5* illustrates what can happen if the spacing is too wide. In this case, the sprinkler spacing was 17.5 feet (equal to the width of seven crop rows). The yield for rows close to the sprinkler devices was about 220 bushels of corn per acre while the yield halfway between sprinklers was only 180 bushels/acre. The yield reduction for the field averaged about 15 bushels/acre which equals about 2,000 bushels for a traditional 130-acre pivot.

Center pivots that are used for chemigation can exacerbate the yield impact and potentially lead to water quality issues. The variation in yield depicted in *Figure L-5* clearly indicates that water was not reaching the rows midway between the sprinklers. If liquid nitrogen is applied with the water, lack of nitrogen also could have been a factor in the yield reduction.

Figure L-5 also indicates that excess water was being applied to one to two rows either side of each sprinkler. If liquid nitrogen was being applied, the combination of extra water and nitrogen application creates a scenario where the potential for nitrate leaching is much greater than if the N were applied via a ground rig.

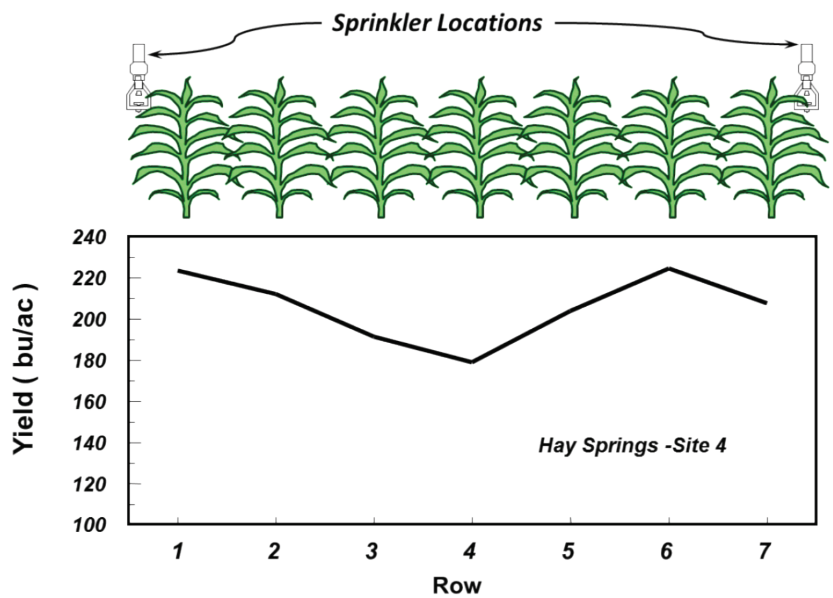


Figure L-5. Variation of yield for wide spacing of sprinklers perpendicular to rows of corn.

Runoff problems

Runoff of irrigation water occurs when the center pivot applies water at a rate that exceeds the ability of the soil to infiltrate the water. Water applied at rates that exceed the infiltration rate will initially accumulate in depressions on the soil surface. If the water applied exceeds what the soil can infiltrate or store on the surface then water will begin to flow across the field (run off) as illustrated in *Figure L-6*. The sketch on the bottom-left portion of *Figure L-6* shows that less storage is possible on steep slopes, hence the potential for runoff is greater on steeply sloped fields.

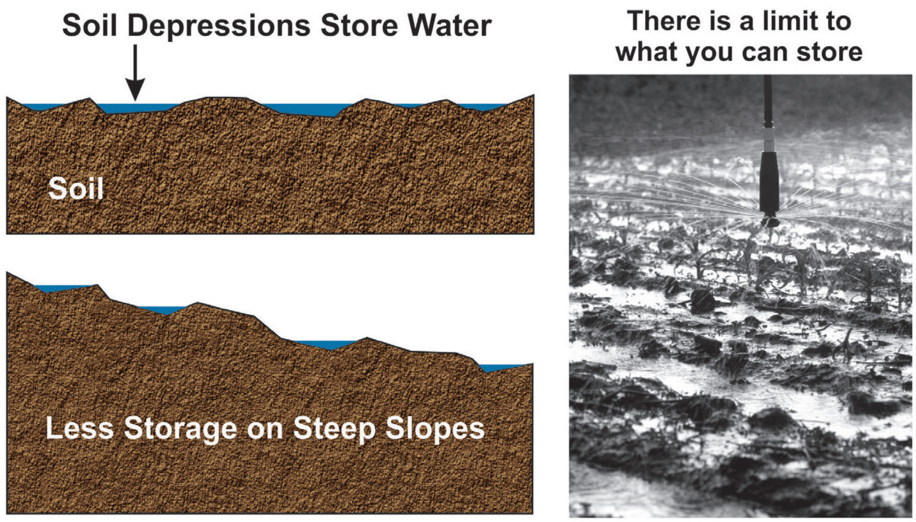


Figure L-6. Illustration of surface storage that provides detention of water application to enhance time for infiltration.

The peak application rate shown in *Figure L-7* is determined by the sprinkler package design. The duration of the irrigation controls the depth of water applied. Note that the application of 2.4 inches of water leads to a large runoff potential. As the application duration decreases, the peak application is not affected but the application depth decreases and the runoff potential drops to nearly zero when the application drops to 0.8 inches.

Control of the depth of application is about the only option available to reduce runoff during the irrigation season. Inspection of the water application at the outer end of the pivot on the steepest portion of the field can be used to determine if runoff is an issue in the field. If runoff occurs, the irrigator should consider speeding up the pivot to apply less water and reduce runoff. Long-term the best solution is to increase the wetted diameter of the sprinkler system.

Surface runoff can impact water quality and crop production in the field and offsite. Often surface runoff occurs in the field that does not leave the field boundary. This runoff finds its way to low lying areas where it infiltrates. Because it is extra water, the potential for nitrate leaching increases in these low lying areas. Runoff that leaves the field can degrade surface water streams and lakes. Thus, proper selection of sprinkler packages is critical to preventing negative water quality impacts.

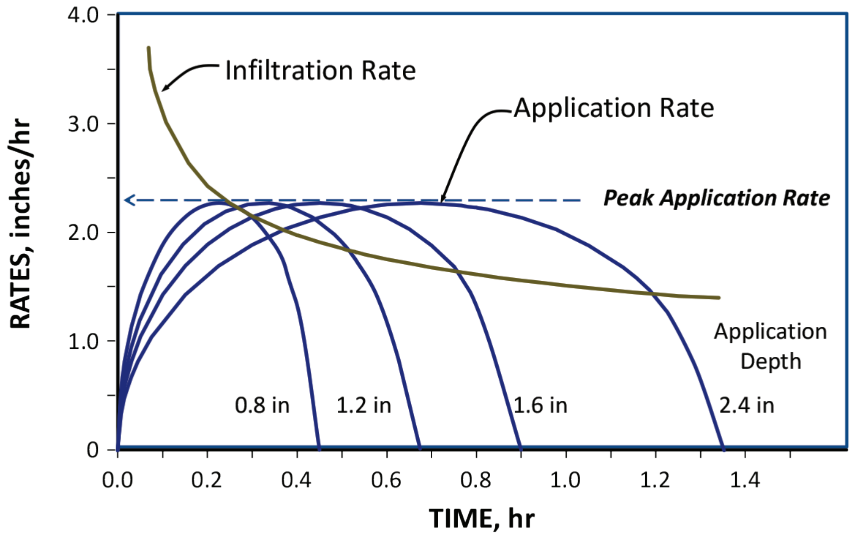


Figure L-7. Effect of water application depth per irrigation on runoff potential.

More Extension Publications (available at ianrpubs.unl.edu)

G1328, Water Loss from Above-Canopy and In-Canopy Sprinklers

G1712, Application Uniformity of ln-Canopy Sprinklers

G1124, Converting Center Pivot Sprinkler Packages: System Considerations

G1851, Minimum System Design Capacities for Nebraska

G888, Flow Control Devices for Center Pivot Irrigation Systems

G1532, Operating Characteristics of Center Pivot Sprinklers

For More Information

von Bernuth, R.D., D.L. Martin, J.R. Gilley and D.G. Watts. 1984. Irrigation System Capacities for Corn Production in Nebraska. Transactions of ASAE 27(2): 419-424, 428.